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A comparison of methods for selecting untagged animals for breeding purposes

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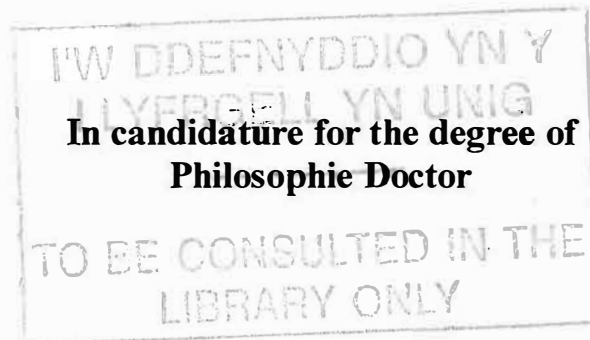
A COMPARISON OF METHODS FOR SELECTING UNTAGGED ANIMALS FOR BREEDING PURPOSES

A thesis submitted to the University of Wales

BY

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CONTENTS PAGE

CONTENTS	I
LIST OF TABLES	XI
LIST OF FIGURES	XIII
LIST OF ABBREVIATIONS	XV
ABSTRACT	XVII
CHAPTER 1 INTRODUCTION	1
1.1. BRIEF OVERVIEW OF TRACING SYSTEMS AND THEIR USAGE	1
1.2. BASIS OF THE METHODS PROPOSED	2
1.3. AIM OF CURRENT RESEARCH	3
CHAPTER 2 LITERATURE REVIEW	5
2.1. ANIMAL BREEDING STRATEGIES AND SELECTION CRITERIA	5
2.1.1. Approaches to Selection	6
2.1.2. Selection Criteria for Milk Yield	7
2.1.2.1. <i>Dairy Cows</i>	7
2.1.2.2. <i>Milking Ewes</i>	10
2.1.3. Selection Criteria for Carcass Characteristics	13
2.1.3.1. <i>Beef Cattle</i>	13
2.1.3.2. <i>Sheep Meat</i>	14
2.1.4. Selection Criteria – Fertility Traits	15
2.1.4.1. <i>Ovulation Rate</i>	16
2.1.4.2. <i>Fertility Rate and Prolificacy</i>	17
2.1.5. Repeatability	18
2.1.5.1. <i>Muscle Depth</i>	18
2.1.5.2. <i>Ovulation Rate</i>	18
2.1.5.3. <i>Milk Yield</i>	19
2.2. ENVIRONMENTAL EFFECTS	20
2.2.1. Age Effects	21
2.2.1.1. <i>Effects of Age on Sheep Traits</i>	22

2.2.1.2.	<i>Effects of Age on Milk Yield in Cattle</i>	22
2.2.2.	Lactation Number	23
2.2.3.	Rearing Type	24
2.3.	HERITABILITY, ESTIMATION OF BREEDING VALUE AND SELECTION INDICES	24
2.3.1.	Heritability	24
2.3.2.	Best Linear Unbiased Prediction (BLUP) and Threshold Models	25
2.3.3.	Threshold Models	26
2.3.4.	Selection Indices	27
2.4.	BREEDING SCHEMES	28
2.4.1.	General Structures	28
2.4.2.	Group Breeding Schemes	29
2.4.2.1.	<i>Advantages of Group Breeding Schemes</i>	30
2.4.2.2.	<i>Disadvantages of Group Breeding Schemes</i>	31
2.4.2.3.	<i>Sire Referencing Schemes</i>	31
2.5.	LIVESTOCK PRODUCTION IN EXTENSIVE SYSTEMS	32
2.5.1.	Range Production Systems	33
2.5.2.	Hill Farming – Wales And England	35
2.6.	ADOPTION OF TECHNOLOGY IN AGRICULTURE	37
2.6.1.	Factors Affecting Extension	39
2.6.1.1.	<i>Cultural Barriers</i>	39
2.6.1.2.	<i>Economics</i>	40
2.6.1.3.	<i>Labour</i>	40
2.7.	DETAILS OF STATISTICAL CONCEPTS	40
2.7.1.	Normal Distribution	40
2.7.2.	Measures of Variability	41
2.7.2.1.	<i>Variance</i>	41
2.7.2.2.	<i>Standard Deviation</i>	42
2.7.3.	Areas Under Normal Distribution Curve	42
2.7.4.	Random Sampling	43
2.7.5.	Transformation of data	43

CHAPTER 3 GENERAL MATERIALS AND METHODS	44
3.1. EXAMPLE DATA SETS	44
3.1.1. Muscle Depth Records	44
3.1.1.1. <i>Source of Data</i>	44
3.1.1.2. <i>Method of Data Recording</i>	44
3.1.1.3. <i>Summary of Available Records</i>	44
3.1.2. Milk Yield Records	45
3.1.2.1. <i>Source of Data</i>	45
3.1.2.2. <i>Method of Data Recording</i>	45
3.1.2.3. <i>Summary of Available Records</i>	45
3.1.3. Ovulation Rate Records	46
3.1.3.1. <i>Source of Data</i>	46
3.1.3.2. <i>Method of Data Recording</i>	46
3.1.3.3. <i>Summary of Available Records</i>	46
3.2. SELECTION METHODS	47
3.2.1. Description of Methods	47
3.2.1.1. <i>Method 1</i>	47
3.2.1.2. <i>Method 2</i>	47
3.2.1.3. <i>Method 3</i>	47
3.2.1.4. <i>Method 4</i>	47
3.3. CALCULATION OF THRESHOLD VALUE	48
3.4. APPRAISAL OF METHODS	48
3.5. EVALUATION OF METHODS	49
3.6. COMPUTING STRATEGIES	49
3.6.1. Data Entry Sheet (Sheet 1)	49
3.6.2. Trait Sorted Data Sheet (Sheet 6)	51
3.6.3. Creation of Random Sequence Data Sets	52
3.6.3.1. <i>Data Set Randomisation</i>	52
3.6.3.2. <i>Randomisation of Data Sets for Methods 1 and 4</i>	52
3.6.4. Method - Computing Strategies	53
3.6.4.1. <i>Calculation of Method Threshold Values</i>	53
3.6.4.2. <i>Identification of Animals Selected by the Methods</i>	54
3.6.4.3. <i>Identification of Target Number of Animals to be</i>	55

	<i>Selected</i>	
	3.6.4.4. <i>Identification of Correctly Selected Animals</i>	55
	3.6.5. Programming of the Success Rate	55
3.7.	TRANSFORMATION OF SR, C/TN and C/TS RESULTS	56
3.8.	STATISTICAL MODELS FOR COMPARISON OF METHODS	57
	3.8.1. General Linear Model	57
	3.8.2. Tukey 95% Simultaneous Confidence Intervals	57
	3.8.3. Tabulation of Results	58
CHAPTER 4	SAMPLE SIZE SELECTION FOR SELECTED TRAITS	59
4.1.	INTRODUCTION	59
	4.1.1. Sampling from a Normally Distributed Population	59
	4.1.2. Sampling and Sample Size	60
	4.1.3. Objectives	61
4.2.	MATERIALS AND METHODS	61
	4.2.1. Principles of Sample Size Selection	62
	4.2.1.1. <i>Procedure A – Sample Size Using Formula</i>	62
	4.2.1.2. <i>Procedure B – Sample Size by Application to Data Sets</i>	63
	4.2.2. Computing Strategies	63
	4.2.2.1. <i>Procedure A – Sample Size Selection Using Formula</i>	63
	4.2.2.2. <i>Procedure B – Sample Size Selection From Application to Data Sets</i>	64
4.3.	RESULTS	65
	4.3.1. Procedure A – Sample Size Using Formula	65
	4.3.1.1. <i>Muscle Depth</i>	65
	4.3.1.2. <i>Milk Yield</i>	66
	4.3.1.3. <i>Ovulation Rate</i>	67
	4.3.2. Procedure B – Sample Size by Application to Data Sets	68
	4.3.2.1. <i>Muscle Depth</i>	68
	4.3.2.2. <i>Milk Yield</i>	69
	4.3.2.3. <i>Ovulation Rate</i>	69

4.4.	DISCUSSION	70
4.4.1.	Muscle Depth	71
4.4.2.	Milk Yield	71
4.4.3.	Ovulation Rate	72
4.4.4.	Chapter Conclusions	72
CHAPTER 5	A COMPARISON OF FOUR METHODS TO SELECT	75
	ANIMALS WHICH ARE NOT UNIQUELY IDENTIFIABLY TAGGED	
5.1.	INTRODUCTION	75
5.2.	MATERIALS AND METHODS	76
5.3.	RESULTS	76
5.3.1.	Muscle Depth	77
5.3.1.1.	<i>Success Rate</i>	77
5.3.1.2.	<i>Proportion of the Target Number Identified by the</i>	79
	<i>Program (C/TN)</i>	
5.3.1.3.	<i>Proportion of those Selected that were Correct</i>	81
	<i>(C/TS)</i>	
5.3.2.	Milk Yield	82
5.3.2.1.	<i>Success Rate</i>	82
5.3.2.2.	<i>Proportion of the Target Number Identified by the</i>	84
	<i>Program (C/TN)</i>	
5.3.2.3.	<i>Proportion of those Selected that were Correct</i>	86
	<i>(C/TS)</i>	
5.3.3.	Ovulation Rates	88
5.3.3.1.	<i>Success Rate</i>	88
5.3.3.2.	<i>Proportion of the Target Number Identified by the</i>	90
	<i>Program (C/TN)</i>	
5.3.3.3.	<i>Proportion of those Selected that were Correct</i>	92
	<i>(C/TS)</i>	
5.4.	DISCUSSION	94
5.4.1.	Success Rates of the Methods	94
5.4.1.1.	<i>Muscle Depth and Milk Yield</i>	94
5.4.1.2.	<i>Ovulation Rate</i>	95

5.4.2.	Effects of Methods 1 and 4 Starting Values on the SR	96
5.4.3.	Effects of Historical Data on the Success Rate of Methods 2 and 3	97
5.4.3.1.	<i>Muscle Depth</i>	97
5.4.3.2.	<i>Milk Yield</i>	98
5.4.3.3.	<i>Ovulation Rate</i>	99
5.4.4.	Effects of % to Select on SR	100
5.4.5.	Chapter Conclusions	100
 CHAPTER 6 A REFINEMENT OF METHODS 2 AND 3 IN THE COMPARISON OF FOUR METHODS TO SELECT ANIMALS WHICH ARE NOT UNIQUELY IDENTIFIABLY TAGGED		103
6.1.	INTRODUCTION	103
6.2.	MATERIALS AND METHODS	104
6.2.1.	Computing Strategies	104
6.2.2.	Data Set for Comparison of Methods Across Chapter 5 and Current Chapter	104
6.3.	RESULTS	104
6.3.1.	Muscle Depth	105
6.3.1.1.	<i>Success Rate</i>	105
6.3.1.2.	<i>Proportion of the Target Number Identified by the Program (C/TN)</i>	107
6.3.1.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	108
6.3.2.	Milk Yield	110
6.3.2.1.	<i>Success Rate</i>	110
6.3.2.2.	<i>Proportion of the Target Number Identified by the Program (C/TN)</i>	112
6.3.2.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	113
6.3.3.	Ovulation Rates	115
6.3.3.1.	<i>Success Rate</i>	115
6.3.3.2.	<i>Proportion of the Target Number Identified by the</i>	116

	<i>Program (C/TN)</i>	
6.3.3.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	118
6.4.	DISCUSSION	120
6.4.1.	Comparison of Methods 2M and 3M Verses Methods 2 and 3	120
6.4.2.	Comparison of Methods 2M and 3M Versus Methods 1 and 4	123
6.4.3.	Chapter Conclusions	124
CHAPTER 7	A COMPARISON OF FOUR METHODS TO SELECT NON-UNIQUELY TAGGED ANIMALS USING TRANSFORMED OVULATION RATE DATA	126
7.1.	INTRODUCTION	126
7.2.	MATERIALS AND METHODS	128
7.2.1.	Computing Strategies	128
7.2.1.1.	<i>Transformation of OR Values</i>	128
7.2.1.2.	<i>Transformation of Historical Data</i>	128
7.2.2.	Data Set for Comparison of Methods Across Chapter 5 and Current Chapter	129
7.3.	RESULTS	129
7.3.1.	Square Root Transformation of OR	130
7.3.1.1.	<i>Success Rate</i>	130
7.3.1.2.	<i>Proportion of the Target Number Identified (C/TN)</i>	132
7.3.1.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	134
7.3.2.	Log (10) Transformation of OR	136
7.3.2.1.	<i>Success Rate</i>	136
7.3.2.2.	<i>Proportion of the Target Number Identified (C/TN)</i>	138
7.3.2.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	140

7.4.	DISCUSSION	142
7.4.1.	Effects of Transformation on Method 1	142
7.4.2.	Effects of Transformation on Method 2	143
7.4.3.	Effects of Transformation on Method 3	145
7.4.4.	Effects of Transformation on Method 4	146
7.4.5.	Chapter Conclusions	147
CHAPTER 8	A COMPARISON OF FOUR METHODS TO SELECT NON-UNIQUELY TAGGED ANIMALS USING MUSCLE DEPTH AND MILK YIELD DATA CORRECTED FOR ENVIRONMENTAL EFFECTS	150
8.1.	INTRODUCTION	150
8.1.1.	Correcting for Environmental Factors	150
8.1.1.1.	<i>Additive Correction Factors</i>	150
8.1.1.2.	<i>Multiplicative Correction Factors</i>	151
8.1.1.3.	<i>Standardising to Adjust Records</i>	151
8.1.1.4.	<i>Regression Coefficients</i>	152
8.1.1.5.	<i>Best Linear Unbiased Prediction (BLUP)</i>	153
8.1.2.	Environmental Factors Affecting Muscle Depth	153
8.1.3.	Environmental Factors Affecting Milk Yield	153
8.1.4.	Aims of Current Research	154
8.2.	MATERIALS AND METHODS	154
8.2.1.	Application of Correction Factors	155
8.2.1.1.	<i>Muscle Depth</i>	155
8.2.1.2.	<i>Milk Yield</i>	156
8.2.2.	Computing Strategies	158
8.2.2.1.	<i>Muscle Depth</i>	158
8.2.2.2.	<i>Milk Yield</i>	158
8.2.3.	Data Set for Comparison of Methods Across Chapter 5 and Current Chapter	158
8.3.	RESULTS	159
8.3.1.	Muscle Depth	159
8.3.1.1.	<i>Success Rate</i>	159

8.3.1.2.	<i>Proportion of the Target Number Identified by the Program (C/TN)</i>	161
8.3.1.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	163
8.3.2.	Milk Yield	165
8.3.2.1.	<i>Success Rate</i>	165
8.3.2.2.	<i>Proportion of the Target Number Identified by the Program (C/TN)</i>	167
8.3.3.3.	<i>Proportion of those Selected that were Correct (C/TS)</i>	169
8.4.	DISCUSSION	171
8.4.1.	Effects of Environmental Correction Factors - Method 1E	171
8.4.2.	Effects of Environmental Correction Factors - Method 2E	172
8.4.3.	Effects of Environmental Correction Factors - Method 3E	173
8.4.4.	Effects of Environmental Correction Factors - Method 4E	174
8.4.5.	Chapter Conclusions	175
CHAPTER 9	GENERAL DISCUSSION	176
9.1.	COMPARISON OF METHODS AND FACTORS AFFECTING SUCCESS RATE	176
9.1.1.	Comparison of Method Performance	176
9.1.2.	Factors Affecting Method Performance	179
9.1.2.1.	<i>Example Data Set Characteristics - Normal Distribution</i>	179
9.1.2.2.	<i>Example Data Set Characteristics-Effects of Year/Farm</i>	180
9.1.3.	Overall Summary	181
9.2.	DEVELOPMENT AND APPLICATION	183
9.2.1.	Uptake of Simplified Recording in a Commercial Environment	183
9.2.2.	Future Investigations of Methods	186
9.3.	GENERAL CONCLUSIONS	186
	REFERENCES	189

APPENDICES	203
APPENDIX 1 – Example Excel Spreadsheet Programs	203
APPENDIX 2 – Minitab Macros for Statistical Analysis	211
APPENDIX 3 – Chapter 4 Sample Size Evaluations for Procedures	212
A and B	
APPENDIX 4 – Anderson-Darling Normality Test Results	217
APPENDIX 5 – Tabulated Results for Chapters 5 to 8	228
APPENDIX 6 – Graphs Illustrating the Random Sorting of Data	248
Sets	
APPENDIX 7 – Ovulation Rate Data Illustrated by a Parabolic	252
Shape Graphs	

LIST OF TABLES

Table 1.1.	An Overview of the Topics Examined in the Experimental Chapters of this Study	4
Table 2.1.	Examples of Environmental Effects Affecting Animal Performance	21
Table 3.1.	Brief Statistical Summary for Muscle Depth by Year	44
Table 3.2.	Brief Statistical Summary for Milk Yield by Farm	45
Table 3.3.	Brief Statistical Summary for Ovulation Rate by Year	46
Table 3.4.	Arcsine Equivalents of SR, C/TN and C/TS Values	57
Table 4.1.	The Averages of the Data Set Trait Mean and Standard Deviations	62
Table 5.1.	Success Rate for the Four Methods for Muscle Depth	78
Table 5.2.	C/TN for the Four Methods for Muscle Depth	80
Table 5.3.	C/TS for the Four Methods for Muscle Depth	82
Table 5.4.	Success Rate for the Four Methods for Milk Yield	84
Table 5.5.	C/TN for the Four Methods for Milk Yield	86
Table 5.6.	C/TS for the Four Methods for Milk Yield	88
Table 5.7.	Success Rate for the Four Methods for Ovulation Rate	90
Table 5.8.	C/TN for the Four Methods for Ovulation Rate	92
Table 5.9.	C/TS for the Four Methods for Ovulation Rate	93
Table 5.10.	A Summary of the Success Rates for Muscle Depth, Milk Yield and Ovulation Rate over the Four Methods	102
Table 6.1.	Success Rate for Methods 2M and 3M for Muscle Depth	106
Table 6.2.	C/TN for Methods 2M and 3M for Muscle Depth	108
Table 6.3.	C/TS for Methods 2M and 3M for Muscle Depth	110
Table 6.4.	Success Rate for Methods 2M and 3M for Milk Yield	111
Table 6.5.	C/TN for Methods 2M and 3M for Milk Yield	113
Table 6.6.	C/TS for Methods 2M and 3M for Milk Yield	115
Table 6.7.	Success Rate for Methods 2M and 3M for Ovulation Rate	116
Table 6.8.	C/TN for Methods 2M and 3M for Ovulation Rate	118
Table 6.9.	C/TS for Methods 2M and 3M for Ovulation Rate	119

Table 7.1.	Success Rate for the Four Methods for Square Root Transformed Ovulation Rate	131
Table 7.2.	C/TN for the Four Methods for Square Root Transformed Ovulation Rate	135
Table 7.3	C/TS for the Four Methods for Square Root Transformed Ovulation Rate	137
Table 7.4.	Success Rate for the Four Methods for Log Transformed Ovulation Rate	139
Table 7.5.	C/TN for the Four Methods for Log Transformed Ovulation Rate	141
Table 7.6.	C/TS for the Four Methods for Log Transformed Ovulation Rate	142
Table 7.7.	Proportions of Method 2 Success Rate of 1	144
Table 8.1.	Success Rate for the Four Methods for Muscle Depth	161
Table 8.2.	C/TN for the Four Methods for Muscle Depth	163
Table 8.3.	C/TS for the Four Methods for Muscle Depth	164
Table 8.4.	Success Rate for the Four Methods for Milk Yield	166
Table 8.5.	C/TN for the Four Methods for Milk Yield	168
Table 8.6.	C/TS for the Four Methods for Milk Yield	170
Table 9.1.	Summary of Success Rate by Trait, Method and Chapter	179
Table 9.2.	The Advantages and Disadvantages of the Methods	183

LIST OF FIGURES

Figure 2.1.	The Structure of Livestock Breeding Industries in many Industrialised Nations	29
Figure 4.1.	The Effect of L (%) on Sample Size (%) for Muscle Depth	66
Figure 4.2.	The Effect of L (%) on Sample Size (%) for Milk Yield	67
Figure 4.3.	The Effect of L (%) on Sample Size (%) for Ovulation Rate	68
Figure 4.4.	The % of Instances of $P < 0.05$ for Muscle Depth	69
Figure 4.5.	The % of Instances of $P < 0.05$ for Milk Yield	70
Figure 4.6.	The % of Instances of $P < 0.05$ for Ovulation Rate	70
Figure 5.1.	Success Rate for the Four Methods for Muscle Depth	78
Figure 5.2.	C/TN for the Four Methods for Muscle Depth	80
Figure 5.3.	C/TS for the Four Methods for Muscle Depth	81
Figure 5.4.	Success Rate for the Four Methods for Milk Yield	83
Figure 5.5.	C/TN for the Four Methods for Milk Yield	85
Figure 5.6.	C/TS for the Four Methods for Milk Yield	87
Figure 5.7.	Success Rate for the Four Methods for Ovulation Rate	89
Figure 5.8.	C/TN for the Four Methods for Ovulation Rate	91
Figure 5.9.	C/TS for the Four Methods for Ovulation Rate	93
Figure 6.1.	Success Rate for Methods 2M and 3M for Muscle Depth	106
Figure 6.2.	C/TN for Methods 2M and 3M for Muscle Depth	108
Figure 6.3.	C/TS for Methods 2M and 3M for Muscle Depth	109
Figure 6.4.	Success Rate for Methods 2M and 3M for Milk Yield	111
Figure 6.5.	C/TN for Methods 2M and 3M for Milk Yield	113
Figure 6.6.	C/TS for Methods 2M and 3M for Milk Yield	114
Figure 6.7.	Success Rate for Methods 2M and 3M for Ovulation Rate	116
Figure 6.8.	C/TN for Methods 2M and 3M for Ovulation Rate	117
Figure 6.9.	C/TS for Methods 2M and 3M for Ovulation Rate	119
Figure 7.1.	Frequency Distribution of Ovulation Rate Data (Across All Years)	127
Figure 7.2.	Success Rate for the Four Methods for Square Root	131

	Transformed Ovulation Rate	
Figure 7.3.	C/TN for the Four Methods for Square Root	133
	Transformed Ovulation Rate	
Figure 7.4.	C/TS for the Four Methods for Square Root	135
	Transformed Ovulation Rate	
Figure 7.5.	Success Rate for the Four Methods for Log Transformed	137
	Ovulation Rate	
Figure 7.6.	C/TN for the Four Methods for Log Transformed	139
	Ovulation Rate	
Figure 7.7.	C/TS for the Four Methods for Log Transformed	141
	Ovulation Rate	
Figure 8.1.	Success Rate for the Four Methods for Muscle Depth	160
Figure 8.2.	C/TN for the Four Methods for Muscle Depth	162
Figure 8.3.	C/TS for the Four Methods for Muscle Depth	164
Figure 8.4.	Success Rate for the Four Methods for Milk Yield	166
Figure 8.5.	C/TN for the Four Methods for Milk Yield	168
Figure 8.6.	C/TS for the Four Methods for Milk Yield	170
Figure 9.1.	A Comparison of the Interval Span between Successive	178
	OR (sorted in ascending order) Values For	
	Untransformed, Logged and Square Rooted OR	

LIST OF SELECTED ABBREVIATIONS

$\sqrt{}$	Square Root
AI	Artificial Insemination
AT	Alternate Months
AF	Morning Milking Only or the Evening Milking Only
BLUP	Best Linear Unbiased Prediction
C	Number of Selected Records That were Correctly Identified
CC	Contemporary Comparison
C/TN	The Proportion of the Target Number that were Identified by the Program
C/TS	The Proportion of those Selected which was Correct
CTS	Cattle Tracing System
E	Environment(al)
EBV	Estimated Breeding Values
EC	European Community
h^2	Heritability
HFA	Hill Farm Allowance
HLCA	Hill Livestock Compensatory Allowances
L	Log(10)
LFA	Less Favoured Area
LS	Litter Size
M	Modified (applied to methods)
MAFF	Ministry of Agriculture, Fisheries and Food
MD	Muscle Depth
MLC	Meat and Livestock Commission
MS	Microsoft
MY	Milk Yield
OR	Ovulation Rate
PC	Personal Computer
SD	Standard Deviation
SE	Standard Error
SLSL	Scottish Livestock Services Ltd
SQRT	Square Root

SR	Success Rate
T	Transformed
T (A)	Transformed Data in Arc-Sine format
T (B)	Transformed Data Back-Transformed to a Proportion
TD	Test Day
TN	Target Number of Records to be Selected
TS	Total Number Selected by Program
UK	United Kingdom
US	United States
UT	Untransformed
WSS	Welsh Sheep Strategy

ABSTRACT

The aim of this research was to evaluate and compare four methods for the selection of animals for future breeding, in flocks/herds where animals are not uniquely tagged. Tagging of animals requires money and technology; both of which are difficult to come by in many rangeland systems in developing countries, or even hill farms in the UK. These methods are seen as an introduction to simplified recording, with the view to farmers then becoming more integrated into breeding schemes that operate in their areas.

Each of the four methods calculates threshold value(s), and those animals that fall above or on the threshold value can be selected for future breeding. The threshold values take into account the top $x\%$ (% to Select) that the farmer wishes to select. The four methods were evaluated using example data sets for three traits, namely Muscle Depth (MD) (with 4 data sets for years 1991–1994), Milk Yield (MY) (with 4 data sets for farms A–D) and Ovulation Rate (OR) (with 4 data sets for years 1988–1989 and 1991–1992) over % to Selects of 5, 15, 25, 35 and 45. To obtain threshold values, method 1 used a sample of the data set; method 2 used historical data; method 3 used historical data (as in method 2) along with the first record of the data set as its starting threshold value and then updated the threshold value each time a new animal was recorded; method 4 used the sample threshold value from method 1 along with the first record of the data set as its starting threshold value and then updated the threshold value as each animal's record was reached.

An experiment using two procedures (A and B) was run to find an appropriate sample size to be used for methods 1 and 4. Method A was derived from a published formula and focussed on accuracy. Method B used the example data sets to test whether the true mean of the data set could be predicted consistently in random samples. On examination of sample size range 5 – 50%, it was concluded that a sample size of 10% was appropriate for the traits to be studied in this thesis.

The initial experiment of the methods showed that for MD and MY, method 4 had a higher success rate (SR) than all other methods: 0.78 and 0.86 for MD and MY, respectively. A % to Select > 5% resulted in better SR values. For OR, method 2 achieved the highest SR (0.73) but the OR data was highly skewed and the results should therefore be treated with caution. The most notable finding for historical effect was for MY farm D, where high historical mean compared to the data set resulted in poor SR (0.19).

The second experiment concentrated on modifying methods 2 and 3 alone; renamed 2M and 3M. To alleviate the problem of extreme values for historical data, the data was replaced by using the minimum and maximum values of the actual data sets for the calculation of the threshold values. MY SR results showed that methods 2M and 3M significantly improved on methods 2 and 3 by 12 and 3%, respectively ($P < 0.05$). MD SR results for 2M and 3M did not significantly differ from methods 2 and 3. For OR SR, methods 2M and 3M significantly decreased SR compared to methods 2 and 3 by 49% and 4%, respectively ($P < 0.05$). A % to Select > 5% resulted in better SR values for MD and MY, while for OR, a % to Select of 5 resulted in a higher SR.

The third experiment concentrated on OR data only. The OR values were transformed using $\log(10)$ (L) and square root ($\sqrt{}$) as a result of the OR data not being normally distributed, with methods renamed with a L or $\sqrt{}$ after the number. Transformation resulted in a wider range of results. Methods 2L and $2\sqrt{}$ significantly decreased SR compared to method 2 by 26% and 31%, respectively ($P < 0.05$). SR for method $1\sqrt{}$ did not alter compared to method 1, but method 1L increased on method 1 by 3%. SR for methods 3L, $3\sqrt{}$, 4L and $4\sqrt{}$ all increased SR compared to methods 3 and 4, by 9, 1, 12 and 10%, respectively. % to Select for $\sqrt{}$ methods can be flexible, but for L methods, % to Selects ≤ 15 are less favourable.

The fourth experiment concentrated on MD and MY data only. The data were corrected for environmental effects, with methods renamed with an E after the number. Correcting for environment effects significantly affected method 2E, which decreased SR compared to method 2 by 17% ($P < 0.05$). None of the other methods were significantly affected.

Consistently good SR (> 0.78 for MD and MY) can be obtained using method 4. Method 4 could be used as the standard with the possibility of adjusting for environmental factors if information on environmental factors is available. For a low-tech method, methods 1 or 2 could be used if the sampling/historical values are reliable and/or available. All methods should be used with caution for OR data. Potential application of the methods is discussed.

CHAPTER 1 INTRODUCTION

1.1. BRIEF OVERVIEW OF TRACING SYSTEMS AND THEIR USAGE

The development and use of breeding programmes based on sound scientific principles has had a major impact on animal production and on the quantity, price and quality of the end products. Attempts by humans to alter populations of animals to make them more suitable for production of food or fibre have been increasingly effective over the last two hundred years. Improved breeds of livestock generally produce food, fibre or other products which are of a higher quality or are better matched to modern requirements than their predecessors. Improved breeds usually have higher efficiency of production than unimproved breeds and so the relative cost of their produce is lower. Genetic improvement is permanent, cumulative when selection is continuous, and is usually highly cost-effective (Simm, 1998). In order to select those animals likely to have the best progeny, they have to be reared and recorded in an organised way, and the data analysed using mathematical and statistical procedures (Hill, 1998).

The European Union has required that all Member States have a computerised tracing system in place for cattle tracing, and the United Kingdom (UK) is no exception. The Cattle Tracing System (CTS) requires that all cattle have a unique number placed on two ear tags, one in each ear. Such tagging enables quick identification of an animal for recording and selection purposes. The Sheep and Goats Identification Order 2000 – England and Wales requires all sheep and goats to be ear tagged or tattooed with their flock or herd mark. The new rules require all sheep and goats born after 1 January 2001 or still on their holding of birth at that date to be included in the tagging (DEFRA, 2001).

Within England and Wales, with there not being any order stipulating that sheep should be individually uniquely identifiable through a tag, those farmers having lower incomes are less likely to invest in expensive, technically demanding breeding selection programmes. Furthermore, it is not the usual practice of sheep and cattle rangeland production farmers, within Africa or Australia for example, to tag their livestock each with a unique identifier. Rangeland farming can cover many thousands of hectares, usually with a low

stocking rate due to the extremes of the land (low forage cover, semi-arid conditions). For the amount of land owned, the income is relatively low. To invest in tags, the time taken to place a tag on each animal and the technology/management required to keep details on each animal, is not economically or practically viable. Rangeland farms employ few people and the workforce may not be enough to accomplish such tasks in an efficient manner.

Effectively, any introduction of new practices, whether it be highly technical or a simple practical addition to a farming method, is considered an extension to agricultural practice. The adoption of agricultural technologies is possible so long as the extension methods are both cheap and practical. For developing countries, Pagot (1992) noted that the transfer of agricultural based technology does not always meet the needs of farmers, and research has shown that the constraints in which farmers farm can make it unprofitable for them to adopt technologies. Farmers with low profitable farms such as hill farming and rangeland production systems are less likely to want to take risks in the adoption of new practices.

Those strategies in place in the UK, such as the Welsh Sheep Strategy (WSS), for the selection of breeding animals are based on formal recording schemes which require tagged animals. In terms of technical knowledge and skill of the farmer, such schemes may add to the increase in differences between those who record and those who do not. The methodologies to be examined could be used as an intermediate step for hill and rangeland farmers worldwide, who wish to start selecting animals for breeding purposes, but whose flocks/herds do not have uniquely tagged animals.

1.2. BASIS OF THE METHODS PROPOSED

The basis of the methods is the calculation of threshold values, and this calculation is performed at the time of recording, and animals can then be selected immediately. The calculation of the threshold values is detailed in Chapter 3. In practical terms, the aim is to have a group of untagged animals, to take the trait measurement and to decide whether

to select a particular animal on the basis of a threshold value.

The methods to be researched could, in practice, be a low-cost option for farmers who do not have the financial or labour resources to support more technical breeding schemes. Furthermore, the knowledge base required is not great; it could be possible for step-by-step instructions to be provided. This is discussed in detail in Chapter 9.

1.3. AIM OF CURRENT RESEARCH

The present study was conducted to evaluate and compare four methods for the selection of animals for future breeding, in flocks/herds where animals are not uniquely tagged. Each of the four methods calculates threshold value(s), and those animals that fall above or on the threshold value can be selected for future breeding. Selected animals would be within the top x % (for example: top 5 %) that the farmer wishes to select.

Modifications to the methods based on characteristics of the data or background information on the animals were applied where appropriate (chapters 6 to 8), with the success rate of the modified methods compared to the success rate of the methods in their original format (chapter 5).

The four methods were evaluated using data for three contrasting traits, namely Muscle Depth (MD), Milk Yield (MY) and Ovulation Rate (OR).

Table 1.1. summarises the topics of each chapter within the thesis.

Table 1.1. An Overview of the Topics Examined in the Experimental Chapters of this Research

Chapter	Topics of each Chapter
5	A comparison of four methods to select animals in non-uniquely tagged groups. Methods 1 and 4 used a sample size of the data while methods 2 and 3 used historical mean and standard deviation values in order to calculate the threshold value. Each method takes into account the % to Select that the farmer wishes to select. Records on or above the threshold value were within the top $x\%$ to Select. MD, MY and OR were examined.
6	The same methods as those in chapter 5, but methods 2 and 3 use the minimum and maximum values of the actual data set in question, in order to estimate the mean and standard deviation. MD, MY and OR were examined.
7	For OR, the same methods as those in chapter 5, but the OR data was transformed using $\log(10)$ and Square Root.
8	The same methods as those in chapter 5, but correction factors for dam-age, ram-age and rearing type were applied to the MD data, while Lactation Number and Breed Type correction factors were applied to the MY data. MD and MY were examined.

MD = Muscle Depth; MY = Milk Yield; OR = Ovulation Rate

Discussions of experimental chapters (chapters 5 – 8) examine the specific results of these chapters, with a critical evaluation of the methods and their potential applications being present in the general discussion (chapter 9).

CHAPTER 2 LITERATURE REVIEW

The aim of the literature review is to provide an overview of the different aspects involved in the selection of animals for breeding purposes. This chapter begins with a review of animal breeding strategies and selection criteria, and continues by reviewing the environmental effects on traits, the estimation of breeding values and selection indices, group breeding schemes, livestock production in extensive systems, and adoption of technology in agriculture. It concludes by reviewing the statistical concepts employed in the remainder of the dissertation. Emphasis is placed on specific traits, namely muscle depth (MD), milk yield (MY) and ovulation rate (OR), as these are the traits that are specifically examined elsewhere in the thesis. Specific issues are further reviewed within chapters relevant to that topic.

2.1. ANIMAL BREEDING STRATEGIES AND SELECTION CRITERIA

Humans have attempted to alter populations of animals in order to make them more suitable for the production of food or fibre, or as providers of transport/draught power for thousands of years. Over the last two hundred years, these attempts have been increasingly effective. Improved breeds of livestock, generally, produce food, fibre or other products which are of higher quality or are better matched to modern requirements than their predecessors. Improved breeds usually have higher efficiency of production than unimproved breeds and so the relative cost of their produce is lower.

Traditionally, three main strategies have been used for the genetic improvement of livestock:

- Selection between breeds or strains – substituting one breed or strain for another
- Selection within breeds or strains – choosing better parents within a particular breed or strain
- Crossbreeding – mating parents of two or more different breeds, strains or species together.

Future strategies may become available as a result of developments in molecular biology,

including the ability to transfer genes within or between species and the ability to regulate or modify the expression of existing or introduced genes (Simm, 1998).

2.1.1. Approaches to Selection

Robert Bakewell (1725-1795) is regarded as the pioneer of livestock improvement. From 1760, Bakewell began letting out rams for hire for the mating season, and is reputed to have ridden around his customers' fields comparing the progeny of different rams, and then using the best of these rams on his own farm. This is an early example of progeny testing, with selection based on visual assessment and handling, which is still in use today.

From the 1900s, some of the scientific foundations for more objective genetic improvement of livestock were laid, but it has only been in the past 50 years or so that these methods of selection (i.e. based on measurements of performance) have become widely used in pig, poultry and dairy cattle breeding, and, to a much lesser extent in beef cattle and sheep breeding. Such methods rely on detailed records of performance and pedigree, requiring individual identification of animals.

Breeding schemes (section 2.4) need to have defined objectives ('Selection Objectives') which are translated into traits that can be measured ('Selection Criteria'). Objective selection within breeds or strains is intended to increase the average level of additive genetic merit (breeding value) of the population. Breeders at all levels of the pyramid hierarchy (section 2.4.1) tailor their breeding objectives to meet the needs of the end users. Ideally, the steps involved are:

1. deciding on the breeding goal and selection objectives
 2. deciding on the selection criteria
 3. designing the breeding programme
 4. implementing the programme
 5. monitoring progress and redesigning the programme where necessary
- (Simm, 1998).

Using the selection criterion, estimated breeding values (EBVs) can be calculated. EBVs are estimates of the additive genetic merit of an animal, and may be based on various sources of information including:

- the animal itself
- the animal's ancestors
- the animal's full or half sibs
- the animal's progeny
- any other relatives of the animal

Based on the animal's own performance, the EBV is the deviation in performance from contemporaries, multiplied by the heritability of the trait concerned. The deviation in performance is calculated after adjusting the performance records for environmental effects (Simm, 1998).

2.1.2. Selection Criteria for Milk Yield

2.1.2.1. Dairy Cows

A milk recording system should be simple and give sufficiently reliable results (Lindstrom, 1976). In the United Kingdom and elsewhere, selection is based on 305-day lactation yields of milk, fat and protein which are predicted from individual test day (TD) records (Pander *et al*, 1992). Accumulated daily milk weights provide the most precise measure of a cow's total MY. However, by sampling less frequently, expense and time are spared (Anderson *et al*, 1989).

The accuracy of estimating MY from samples taken at monthly, bimonthly, and trimonthly intervals has been extensively researched. McDaniel (1969) noted how monthly sampling produces estimates within 5% of actual yield and that error of estimation increases as the length of sampling interval increases. In a comparison of monthly and bimonthly lactation recording methods, Sargent *et al* (1967) noted how there was a much higher frequency of large errors (5% or more) in bimonthly than in monthly testing.

Greater flexibility in the testing schedule can be obtained through the use of irregular interval sampling. Such a method was found to be as efficient as regular interval sampling (Sargent *et al*, 1967). Kennedy *et al* (1978) observed only marginal differences (about 1%) between regular and irregular intervals with 12 tests year⁻¹, while Khanna and Balaine (1989) reported an average bias within $\pm 3\%$ for irregular bimonthly interval records. Similarly, Anderson *et al* (1989) found that unequally spaced sampling methods with four or fewer observations after the peak of lactation exhibit more bias than those including more than four, and noted that the postpeak period of lactation cannot be ignored in sampling for estimation of total MY. It was concluded that for unequally spaced methods, with most sampling completed before and during peak lactation, it was the *c* parameter which represents postpeak decline, that had the greatest influence on the bias in estimated yield (Wood, 1967; Anderson *et al*, 1989).

The extent to which large errors occur in bimonthly estimates is dependent on what day of lactation the first test takes place. The frequency of large errors in bimonthly testing was much greater when recording began in the second rather than the first month of lactation (Bayley *et al*, 1952; Sargent *et al*, 1967). Indeed, McDaniel (1969) concluded that monthly tests were satisfactory provided optimal methods were used for selecting the day for the first test. Khanna and Balaine (1989) reported that both monthly and bimonthly sampling intervals are suitable recording methods if the first test day is between 10 and 45 days, while trimonthly recording methods were only suitable for an initial test-day between 10 and 30 days. However, Shook *et al* (1980) observed bias if estimates of MY were based on records taken in these three periods: before peak production, during peak production, and the last 15 days of lactation. Similarly, Cobby and LeDu (1978) and Congleton and Everett (1980) found that the greatest variation in estimated MY occurred with test-day samples near peak production.

Research has reaffirmed the fact that incomplete MY records for daughters can be used as a basis for sire evaluation without serious loss of accuracy. Both Dommerholt (1975) and Famula and Van Vleck (1981) compared lactation curves and MY between incomplete

and complete records of heifers and concluded that incomplete records could be used for estimating breeding values of sires by extrapolating the records. Famula and Van Vleck (1981) further concluded that little accuracy of estimation of a sire's genetic merit was lost when part records of approximately 5 months were extended and used to replace 305-day information. High genetic correlations between partial yields and complete yields also suggest evaluating sires on partial lactation records (Van Vleck and Henderson, 1961). However, problems have also been reported in the use of part-lactation and records for sire evaluation. Bolgiano *et al* (1979) reported that the inclusion of part records projected to 305 days in sire evaluation could lead to proofs that change more than expected when more complete records are later added. Through examination of relationships between sire evaluation and methods of extended records, Famula and Van Vleck (1981) found that sire proofs calculated entirely from extended incomplete records were overestimated.

An alternative to predicting 305 day MY from part-lactation results is to analyse TD records. In TD models, records from individual test days are used to determine lactation production instead of aggregating records. TD models have gained considerable interest because they are more flexible in handling records from different recording schemes. TD models can predict total production more accurately by accounting for time-dependent environmental effects (Swalve, 2000). Swalve (2000) noted that TD models could be separated into three groups: (1) two-step models under which corrections are carried out at TD level and subsequently corrected TD records are processed in an aggregated form as lactation records. (2) fixed regression models assume that TD records within a lactation are repeated records and because yields in the course of the lactation follow a curvilinear pattern, this curve can be considered by using suitable covariates. (3) random regression models additionally define the animal's genetic effect by using regression coefficients and allowing for covariances among them. The difference between random regression and fixed regression models is that the genetic merit of an individual is allowed to differ in the course of the lactation in random regression models. Meyer *et al* (1989) and Pander and Hill (1993) noted that the most accurate method for genetic evaluation would be multivariate best linear unbiased prediction (BLUP) based directly on TD

records. Alternatively, an index of TD records computed to maximise accuracy of genetic prediction of total MY could be constructed. Computationally, TD models are very demanding particularly for evaluations on a national scale.

Van Tassell *et al* (1992) found that a TD model increased heritabilities for milk, fat and protein, by 12, 11 and 17%, respectively, when compared to 305 day milk records. Furthermore, genetic correlations between all traits were slightly higher for the TD records compared with 305 day MY estimate records (2 – 14% increase). The work of Serrano *et al* (2001) suggested that genetic parameters estimated from TD results for dairy ewes could be affected by the model used for the analysis, particularly where herd-year-season or herd-test day were used as fixed effects. They also found that genetic correlations were higher between adjacent TD records than for records 2 or 3 TD apart.

2.1.2.2. *Milking Ewes*

Milk is an important product from sheep, particularly in the Mediterranean, Middle East and eastern Europe. The specific traits included in genetic improvement schemes for milking ewes result from the fact that they are both dairy animals and meat producing animals. As with dairy cows and milking goats, greater emphasis can be put on an increase in the quantity of milk produced by using some specialised genotypes and intensifying the methods of production. However, milking ewes have been integrated in a very diverse range of production systems (Flamant and Barillet, 1982).

In comparison with other dairy species, ewes have a much lower absolute level of milk production, with an average production varying from about 60-300 litres for recorded breeds. In spite of the better composition and the superior price of the milk and the larger average flock size, the cost of milk recording is significantly higher for ewes compared to cows, relative to the commercial value of the milk produced. Flamant and Boyazoglu (1978) estimated that this ratio was about 2% for cows compared to 4-5% for ewes,

which, unlike cows, do not usually have records for milk composition. Furthermore, Pollott and Gootwine (2000) highlighted that the lack of studies on the complete lactation of dairy sheep was partly due to the fact that in most dairy sheep production systems, lambs are allowed to suck for at least 30 days post lambing and milk recording starts only after weaning. The suckling period coincides with the rising phase and peak of lactation. However, in some dairy sheep flocks operated under intensive management, the common practice is to milk the ewes from the start of the lactation. In such situations there have been attempts to develop milk recording methods.

Records from a flock of Improved Awassi sheep were analysed to investigate the suitability of mathematical functions for describing MY from the complete lactations of dairy sheep (Pollott and Gootwine, 2000), including an investigation into the suitability of such functions to cope with short lactations; a characteristic of dairy sheep. Of the four functions investigated, as described by Wood (1967), Grossman and Koops (1988), Morant and Gnanasakthy (1989) and Pollott (2000), the Grossman, Morant and Pollott models improved on the Wood model. In particular, the Morant function appeared to be the most robust and flexible giving the most accurate values when using monthly MY records, while the Pollott model was more accurate when using weekly MY records.

There have been a number of proposed simplified methods of quantitative milk recording for milking sheep (Flamant and Poutous, 1970; Casu and Labussiere, 1972; Flamant and Barillet, 1982; Barillet, 1985; and Gabiña *et al*, 1986). The methods include the recording of the morning or evening milking in alternate months (AT method) and the recording of the morning milking only or the evening milking only (AF method). A simplified AT method was adopted in 1987 by Gabiña *et al* (1986). Further, an experimental method, namely A, was adopted by the Latxa breeding group, where twice-daily recording of MY was performed. The A method has since been referred to as the "punctual method" because only two or three milk samples are taken during the lactation (Barillet, 1985). In a study by María and Gabiña (1992), the AT method was superior to other methods, although it slightly overestimated the actual production, while the AF method

underestimated the actual values. Such findings confirm those of Gabiña *et al* (1986) and Barillet (1985). Both of these methods, especially the AT method, could replace the A method and retain a high level of accuracy and precision. Further, recording costs would be reduced by 22% (Gabiña *et al*, 1986).

María and Gabiña (1992) compared three differing scenarios within a simplified version of the 'punctual' A method, where two of three records were used to estimate total MY and content. Of the three differing scenarios (P12 contained measurements from the first and second records; P13 from the first and third records and P23 from the second and third records), P13 performed better. For all three methods, protein and fat yield were estimated with a higher precision than protein and fat contents. P13 was the most precise for all production variables. The major difference between the three scenarios was their ability to estimate content. It was concluded that a recording program including an AT method scheme for MY and a P13 punctual scheme for milk composition would be a good choice for the estimation of milk production. In contrast, Flamant and Poutous (1970) proposed adjustment factors in order to correct the bias produced by different milking systems.

Fadel *et al* (1989) noted that large variations between individual ewes, in terms of MY, exist. There are also age effects on the shape of the lactation curve, with MY being more persistent in younger than in older ewes (Peart, 1979). It is, therefore, of great importance that more efficient procedures for estimating MY be examined. High within-flock rank correlations between daily MY recorded on a single recording day and total MY were reported by Fadel *et al* (1989), concluding that this could be an important finding, since selection for ewe MY could, within limits, be based on one daily record taken on one day in one flock, preferably in the early post-weaning stage.

2.1.3. Selection Criteria for Carcass Characteristics

2.1.3.1. Beef Cattle

Accurate prediction methods based on live cattle measurements are required for determining the amount of saleable carcass product (Herring *et al*, 1994). The proportion of fat, bone and muscle affect the cutability percentage of beef carcass. The introduction of carcass specification systems and greater focus of attention on the end product have stimulated a demand for genetic evaluation of carcass traits (Robinson *et al*, 1992).

Kempster *et al* (1982) observed that the least precise predictions of carcass composition were based on carcass dimensions, while the most precise predictions were derived from sample joints, with the precision increasing as the number of joints approached the entire carcass. However, with increasing precision, the costs involved in measuring escalate, both in terms of labour expenditure and loss in product value (Jenkins *et al*, 1995). Thus, more recently, efforts have focused on less-invasive methods to determine carcass constituents. Such methods include ultrasound, magnetic resonance and resistive impedance. These non-invasive methods are effective predictors of carcass constituents and thus reduce the loss in product value associated with the more traditional approaches (Leymaster *et al*, 1985; Jenkins *et al*, 1988 and Mitchell *et al*, 1991).

Ultrasound, used since the 1950's, was initially slow and labour intensive. However, the introduction of the Scanogram in the 1970's and the more recent real-time ultrasonic scanners, have offered the potential to produce quick and accurate measurements at moderate cost. Robinson *et al* (1992) observed ultrasonic scanning as being accurate, effective in predicting carcass measurements and having a potential use in breeding decisions. Results showed that ultrasound fat measurements are at least as accurate as carcass measurements while measurements of muscle depth are only marginally less accurate than careful carcass measurements.

Resistance impedance, as evaluated by Jenkins *et al* (1988), has been reported as the least costly method to obtain an accurate measurement of carcass composition. The inclusion

of resistance impedance with traditional predictor variables significantly reduces the amount of unexplained variation in carcass fat-free tissue. With the relative low cost of data acquisition and the non-destructive procedure, the methodology has been suggested as an effective alternative for evaluating fat-free carcass tissue differences in either commercial or research environments (Jenkins *et al*, 1995).

2.1.3.2. *Sheep Meat*

To a great extent, profitability of sheep production for meat depends on lamb weight. As a result, selection objectives concentrate on this trait alongside growth rates (Tosh and Kemp, 1994; Gilmour *et al*, 1994). Additionally, improvement of carcass quality is an important objective in sheep breeding; the aim being to increase the amount of lean meat while reducing fat content, such that more carcasses can be graded as superior. The grading of carcasses reflects the consumers' desires for lower fat content (Olesen and Husabø, 1994).

The ability to predict carcass quality on live young animals is important in accelerating the rates of genetic progress for carcass quality traits (Olesen and Husabø, 1994). While ultrasonic measurements have been used extensively to predict carcass composition in pigs and cattle (Stouffer and Westerwelt, 1997; Houghton and Turlington, 1992 and Wilson, 1992), contradictory results from the use of ultrasonic techniques on lambs have been reported. In a review, Houghton and Turlington (1992) concluded that most results for sheep indicated that weight or visual estimations of fat were at least as accurate as ultrasound predictions of carcass composition. Further, muscle scans generally were not useful in predicting carcass composition (Wilson, 1992).

Ultrasonic scanner operators have observed how the A mode ultrasound scanner had insufficient resolution (one-dimensional) to adequately measure the depth of eye muscle. However, the two-dimensional image produced by the B mode ultrasound scanner gave sufficient outline of the eye muscle, although the resolution of interfaces perpendicular to the skin was poor (Gilmour *et al*, 1994 and McEwan *et al*, 1991). Further, Gilmour *et al*

(1994) reported that both the A and B mode ultrasound scanners gave consistent results for fat depth measurements. Using a B mode ultrasonography, ultrasound images of a muscle cross-section were analysed by Slosarz *et al* (2001), and they found that 87% of the intramuscular fat on the ultrasound images obtained on live lambs was in accordance with that on the images obtained post-slaughter, indicating a considerable precision of the method. Olesen and Husabø (1994) observed a considerable increase in the accuracy of predicting fat score, but only a small increase in the accuracy of predicting carcass weight and grade, when using ultrasound in addition to weaning weight and grade. However, they did observe a significant increase in the accuracy of selection indices for carcass weight, carcass grade and fat score based on weaning weight and half-sib information by the addition of ultrasonic measurements. In contrast, Nichols *et al* (1992) concluded that ultrasonic measurement of fat thickness and ribeye area in sheep were inconsistent, with only 31% of the scans being within 1.02mm of the actual backfat, and only 50% of scans for ribeye area being within 6.35mm². These findings are supported by the results of Conington *et al* (1998), who found moderate to weak correlations between ultrasonic fat and muscle depth measurements at weaning and slaughter.

In a previous study, Conington *et al* (1995) noted an important environmental effect on the heritability estimate for backfat thickness; noting that lambs reared on improved pasture had double the heritability estimate to that for hill-reared lambs. These findings were supported by a further study (Bishop *et al*, 1996) when two groups: intensively reared and extensively reared sheep were examined. The heritabilities for the two environments were 0.39 and 0.20 for fat depth, 0.36 and 0.25 for muscle depth, and 0.23 and 0.12 for live weight.

2.1.4. Selection Criteria – Fertility Traits

Low lambing rates represent a major obstacle to the sheep industry as a whole. The potential for number of lambs born is affected by many components, including ovulation rate (OR). OR influences prolificacy, fertility and ewes lambing per ewe exposed (Bunge

et al, 1993).

2.1.4.1. Ovulation Rate

Past emphasis on visual selection for wool and weaning weight has likely reduced overall reproduction efficiency (Lewis and Shelton, 1986). Phenotypic selection of ewes at an early age as replacements favours single born lambs since they are larger and in better condition at weaning. In range flocks, where birth data are seldom available and environmental conditions may restrict the growth of lambs from multiple births, discrimination against twins is of particular concern (Purser, 1965).

Bradford *et al* (1986) demonstrated how selection for litter size (LS) can alter OR without affecting embryonic mortality, while Schoenian and Burfening (1990) studied the differences in OR among lines of sheep that had been selected for high or low reproductive (line) rates over 19 years. The result showed how OR was affected by line. The three lines (high-, low- and control-line) had differing mean OR's, with more single ovulations being observed in low-line ewes than in the other lines. High-line ewes had more twin ovulations than low- or control-line ewes.

Smith (1989) reported factors which influenced OR. These included liveweight, liveweight change, nutrition, genotype, seasonal factors and age. A study by Ap Dewi *et al* (1996) confirmed the influence of age and liveweight. They also reported effects of year of recording, condition and rearing type (with singles and triplets having significantly greater OR than twins) on OR. Timashev *et al* (1982) reported that a breeding programme in which matings were made between rams and ewes both born as twins increased litter size by 16 – 18% compared with matings between single born rams and ewes. Further, matings between rams and ewes both born as triplets gave a lambing rate of 127% at the 1st lambing, and this was 9.4% higher than for matings between single born rams and ewes.

In a study comparing the heritability of OR and litter size (LS) in a flock of Corriedale ewes, Rodriguez-Inglesias *et al* (1992) concluded that OR would provide a better selection criterion for reproductive performance than litter size. Ap Dewi *et al* (1996) concluded that prolificacy could be improved by selection of ewe lambs, particularly on the basis of OR. However, the use of OR as a sole selection criterion needs care, for it had been observed that some ewe lambs with low OR subsequently produce high OR and LS during their lifetime.

2.1.4.2. Fertility Rate and Prolificacy

Fertility rate can be expressed as the number of ewes lambing per ewe mated. Prolificacy (LS) has been widely studied in animal production. Morley (1990) reported that gains and cash flows were greatly influenced by prolificacy of the ewe. Lee and Atkins (1994) suggested that ewes could be selected for fertility based on performance at 2 – 3 years of age because this was strongly linked to performance in later life. Gabiña (1995) reported that selection for female fertility and LS would be more efficient for the improvement of meat production than selection for growth. In a study with high or low reproductive rate and a control group, fertility at first service was significantly lower in the high group (0.67) than in the control group (0.77), with the low line being intermediate (0.73). This could be attributed to the ORs for the three groups, where the high, low and control groups had ORs of 1.23, 1.75 and 1.48, respectively. Fertility can be affected by season. Fogarty and Gilmour (1998) observed a significant effect of season on fertility and LS in Australian merino, with June matings resulting in the lowest and February and October mating resulting in the highest fertility and LSs. LS can be affected by age of ewe, litter type (singles/twins/triplets) and season (Dimitrov, 1978; Owen *et al*, 1980; Radomska *et al*, 1985).

A significant effect of season on LS was reported by Notter and Copenhaver (1980) who reported that lambing in September had the lowest LS (1.84), while April had the highest (2.46), with January being intermediate (2.21). As noted above, Fogarty and Gilmour (1998) also observed seasonal effects on LS, as did Mavrogenis (1996) who reported both

year and season of lambing significantly affecting prolificacy.

2.1.5. Repeatability

Repeatability is a parameter frequently used to measure the ability of an individual to repeat its level of performance at successive intervals in time. As opposed to the individual exhibiting exactly the same measurement each time, repeatability means that the level of performance will tend to come near the top (or near the bottom) of the range of observations consistently (Fahmy, 1989).

2.1.5.1. Muscle Depth

Repeatabilities are important to commercial scanning services where there is a trade-off between accuracy of measurement and speed of scanning. Repeatabilities for ultrasonic muscle depth (MD) were reported to be high within the pig industry, with repeatabilities of 0.97–0.99 (Rogdakis *et al* (1994). Research by Purchas and Beach (1981) identified repeatabilities for ultrasonic fat depth measurement of sheep by A-mode machines, but equivalent data for measurements obtained with real-time ultrasound machines are less well known, particularly for ultrasonic muscle depth (Young *et al*, 1992). Young *et al* (1992) reported repeatabilities for muscle depth between 0.77 to 0.95, inclusive. Pritchard and Ap Dewi (2003) found that ranking of Welsh Mountain rams based on muscle depth was not significantly affected by scanning date with animals scanned over a 3 months period.

2.1.5.2. Ovulation Rate

Repeatability estimates for ovulation rate (OR) have ranged from 0.10 (Davis *et al*, 1982) to 0.91 (Hanrahan and Owen, 1985). Fahmy (1989) reported that the repeatability of OR was affected by genetic group, physiological development such as maturation and advance in the breeding season, nutrition, and the method of calculating repeatability.

The effects of breeding season and nutritional status were examined by Carrick *et al*

(1976). Three groups of ewes with low, medium and high nutritional statuses had mean bodyweights of 37kg, 41kg and 46kg, respectively, were examined for repeatability coefficients. Within a breeding season, all groups had a repeatability coefficient of around 0.5. However, between breeding seasons, the estimate of repeatability of OR was dependent on the nutritional status of the ewes between the seasons. Those animals that stayed at the same nutritional level across seasons had a repeatability coefficient of 0.67, but those who had their nutritional status increased from low to medium or high had low repeatability coefficients of 0.42 and 0.24, respectively.

Low repeatabilities have been observed in breeds of sheep with low OR (e.g. Merino, 0.3 and Romney, 0.10 – 0.13), while for prolific breeds (e.g. Finnsheep, 0.66 – 0.78), repeatabilities were generally high. Hanrahan and Owen (1985) identified repeatabilities ranging from 0.87 to 0.91 for the Cambridge breed. Among prolific breeds, only the Romanov breed showed a lower repeatability in OR (0.3) (Ricordeau *et al*, 1986).

2.1.5.3. *Milk Yield*

Repeatability estimates for milk yield (MY) have varied widely. The wide range of repeatability values is due to a number of reasons, as detailed below.

In a study of Japanese Holsteins, Suzuki and Van Vleck (1994) observed an average repeatability of 0.54 for MY. These are comparable with estimates obtained by Visscher and Thompson (1992), but are higher than that reported by Kominakis *et al* (1998), where the range of mean MY repeatability was 0.32 to 0.38. However, Tekerli *et al* (2000) reported how repeatability of MY differed between lactations, with a moderate value for peak (0.26) and lactation (0.34) yields, but lower (0.06 to 0.20) for other lactation curve traits. The low repeatability for peak lactation, as also reported by Ferreira and Fernandes (2000), would suggest that yields at this time would not be a good indicator of subsequent yields. Repeatability estimates for MY became more favourable further into the lactation curve, with mean estimates of 0.47, 0.50, 0.50 and 0.49 for 90, 150, 210 and 305 days, respectively (Verneque *et al*, 2000).

Of the papers reviewed, the highest repeatability noted was that for Massese Sheep, which had an overall repeatability of 0.72 (Secchiari *et al*, 1992). For the same breed, Acciaioli *et al* (2000) found that repeatability was higher with morning than evening milking.

2.2. ENVIRONMENTAL EFFECTS

The term 'Environmental Effect' can be defined as the effect that external (non genetic) factors have on animal performance. Most environmental influences (e.g., pasture quality) are difficult to quantify. Environmental effects like these are generally considered to be unknown, meaning that it is not possible to mathematically adjust animal performance to account for them. Known environmental effects, however, are influences that are consistent so that mathematical adjustment factors have been developed. Table 2.1. shows examples of environmental effects across a number of species and traits, for which adjustment factors are available.

Sections 2.2.1 to 2.2.4. review those environmental factors specific to the traits examined in the thesis, and particularly in relation to chapter 8. Environment effects are further discussed in Section 8.1.

Table 2.1. Examples of Environmental Effects Affecting Animal Performance

SPECIES	TRAIT	ENVIRONMENTAL EFFECT
Cattle (dairy)	Milk Yield	Herd:Year:Season Length of Lactation Lactation Number Breed Milkings per Day Age at Calving
	Fat Yield	Length of Lactation Milkings per Day Age at Calving
Cattle (beef)	Birth Weight	Age of Dam Sex of Calf
	Frame Score	Age Sex
Sheep	Weights (eg 30-day, 90-day, 120-day)	Age of Lamb Type of Birth/Rearing Type (Single, Twin, Triplet) Age of Dam Sex
	Muscle Depth	Rearing Type Ram Age Dam Age
	Wool Traits	Age of Lamb Type of Birth/Rearing Type Age of Dam Sex

(Bourdon, 1997)

2.2.1. Age Effects

Inaccurate preadjustment and subsequent omission of age effects from statistical models used in genetic evaluation may introduce systematic error in selection of breeding stock (Nelsen and Kress, 1981).

2.2.1.1. *Effects of Age on Sheep Traits*

There are several environmental factors influencing weight of lambs. Age of ewe is one of these. Studies reviewing adjustment factors for age of ewe have found that they underestimated weights for lambs born and raised by yearlings and two-year old ewes in several breeds. Furthermore, for Swedish Fur Sheep and Swedish Landrace lambs born to ewes older than two years, the adjustments were considered too low, by some 0.5kg but for Texel, Suffolk and Dalasau lambs, the adjustments were overestimated to the same degree (Kurowska and Danell, 1992). These findings concerning young ewes support those of Newman *et al* (1983), who observed that the most variable group in a flock comprises lambs born to young ewes which are still growing. Kurowska and Danell (1992) concluded that it was important that the adjustments are correct for lambs born to yearlings, as this group was penalised resulting in proportionally fewer lambs from young ewes being kept for breeding.

Earlier studies in the 1970s also reported a varied range of adjustments factors required for the effect of ewe age on lamb weaning weight. Jury *et al* (1979) reported higher regressions on age than other studies, concluding that there were likely to be variations between flocks and between years in the magnitude of adjustment factors.

2.2.1.2. *Effects of Age on Milk Yield in Cattle*

Age at first calving is one of the main factors affecting milk and fat yield in dairy cattle. Other environmental effects usually considered for MY are lactation length, herd, year, and season of calving. Yield records for age are generally adjusted using adjustment factors prior to genetic analysis. Yield increases with age at a decreasing rate and reaches a maximum at maturity. The yield then decreases as cows become older (Mao *et al*, 1974).

Age of calving is often considered together with season of calving, and factors have been developed to account for their effects separately and together. These factors differ by

breed, geographical region and yield trait (Norman *et al*, 1995). An age x season interaction was documented by Cooper and Hargrove (1982). Age effects are more apparent for younger than older cows (Keown and Everett, 1985, Morales *et al*, 1989 and Khan and Shook, 1996). However, seasonal effects assume more importance as a cow matures (Keown and Everett, 1985). Khan and Shook (1996) noted how the effect of age differed over different periods of time, with the increase in yield associated with increasing age and lactation number being greater during more recent years than during earlier years. Advancing age was associated with higher yield within all lactations, but this effect diminished as lactation advanced. Furthermore, differences in MY among cows calving at the same age in different lactations have also been reported (Mao *et al*, 1974). The difference was greater between cows in first and second lactations calving at the same age than between cows in second and third lactations (Ptak *et al*, 1993).

The effects of calving age on yield are reported to have decreased over time. The changes observed were large enough to indicate that new adjustment factors are justified (Norman *et al*, 1995). The use of new adjustment factors confirm the findings by Wilmink (1987) who concluded that age factors need to be estimated periodically, because the age production curve can change due to breeding and/or management/feeding.

2.2.2. Lactation Number

The effect of lactation number on MY has been shown to be significant in a number of studies. Jersey and Holstein cows were studied by Gonzalez and Boschini (1996), and the effect of lactation number was significant ($P < 0.01$) in both breeds. For Jersey cows, their 1st and 6th calvings produced the highest MYs, whilst for Holstein cows, it was the 2nd and 4th calvings. Also, Avadesian (1996) reported a significant effect of lactation number on part- and total lactation yields, and lactation length in buffaloes. Like Holstein cows observed by Gonzalez and Boschini (1996), buffaloes achieved the highest lactation at the 4th calving, but unlike Jersey cows, buffaloes had the lowest lactation at the 6th calving. Furthermore, Özcelik and Arpacik (2000) found that MY increased, but lactation duration

decreased, with increasing lactation number, and the best MY was obtained in the fourth lactation.

2.2.3. Rearing Type

A number of reports have identified a significant effect of rearing type (single, twins, triplets, artificial rearing) on weight and fat depth. Brash *et al* (1992) results suggested that the adjustment figure for lambs born as twins was 5 – 6%, while for triplets, it was 6 – 9%. In a further study, Brash *et al* (1994) reported significant effects on weaning weight of rearing type. Abdel-Aziz (1994) reported heavier weights at weaning for single born/single reared lambs than for twin/triplet born and single reared or twin/triplet born and twin reared. However, the average weights of lambs born as twins and reared as singles were intermediate to those of lambs born and reared as single and born and reared as twins (Hacıislamoglu and Evrim, 1995). Marcq *et al* (1999) found an effect of rearing type (artificial rearing, and natural rearing with 1, 2 or 3 lambs) at 10 and 30 days of age for Texel lambs. The effect of rearing type on body weight, for single and twin born lambs, decreased significantly with age (Yazdi *et al*, 1998).

Brash *et al* (1994) found that twin and triplet born lambs had significantly lower fat depth than single born lambs. Sormunen-Cristian *et al* (1997) observed that for single, twin and triplet suckled ewes, the accumulated MYs for single, twin and triplet suckled ewes were 414, 285 and 163 kg, respectively. The significantly lower fat depths observed by Brash *et al* (1994) could be partly a result of such lower MYs.

2.3. HERITABILITY, ESTIMATION OF BREEDING VALUE AND SELECTION INDICES

2.3.1. Heritability

The heritability (h^2) of a trait is the proportion of the selection differential which, on average, is passed on to offspring. Thus, if the h^2 of a trait was high, much of the

superiority of the parents should be passed on to the offspring. Heritabilities are expressed as proportions (0 to 1) or as percentages (0 to 100%) (Simm, 1998). Estimates of heritability have been widely published and summarised in various texts (e.g. Bourdon, 1997) and are not reproduced here. An important function of h^2 in livestock improvement is its role in estimating the breeding value of animals (Zerabruk, 1995).

2.3.2. Best Linear Unbiased Prediction (BLUP) and Threshold Models

Assessing the genetic merit of stock, with the aid of performance records is one of the main objectives of livestock breeders. Best Linear Unbiased Predication (BLUP) is a method to estimate breeding values.

BLUP is a method of genetic prediction that is particularly appropriate when performance data come from genetically diverse contemporary groups. Because of its ability to account for genetic differences among contemporary groups, and because it provides genetic predictions for many animals at once, BLUP is the preferred method for large-scale genetic evaluation (Bourdon, 1997). BLUP is a statistical technique which disentangles genetics from management and feeding; producing a more accurate prediction of breeding value. This is achieved by:

- Estimating environmental effects (like dam age) and predicting breeding values simultaneously
- 'Recognising' that some performance records are from related animals, and so they are expected to be more alike than those from unrelated animals (Simm, 1998).

BLUP can be applied under different sets of models; the most common being: sire models, sire-maternal grandsire models and individual animal models. The name of the model specifies the animal for which the breeding values have been predicted. BLUP methods are used for the prediction of breeding values of animals in a large number of countries and species, taking into account effects such as herd-year-season. The prediction of an animal's breeding value using this method is based on phenotypes of the

animal itself and/or those of its relatives (Van Arendonk *et al*, 1994). One of the merits of BLUP is its ability to provide directly compared estimates of the average breeding value of groups of animals born in different herd/flock years. Furthermore, BLUP accounts for environmental effects, sires coming from one distinct group or population, herd differences in the average breeding values of dams, and bias to selection and culling.

2.3.3. Threshold Models

A number of traits in natural populations show discontinuous variation. In order to understand the inheritance of such characters it has to be assumed that the trait has an underlying continuity with a threshold which imposes a discontinuity on the visible expression (Falconer, 1989).

Those individuals with underlying phenotypic values above the threshold exhibit the trait and are classed as “affected”, while all those below it do not exhibit the trait and are classed as “normal” (Lynch and Walsh, 1998). The underlying continuous variation (known as the liability) of a trait is both genetic and environmental in origin, and can be a combination of several different physiological or developmental processes (Falconer and Mackay, 1996).

Threshold models have been suggested to be more appropriate for analysing traits that are scored into one or several ordered categories than models that ignore this characteristic of the data (Jamrozik *et al*, 1991). If the shape of the distribution is non-normal, such that the observations occur mostly in an extreme category, for example, then a threshold model may be preferred more than a linear model.

A drawback of the threshold model is the increased amount of computing needed to estimate thresholds and breeding values simultaneously compared to a linear model (Jamrozik *et al*, 1991).

2.3.4. Selection Indices

When there are several traits of economic or functional importance, the calculation of a selection index is appropriate. A selection index is a measure of overall genetic merit for each of the animals available for selection, based on their or their relatives' performance in the traits of interest. With selection index, an animal can compensate for poor performance in one trait by excelling in another (Simm, 1998). In practice, the traits of interest are often measured in different units, and they have different heritabilities, making the calculation of appropriate weighting complicated. Simm (1998) notes that in order to derive the weighting factors, it is necessary to know: (1) how much additive genetic variation there is in the traits of interest, (2) the direction and strength of association among these traits and (3) their relative economic importance. Obtaining reliable estimates of the genetic variation in traits and associations among them requires comprehensive recording. This works well when the traits of interest are already recorded in a large regional or national scheme, but it is more difficult and costly to obtain them for traits which are not already recorded, thus causing a major limitation to the wider use of index selection (Simm, 1998).

Selection indexes have become widely used in meat and dual-purpose sheep breeds. In the UK since the mid-1980s, participants in the sheep breeder recording scheme have had a choice of four breeding goals: lamb growth, ewe mature size, litter size and maternal ability. These can be used individually or weighted in various combinations using multi-trait selection indexes. Using the MLC/Signet multi-trait indexes for sheep in the UK, hill breeds use a 40, 9, 11 and 40% contribution of lamb growth, mature size, litter size and maternal ability, respectively (Simm, 1998).

The inclusion of ultrasonic MD and fat depth measurements in a selection index have shown encouraging results. Performance testing programs using selection indices for sheep meat provide sheep breeders with estimated breeding values (EBV's) for growth rate and leanness using measured liveweight, fat depth and MD (Gilmour *et al*, 1994). Simm *et al* (1987) and Simm and Dingwall (1989) observed that such an inclusion

increased the correlation between the index and the aggregate breeding value of carcass lean and fat weight significantly. Further, a report by Cameron and Bracken (1992) showed a significant selection response of body composition after three years of selection using an index of ultrasonic backfat depth and liveweight. Cameron (1992) concluded that divergent selection for high and low carcass lean content resulted in animals with different rates of lean growth, but similar rates of fat deposition.

There is growing interest in broader selection goals within cattle breeding schemes. The move away from selecting only for increased output has been stimulated by factors such as the surplus of dairy products in temperate countries, growing public concern for the health and welfare of farm animals and the formation of nucleus breeding schemes in some countries which have facilitated direct recording of new traits for selection, for example, feed intake and health events (Simm, 1998). Such objectives and alternative traits can be accommodated in selection indices.

In support of multi-selection indexes, Ashmawy (1990) reported that selection for MY alone was 5% less efficient in improving MY compared with selection using an index of MY, milk fat and milk protein. However, a selection index comprising milk and fat yields was expected to decrease protein yield by 0.4kg per generation. Murdia and Tripathi (1991) observed the highest aggregate genetic merit when an index incorporating age at first calving, dry period, service period and MY was used. Furthermore, while selection on udder traits, foot angle and milk yield resulted in only a small increase in efficiency over selection for MY alone the inclusion of these traits may help reduce involuntary culling (Rogers and McDaniel, 1989).

2.4. BREEDING SCHEMES

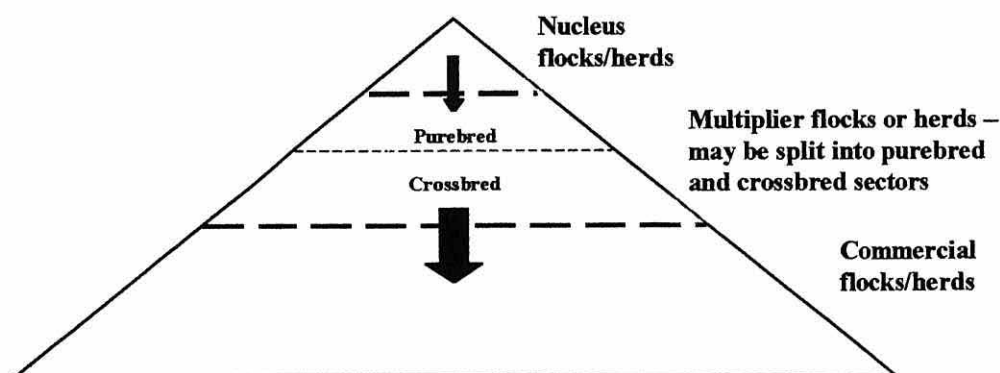
2.4.1. General Structures

The structure of livestock breeding industries in most industrialised nations is often described schematically as a pyramid, with nucleus breeders at the top, one or more tiers

of purebred or crossbred multipliers, and a final tier of commercial herds/flocks (Figure 2.1).

In the pyramid structure illustrated in Figure 2.1., the nucleus flocks/herds are the main focus for genetic improvement. The nucleus breeders' role is to produce breeding stock, particularly males, for use within the top tier and in multipliers' herds and flocks. The multiplier flocks/herds take improved stock from the tier above to create larger numbers of animals for sale to the tier below (Simm, 1998). Generally, selection in the higher tiers will be based on quantitative measurements of traits, whereas in the lower tiers more emphasis is likely to be placed on subjective assessment. Breeding schemes are further discussed in Section 5.1.

Figure 2.1. The Structure of Livestock Breeding Industries in many Industrialised Nations



(Source: Simm, 1998)

2.4.2. Group Breeding Schemes

A group breeding scheme is a cooperative breeding scheme with a nucleus of elite animals screened from members' flocks or herds. Recording and selection are concentrated in the nucleus, which then produces breeding stock for members. The first group breeding scheme was set up in New Zealand, in the 1960s. Farmers initiated the cooperative

breeding schemes to produce their own replacement breeding stock, especially males. In most cases, this involved the formation of nucleus flocks or herds. The success of the original schemes in the 1960s and 1970s led to the establishment of similar schemes elsewhere. For example, group breeding schemes were established in several sheep breeds (Welsh Mountain, Llŷn and Cambridge breeds) and cattle breeds (Welsh Black Cattle) in the United Kingdom (UK).

The longest established group in the UK is the CAMDA Welsh Mountain group breeding scheme in North Wales (Simm, 1998, Ap Dewi, 1999). Founded in 1976, CAMDA was the first group breeding scheme in the UK. The breeding objectives of the group are to produce ewes that lamb easily and rear heavier lambs on hill pastures.

2.4.2.1. Advantages of Group Breeding Schemes

Group breeding allows intense selection for traits of commercial and economic value under commercial conditions. Detailed and accurate selection can be carried out in the nucleus flock and special tests (e.g. progeny testing) can be carried out on the nucleus farm. All the replacement rams for the co-operating farms come from the nucleus flock so the improvements are quickly spread throughout the group and inbreeding problems are avoided.

Other benefits of belonging to a co-operative scheme include:

1. Group discussions and pooling of expertise can lead to general improvements in management
2. As a group, farmers would be able to afford to employ technical help and advice on both management and veterinary aspects
3. Group will have a larger corporate identity which would benefit the marketing of both slaughter lambs and breeding stock.

(Speedy, 1980).

2.4.2.2. *Disadvantages of Group Breeding Schemes*

There has been a relatively low involvement in this type of scheme in many countries, compared to that seen originally in New Zealand, and then Australia. The popularity of these schemes has also recently declined in New Zealand and Australia. The reasons for this could be in part due to the high level of co-operation, financial and legal commitment required to make the schemes work (Simm, 1998).

Other potential disadvantages include the possible transfer of infectious diseases. Screening of co-operating flocks by a veterinary surgeon should be undertaken at the outset, and an agreed programme of preventive medicine implemented thereafter.

2.4.2.3. *Sire Referencing Schemes*

Sire referencing schemes have similar aims to group breeding schemes but they do not require the formation of central nucleus flocks or herds. Instead, genetic links are created across members' flocks by the use of a panel of artificial insemination (AI) rams on a portion of the ewes in each flock, or by sharing rams across flocks. Because of these links between flocks, across-flock BLUP methods can then be used to produce EBVs which can be compared fairly across cooperating flocks (Simm, 1998).

Sire referencing schemes have been in operation for sheep and beef cattle in Australia, New Zealand, the United States (US), South Africa and France for over a decade. The development of these schemes has been assisted in several countries recently by improvements in AI techniques for sheep, the wider accessibility of BLUP evaluation procedures, and the availability of cheaper, more powerful computers. For example, sire referencing schemes have been established in about fifteen sheep breeds in the UK since 1990. About half of the Signet-recorded flocks are now members of these schemes (Simm, 1998). The operation of these schemes usually involves:

- **Selection of a panel of reference rams for use across members' flocks:** To qualify as potential reference sires in most schemes, animals must have high EBVs

or index scores, be functionally sound. Most schemes have a panel of about six reference sires in use at any one time.

- **Use of two or three reference sires, by AI or natural mating, on a proportion of the ewes in each member's flock:** Laparoscopic AI with frozen semen is often used in schemes where geographic spread of members is wide. A total of 30 ewes per flock is usually recommended for mating to reference sires.
- **Recording performance in appropriate traits:** This is done via the Signet Sheepbreeder recording scheme.
- **Evaluation of performance records using across-flock, multi-trait animal model BLUP:** This produces EBVs which can be compared fairly across flocks and across years.
- **Use of these results to select the next generation of potential reference sires and to select sires and replacement females for the members' flocks.**

(Simm, 1998)

2.5. LIVESTOCK PRODUCTION IN EXTENSIVE SYSTEMS

Animal production within upland areas or on areas of extensive hectarage; both of harsh environments with extremes of weather can be low in profit and output. Livestock are usually left to roam in large areas and the rounding up of the livestock can be very time consuming. Such livestock are not normally uniquely tagged. Certainly, within the UK, there is no legislation stating that sheep have to be uniquely tagged (cattle have unique identifiers in the UK) (MAFF, 2000). Ear tags for sheep simply state the farm at which they were born. Financial constraints do not allow many farmers in developing countries, or even hill farmers in the UK for example, to invest in costly breeding programs. Therefore, in terms of non-unique tagging and the financial constraints, the selection programmes and breeding schemes outlines in sections 2.1. to 2.4. are rarely adopted by hill or rangeland farmers.

2.5.1 Range Production Systems

Rangelands represent an important resource in many countries around the world. Sandford (1983) reported that about 30 to 40 million people in arid and semi-arid regions have “animal based” economies, and that over 50% of these people live on the continent of Africa and are commonly referred to as “pastoralists”.

Rangelands are semi-natural ecosystems with its natural vegetation forming the basis of any enterprise placed upon it. The principle management method is the deployment of grazing pressure which can be manipulated according to rainfall and condition of the plants, and by resting some areas at critical times. Rangelands play a major role in supplying human populations with animal products. Africa, India, Australia and the United States are just some examples of countries/regions with range farming (Holechek *et al*, 1995).

There are many different types of rangeland. Grassland, desert shrubland, savanna woodlands, forests, and tundra are the basic rangeland types of the world. Activities such as grazing have substantially altered the natural biota in all the rangeland types. Grasslands are the most productive rangelands in the world when forage production for farming is the major consideration. Grasslands are typically free of woody plants (shrubs and trees) and are dominated by plants in the family Gramineae (grasses). Grasslands occur from sea level to 5000m but are most common on relatively flat, inland areas at elevations from 1000 to 2000m. Grasslands generally occur in areas receiving between 250 and 900mm annual precipitation, and this precipitation generally occurs as frequent light rains over an extended period (90 days or more) (Holechek *et al*, 1995).

However, it is the desert shrublands, which have received the greatest degradation by heavy grazing, and show the slowest recovery degradation. Desert shrublands are the driest of the world's rangelands, receiving less than 250mm of annual precipitation in infrequent, high intensity rains during a short period (less than 90 days). Of the different rangelands, desert shrublands cover the largest area. In some cases, desert shrublands

have been created by degradation of arid grasslands by heavy livestock grazing.

Range farming is usually based on large size properties. In Australia, for example, a property for the production of mutton and lamb can be as large as 100,000 hectares (ha), and on average, wool-growing properties are larger (Holechek *et al*, 1995).

In Australia and the US, for example, range farming does not require a large work force, for the gathering of the herds/flocks for operations such as castration and selection of animals for slaughter is often done with the aid of aircraft. Furthermore, manual work is reduced to a minimum. The guarding of the herd is replaced by the use of enclosures, and animals remain at pasture day and night throughout the year (Pagot, 1992).

One of the major indirect costs with potential for reduction is better detection of unproductive animals. Rangeland farming is characterised by its low calf or lamb production (below 70%). This relates to the percentage of breeding females in the herd that produce a salable offspring. The reasons for such a low production are varied but include low nutritional plane and disease. However, identification of low-producing females is difficult when young are born throughout the year, as has been the case in the US. Efforts have been made to enable a group spring calving or lambing period each year. This enables all female livestock to be on a high nutritional plane during lactation and the young will not be exposed to adverse climate conditions. Currently, non breeding animals are removed from the herd/flock and sold immediately after the breeding season (Pagot, 1992).

Putting genetic improvement plans for rangeland breeds into operation brings difficulties which arise from both the harshness of the natural environment and the technical mastery of the stock person (milk recording for example) (Pagot, 1992). When selecting animals for rangeland production, it is necessary to select species that are adapted to the harsh conditions. Some of the important factors affecting species selection are: 1. Type of vegetation, 2. Topography, 3. Water requirements, 4. Predators, 5. Pests and diseases,

and 6. Economic and social conditions. To select animals on just one or a few of the above factors would be both uneconomical and impractical.

The very essence of performance recording requires skill from the stock person, but this may not fit in with the realities of range herds (transhumanance, for example). The most rapid improvements will firstly be seen from improvements in the environment (feeding, shelter, for example) and secondly, on preselection activities which are quick and easy to set up, for example, the culling of unproductive females. Setting up sophisticated selection schemes should be kept for the most favourable situations, such as sufficiently large sedentary herds, and should be accompanied by a thorough consideration of the production systems and their development (Pagot, 1992). To transfer sophisticated breeding programmes devised for the developed world to developing regions which may not possess the necessary infrastructure would be both difficult and unrealistic. It could not be expected that such complex systems would be practical in such environments. Highly commercial and highly specialised systems may not be biologically, economically or even socially desirable for the developing world (Willis, 1998; Pagot, 1992).

2.5.2 Hill Farming – Wales And England

The hills and uplands of Wales and the North of England are recognised as harsh environments in which to farm. In the traditional system of hill sheep management, ewes are set-stocked on hill pastures throughout the year. The stock are often territorial and little if any control is exercised over their grazing. The stock are dependent on grazed herbage at all times with a supplement of concentrate feeding in the weeks prior to lambing. Stocking rates are generally low, varying from about 0.75 – 4.00 ha/ewe, and are determined by the ‘winter carrying capacity’, which is the number of ewes which experience has shown can be overwintered commensurate with an acceptable lambing performance and the minimum supplementary feeding (Russel, 1983).

Ewes are brought down from the hill for lambing, which takes place in paddocks of

improved pasture. Improved pasture is important during lactation and the lamb growth period. Where improved pasture is limited, ewes with singles are turned onto the hill, with ewes with twins given preference for the best grass. Summer grass production on the hills is utilised by young breeding sheep, dry ewes and cattle. The lambs are usually weaned in mid-August. Some or all of the lambs may be fattened using available hay, rape or turnips. The ewes are turned back to the hill and the improved pastures rested to allow regrowth. Prior to mating, the ewes are returned to the improved areas in early October with the intention of improving body condition before mating. Rams are withdrawn at the end of December to avoid a protracted lambing and the ewes are returned to the hills for the winter. During the winter, the ewes rely on the hill to provide a bare maintenance ration. This is during the period of mid-pregnancy when some decline in weight and condition is acceptable and inevitable (Speedy, 1980).

The potential for income is constrained by environmental and physical conditions that restrict the farm systems to low output, extensive livestock enterprises (Venus and Cain, 1997). Hill farming occupies 44% of agricultural land, making it the largest agricultural sector in Britain, as classified by area mass. However, Haines (1987) reported the output from hill farming made up only 8% of the agricultural sector output.

When the UK joined the EC in 1973, the upland areas were designated a Less Favoured Area (LFA). This designation was established to ensure the continuation of farming in the hill areas through the payment of additional subsidies. Until the year 2000, subsidies were in the form of Hill Livestock Compensatory Allowances (HLCAs), which were headage payments available on breeding cattle and breeding sheep on a farm which has a qualifying area of LFA land. For Wales and England, the HLCA scheme has now been replaced by the Tir Mynydd and Hill Farm Allowance (HFA) schemes, respectively (MAFF, 2000).

Of the total sheep and cattle in Wales, 89% and 67%, respectively, are situated in LFA (National Assembly of Wales, 2000), and will thus gain support from the Tir Mynydd scheme. A comparison of the Tir Mynydd scheme against the former HLCA scheme

showed that a farmer would only gain the same subsidies as provided by the HLCA if the stocking rate was ≤ 3 ewes/ha (Ap Dewi, unpublished). They could gain about £2000/year more if their farming methods were sensitive to environmental issues. Therefore, any farm with a high stocking rate would receive lower subsidies.

2.6 ADOPTION OF TECHNOLOGY IN AGRICULTURE

Agricultural extension involves the conscious use of communication of information to help people form sound opinions and make good decisions. Agricultural production has increased substantially in many countries since the 1940s. This is a result not only of increased inputs in irrigation, fertilisers etc., but also to a large extent the increased productivity of the inputs used. Agricultural extension organisations try to change farmers' behaviour through education and communication (Van den Ban and Hawkins, 1988). Research has shown that investments in agricultural research and extension often gives a high rate of return. The average internal rate of return is about 40 per cent which is much higher than for other investments in agricultural development. Competent farmers are an important condition for this development. If a farmer is taught a new idea he may use it for many years and stimulate his colleagues to use it also. However, studies have shown there is a large variation in this rate of return, one reason being that extension is not always well organised (Van den Ban and Hawkins, 1998).

Since the 1960s, there has been increasing emphasis on rural development programmes and projects, and recognition that the development of rural areas is just as important as the building up of urban, industrialised complexes. There are strong reasons why resources should be put into rural development. More than half the people of the world and the vast majority of people in developing countries (Asia, Africa and Latin America) live in rural areas and gain part or all of their livelihoods from some form of agriculture. Most of these people are also still very poor and dependent on agricultural practices that have benefited little from modern technology (Oakley and Garforth, 1985).

Van den Ban and Hawkins (1998) noted that agricultural extension must be oriented primarily towards the farmer's problems as the farmer perceives them, and not towards agricultural technology. The information or advice given must be in the best interests of the farmer, and more so, for the best interests of the community at large. The use of an extension programme may help to overcome the problems that prevent farmers from achieving their goals. Barriers could include:

1. Knowledge – farmers may lack adequate knowledge and insight to recognise their problems, to think of a possible solution, or to select the most appropriate solution to achieve their goals.
2. Motivation – farmers may lack motivation to behave in a certain way. This may be because the desired change in behaviour conflicts with other motives, for example, not paying attention to milking shed hygiene because disinfectants are expensive.
3. Resource – some extension organisations have the responsibility for removing the barrier of a lack of resource.
4. Insight – some farmers may lack insight into how to obtain the necessary resource.

Livestock extension has been low on the list for Africa's formal extension programmes. In many countries, livestock development is the official responsibility either of the Veterinary Department or of a livestock services section dominated by veterinarians (Morris, 1991). Working alongside veterinarians, governments promote livestock development by promoting effective disease control, introducing high yielding 'exotic' breeds or upgrade 'improved' local breeds, promote modern ranching and commercial production, remove tsetse flies, and assist dairy farmers with better pastures and AI (Jahnke, 1982). With little or no contribution from users, introducing extension practices in the form of transfers of ranching and dairying technologies from large farms to widespread use among smallholders has had little acceptance among average producers (Morris, 1991).

Studies have demonstrated that many of the techniques applied by animal scientists to smallholders are erroneous (Behnke, 1985; Hill, 1985). Furthermore, the techniques are

often capital-intensive, and increase producers' risks in an already very risky environment (Morris, 1991).

Livestock extension thus inherits excessive erroneous assumptions and long periods of coercive regulation. It has also suffered because the technologies being promoted are particularly vulnerable to economic and political dislocations. Improved animals represent a huge financial commitment to a smallholder. Farmers tend to avoid such investments when faced with multi-year droughts, the absence of commercially available feedstuffs and veterinary products. There is a need for better technical packages which deal with agro-pastoralism, and which can assist nomads and settlers alike (Morris, 1991).

2.6.1. Factors Affecting Extension

The management of agricultural extension practices must carefully consider a number of factors in order to enable any change to an existing system to commence smoothly.

2.6.1.1. *Cultural Barriers*

Farmers and their families are members of the society in which they live, and in any society there are strong pressures on its members to behave in certain ways. Farmers' attitudes are influenced by their society's culture. Even if the benefits of methods not currently adopted by a society are explained to them, a farmer's strongly held attitudes may make it difficult for them to change.

The culture of a society is the way in which people live, their customs, traditions and methods of cultivation. Each aspect of the culture of a society has a definite purpose and function and is related to all the other aspects of its culture. An extension programme will only be successful if it is acknowledged that change in one aspect of culture ultimately affects all of the culture. It is therefore beneficial to have local leaders and farmers involved in the planning of an extension programme (Oakley and Garforth, 1985).

2.6.1.2. *Economics*

In most countries, the agricultural extension service is one of the departments of the *Ministry of Agriculture*, while for some countries agricultural extension is provided by university establishments. Increasingly, agricultural extension and information is provided by commercial firms, banks and private consultants, and in more recent years, there has been a trend towards the privatisation of governmental services. Farmers are expected to share the responsibility for this service and pay for all or part of the costs. A farmer may contribute to the costs in one of the following ways:

1. Pay a fee for each visit an extension agent makes to their farm,
2. Payment of a levy, charged on certain agricultural products from which agricultural extension is financed,
3. Membership fee paid to a farmer's association
4. The extension service may receive a specified portion of the extra income a farmer earns as a result of the advice given by the extension agent (Van den Ban and Hawkins, 1998).

2.6.1.3. *Labour*

The whole extension process is dependent upon the extension agent. Often, the effectiveness of the extension agent can determine the success or failure of an extension programme. The extension agent must be resourceful, a good communicator and have an appreciation for social and cultural life styles. An extension agent can be categorised by the following statement: 'An extension agent tries to arouse people to recognise and take an interest in their problems, to overcome these problems, to teach them how to do so, to persuade them to act on his teaching, so that they ultimately achieve a sense of satisfaction and pride in their achievements' (Oakley and Garforth, 1985).

2.7. **DETAILS OF STATISTICAL CONCEPTS**

2.7.1. **Normal Distribution**

The frequency distribution of many recorded characteristics of farm livestock conform to

the normal distribution. The normal distribution is the most important distribution in statistics (Ott and Mendenhall, 1985). There are two main reasons for this: firstly, it arises when a variable is measured for a large number of nominally identical objects, and when the variation may be assumed to be caused by a number of factors each exerting a small positive or negative random influence on an individual object. Secondly, the properties of the normal distribution have a very important use in the statistical theory of drawing conclusions from sample data about populations from which the samples are drawn.

The normal distribution can be defined by the equation:

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-[(x-\mu)^2/2\sigma^2]}$$

where: variable y is the probability density function of a value of the variable (Ott and Mendenhall, 1985).

variable x is the area of the curve that lies between two values

μ is the population mean

σ is the standard deviation of a normal distribution

and e and π are mathematical constants (Parker, 1973).

2.7.2. Measures of Variability

2.7.2.1. Variance

The variance of a set of measurements utilises the deviations of the measurements from their mean. The larger the deviations, the greater will be the variation of the set of measurements. The deviations of the measurements are computed by using the formula: $(x-\bar{x})$ where x is a measurement and \bar{x} is the mean of the set of measurements. It is normal practice to use the squared deviations of the measurements from their mean. This eliminates the fact that non-squared negative and positive deviations balance one another, resulting in their sum (and hence mean) equalling zero. The square of a deviation is

represented as $(x - \bar{x})^2$ and the sum of the squared deviations is known as the 'sum of the squared deviations'. The sum of the squared deviations is divided by $n-1$, on the assumption that the data is not the whole population. The result is known as the variance (Ott and Mendenhall, 1985).

2.7.2.2. *Standard Deviation*

The standard deviation of a set of measurements is the positive square root of the variance.

The empirical rule that applies to a normally distributed set of measurements is:

$(\bar{x} - N)$ to $(\bar{x} + N)$ contains approximately 68% of the measurements

$(\bar{x} - 2N)$ to $(\bar{x} + 2N)$ contains approximately 95% of the measurements (exactly 95% of the area lies within 1.96 standard deviations of the mean)

$(\bar{x} - 3N)$ to $(\bar{x} + 3N)$ contains approximately 99.7% of the measurements

where \bar{x} is the mean and N is the standard deviation

(Ott and Mendenhall, 1985).

2.7.3. **Areas Under The Normal Distribution Curve**

Areas under the standard normal probability distribution, between the mean and successive values of z are available in standard tables and can be obtained by appropriate functions in statistical computer packages and spreadsheets (Minitab, v10Xtra; MS Excel 1997). z values relate to the areas in the tail of a normal distribution, and can be calculated using the formula: $z = (\bar{x} - \mu) / \sigma$. z is in standard deviation units and can range from 0 to 4. For selection on the basis of a measured characteristic, for example, a trait, the appropriate value of z can be obtained from tables from a knowledge of the proportion to be selected (Ott and Mendenhall, 1985). \bar{x} , μ and σ are explained in section 2.7.1.

2.7.4. Random Sampling

A sample is a sub-set of a population, a set of some of the measurements, which comprise the population. Sampling saves time, money and effort, provided that the appropriate sampling method and sample size are used.

The most important method of sampling, random sampling, can be defined as one for which each measurement in the population has the same chance (probability) of being selected. Random sampling requires that we can identify all the individuals or objects which constitute the population, and that each measurement to be included in the sample is chosen using some method of ensuring equal probability, for example, by the use of random number tables (Ott and Mendenhall, 1985). Sampling is further discussed in Chapter 4.

2.7.5. Transformation of data

In order to perform statistical analysis on any given data set, it is necessary to know whether the data set conforms to the following two important assumptions:

- That the effects are additive, i.e., an individual value is considered to be made up of the grand mean + treatment effect + uncontrolled error
- That the uncontrolled error is normally distributed and has an equal variance for all treatments (Parker, 1973).

Where these assumptions are not met, adjustments are necessary and such adjustments can take the form of transformation. Transformation is the conversion of the original data to a new scale prior to analysis. A change in scale does not alter the information content of the original data; it changes the relationship of one value to one another. The aim of transforming data is for the data to resemble normality as closely as possible prior to analysis (Lynch and Walsh, 1998). Transformation is considered further in chapter 7.

CHAPTER 3 GENERAL MATERIALS AND METHODS

3.1. EXAMPLE DATA SETS

3.1.1. Muscle Depth Records

3.1.1.1. Source of Data

Muscle depth (MD) records for lambing years 1991, 1992, 1993 and 1994 were available from a group of Welsh Mountain rams that had been on an over winter performance test (October-May annually). All rams were from the nucleus flock of the CAMDA group breeding scheme.

The historical mean and standard deviation data, which were used for methods 2 and 3, were obtained from records for commercial flocks of Welsh Mountain rams. These records were for the year 1989 (Ap Dewi *et al*, 1990).

3.1.1.2. Method of Data Recording

Muscle depth measurements were obtained by ultrasonic scanning. A Dynamic Imaging Concept L real time ultrasonic scanner with a 7.5 Mhz transducer was used. Experienced operators from the Meat and Livestock Commission carried out the measurements according to their defined procedure (MLC, 1989).

3.1.1.3. Summary of Available Records

For MD, there were 39, 38, 44 and 43 records for the years 1991, 1992, 1993 and 1994, respectively.

Table 3.1. Brief Statistical Summary for Muscle Depth by Year

Year	MD Mean (mm)	MD SD	MD (mm)		Rearing (1=Single 2=Twin)		Dam Age (Years)		Ram Age (Days)		Weight (kg)	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1991	24.4	2.20	19	29	1	2	2	6	370	403	47	60
1992	27.4	2.00	24	33	1	2	2	5	379	404	46	68
1993	27.7	2.18	24	33	1	2	2	6	380	405	50	80
1994	24.5	1.71	21	29	1	2	2	6	362	392	41	61
All	26.0	2.02	21	29	1	2	2	6	373	401	46	67

MD = Muscle Depth, SD = Standard Deviation

3.1.2. Milk Yield Records

3.1.2.1. Source of Data

Milk yield (MY) records for the year 1994, for farms F328 (A), F331 (B), F353 (C) and F479 (D) were extracted from data sets provided by the Scottish Livestock Services Ltd. (SLSL) (Pryce *et al*, 1997). Data from SLSL were chosen as they provided a data set of the size required, with several years' worth of data. Farms with a very small or large number of records were avoided. Essentially, the farms were chosen at random without knowing the true identity or location.

The historical mean and standard deviation data, which were used for methods 2 and 3, were obtained from a data set provided by SLSL (Pirzada, 2001).

3.1.2.2. Method of Data Recording

The 305-day MY data was estimated lactation yield, based on monthly samples on the farm, without being corrected for lactation length.

3.1.2.3. Summary of Available Records

For MY, there were 100, 118, 101 and 113 records for farms A, B, C and D, respectively. Cows comprised a mixture of Holstein Friesian and British Holstein.

Table 3.2. Brief Statistical Summary for Milk Yield by Farm

Farm	Milk Yield Mean (Litres)	Milk Yield Standard Deviation	Milk Yield (Litres)		Lactation Number		Calving Age (Months)	
			Min	Max	Min	Max	Min	Max
A	7548.6	1104.63	5035.4	10800	2	10	34.5	133.40
B	7014.3	1251.64	4352.2	10731.8	1	11	27.6	153.40
C	7865.6	1379.06	4416.4	10763.4	2	7	35.5	107.30
D	5907.3	975.45	3401.4	8374.9	1	10	29.6	129.30
All Farms	7083.9	1178.19	4301.35	10167.53	1.5	9.5	31.8	130.85

Milk Yield is corrected to 305 Day

3.1.3. Ovulation Rate Records

3.1.3.1. Source of Data

Ovulation rate (OR) records for lambing years 1988, 1989, 1991 and 1992 were available from a flock of Cambridge ewes, College Farm, University of Wales, Bangor.

The historical mean and standard deviation data, which were used for methods 2 and 3, were obtained from the same flock, using records from the year 1986.

3.1.3.2. Method of Data Recording

OR was routinely assessed in this flock by laparoscopy particularly during the first and second mating season. OR counting was carried out in October/November when the animals were about 8 months old. OR was estimated by counting the number of corpora lutea on ovaries by laparoscopy 6 to 13 days after ewes exhibited oestrus. OR is expressed as the total number of corpora lutea found on both the right and left ovaries (Ap Dewi *et al*, 1996).

3.1.3.3. Summary of Available Records

For OR rate, there were 70, 96, 90 and 61 records for the years 1988, 1989, 1991 and 1992, respectively.

Table 3.3. Brief Statistical Summary for Ovulation Rate by Year

Year	Ovulation Rate Mean (Count)	Ovulation Rate Standard Deviation	Ovulation Rate (Count)		Rearing (1 = Single 2 = Twin 3 = Triplets)	
			Min	Max	Min	Max
1988	2.8	1.34	1	7	1	3
1989	2.2	1.00	1	5	1	3
1991	2.7	1.48	1	10	1	3
1992	2.4	1.37	1	7	1	3
All Years	2.5	1.3	1	7.25	1	3

3.2. SELECTION METHODS

3.2.1. Description of Methods

The basis for all the methods was the calculation of threshold values(s). The threshold values were used as the basis for selection decisions. Animals on or above the threshold value were selected for breeding purposes. The calculation of threshold values (sections 3.3. and 3.6.4) was the same for all methods, but the origins of the data input into the threshold calculation differed, as detailed in sections 3.2.1.1. to 3.2.1.4.

3.2.1.1. Method 1

The threshold value used for method 1 was calculated using a sample of the actual data set. Refer to Chapter 4 for details on how the sample size was obtained.

3.2.1.2. Method 2

The threshold value used for method 2 was based on historical mean and standard deviation data (Sections 3.1.1.1., 3.1.2.1. and 3.1.3.1.).

3.2.1.3. Method 3

For the first record, the threshold was based on an average of the historical mean and the first record itself, and the standard deviation was the historical standard deviation, alone. For subsequent records, the mean and standard deviation were calculated using an average of all records collected up to that point, as well as including the historical mean and standard deviation. As the number of records increased the contribution of the historical data decreased.

3.2.1.4. Method 4

For the first record, the threshold value was based on Method 1's sample size data and the trait value for that record. Then, like Method 3, the method updated the threshold for each new record.

3.3. CALCULATION OF THRESHOLD VALUE

A threshold value is calculated as:

$$\bar{x} \pm (sd * z)$$

where:

- \bar{x} is the data set mean
- $(sd * z)$ is added to the mean when the requested threshold lies above the mean of the data. The converse is true for where the threshold lies below the mean.
- sd is the data set standard deviation, and
- z can be obtained from a table of statistical z scores.

The z score relates to the percentage to be selected (% to Select). On a normal distribution curve, the mean lies exactly at the 50% point, with half the data to the left of the mean and the other half to the right. In order to know the z score when wanting to select for the top 5%, for example, then the z score would relate to a value of 45, as the z score is relative to the mean (50%).

The top $x\%$ (% to Select) to be examined within this research are 5, 15, 25, 35 and 45%.

Refer to section 3.6.1. for a description of the function within MS Excel used to calculate threshold values.

3.4. APPRAISAL OF METHODS

In order to appraise the methods, example data sets for three traits (MD, MY and OR) were used (section 3.1.). For each of the traits, there were four data sets. Each of these four data sets was replicated four times, with each of these replications being a randomly sorted sequence of the trait data. For each of the replications across the three example traits, the methods were appraised using the % to Selects detailed in section 3.3.

3.5. EVALUATION OF METHODS

The success rate (SR) for each method was calculated from the formula:

$$SR = \frac{C^2}{TN \cdot TS}$$

Where:

C = Number of actual records in top x% that were correctly identified by the method

TN = Target number of records to be selected, i.e., those data set records that were in the top x%

TS = Total number selected by program, i.e. those individual record values that were greater than or equal to the threshold value for that particular method

This equation asked two questions: What proportion of the target number were identified by the program (C/TN), and secondly, what proportion of those selected were correct (C/TS)? Ratios C/TN and C/TS were then multiplied together to get a combined estimate of the SR.

If the selection was perfect, then C = TN = TS and SR = 1. If the selection procedure did not identify any records correctly, then C = 0 and SR = 0. By definition, C could not be greater than TN or TS, and thus, the SR varied between 0 and 1.

3.6. COMPUTING STRATEGIES

For chapters 5 to 8, inclusive, a single template model within Microsoft (MS) Excel was constructed. The template was applied to each year/farm in turn. Six sheets within one Excel document were used: one for data entry, four being randomly sorted copies of the data set in question (e.g., MD year 1991) and the final sheet being the data set with the trait in descending order.

3.6.1. Data Entry Sheet (Sheet 1)

Consideration was given to the ease of template use. As such, the template was

programmed to enable all data entry to occur on sheet 1, with sheets 2 to 6 receiving information from that sheet. Refer to Appendix 1 for an example sheet 1.

Within sheet 1, animal data was entered into columns A to H, with the trait in column H and background details (e.g. year, weight, age) in columns A to G.

The data set trait:

Mean =AVERAGE(column H),

Standard Deviation =STDEV(column H) and

Threshold Values =NORMINV(((100-% to Select)/100), Mean, Standard Deviation), where NORMINV returned the inverse of the normal cumulative distribution for the specified mean and standard deviation, formulae were entered.

The NORMINV function is the MS Excel method for calculating a threshold value. The historical mean (cell M20) and standard deviation (cell M21), as well as the sample size (cell K12) and top x% of records to select (% to Select, cell M13) were also entered. The sample size, as determined in Chapter 4, was constant throughout chapters 5 to 8.

Five % to Selects were examined: 5, 15, 25, 35 and 45. The data set threshold was calculated for each of the % to Selects, with the results stored in cells M3 to M7 within sheet 1. When the user inputted the % to Select into cell M13, the associated threshold was located, using the VLOOKUP function,

e.g., =VLOOKUP(M13, L3:M7, 2, FALSE)

where:

Column L was the % to Select range (i.e., 5, 15, 25, 35 and 45),

Column M was the associated threshold value column and

‘2’ indicated the return of values in the second column (associated threshold value); else, it returned “FALSE”.

These threshold values, being based on the whole data set, were the best that could be achieved, and were available for comparisons against those threshold values calculated by each of the methods. The historical data threshold (cell M22) was obtained using the historical mean (cell M20), standard deviation (cell M21) and the % to Select.

3.6.2. Trait Sorted Data Sheet (Sheet 6)

This sheet was sorted in descending order of trait (column I) and was constructed in order to define the true top x % of records. Refer to Appendix 1 for an example of sheet 6.

Details of:

- total count (cell N1) of data set records: =COUNT(I3:I1000),
- minimum number to be selected (cell N2), based on the % to Select defined on the data entry sheet (referenced in cell L1) and rounded to the nearest integer: =ROUND(((L1/100)*N1),0)
- actual number of records selected (cell N3): =COUNT(L3:Lx), where Lx referenced the final animal in the data set, were captured.

Cell 3 and onwards of Column L were programmed to place a flag ("1") beside those records that were within the true top x % of records to be selected. This was achieved using the following formulae:

- =IF(N2>0,1,(" ")) This formulae was entered into cell L3; the first row for inputting animal data. Here, if the minimum number to select was greater than 0, then it placed a flag ("1") in L3.
- =IF(COUNT(\$L\$3:L3)<\$N\$2,1,IF(L3=("",(" ")),IF(I4=I3,1,(" ")))) This formulae was entered into all further cells for column L, with those cells highlighted in bold, incrementing by one for each additional record. The logic of this formulae read: if L3:Lx < the minimum number to select, then a flag ("1") was entered; if Lx was blank, then it did not enter a flag; if Lx=Lx-1, then a flag of "1" was entered; else, it remained blank.

The actual number to be selected, therefore, took into account all records of the lowest trait value to be selected. For example, if the minimum number to be selected was 10 (i.e., a % to Select of 25 for 39 records), but there were a further five records with the same minimum trait value ($I_x = I_{x-1}$), then they too would be selected. Refer to Appendix 1 for such an example.

3.6.3. Creation of Random Sequence Data Sets

3.6.3.1. Data Set Randomisation

For each year/farm, for the traits MD, MY and OR, four randomly sorted data sets were created. A copy of the data set within sheet 1 was placed within sheets 2 to 5. Refer to Appendix 1 for an example of sheets 2 to 5.

These sheets were individually randomly sorted, using the `=RAND()*x` formulae, where x referred to any number. This was best achieved by placing the function into all rows of the column immediately to the right of the trait. This formulae created a random sequence of numbers. The data set (columns B to J) was sorted in ascending order of the random numbers.

3.6.3.2. Randomisation of Data Sets for Methods 1 and 4

Using the formulae: `=RAND()*x`, a further sequence of random numbers was placed into the next available column (column K), with a copy of the trait column being placed in column L. These two columns were sorted in ascending order of the random numbers. From this random sort of trait, a sample size (as defined in Chapter 4) was selected and used for calculation of Method 1's (and Method 4's starting) threshold value.

3.6.4. Method - Computing Strategies

3.6.4.1. Calculation of Method Threshold Values

Method 1

As detailed in section 3.2.1.1., Method 1 used a sample size of the randomly sorted trait (Column L) to obtain the mean, standard deviation, and hence threshold value. For sheets 2 to 5, these values were stored in N1, N2 and O2, respectively.

With the sample size of records identified (cell J1, which obtained its information from Sheet 1), cells N3 onwards were populated, using the corresponding trait value in column L, if the record fell within the sample size used. For example, if the sample size was 4 records, then the first four cells (N3:N6) would be populated. This was achieved using the following formulae: =IF(Mx>J1,(" "),Lx), where Mx and Lx related to the same row number in question, column M from cell M3 onwards was a count of the records which incremented by one as each record was reached, and column L was the randomly sorted trait data set.

Method 2

As detailed in section 3.2.1.2, method 2 used the historical mean and standard deviation data for the calculation of its threshold value. Method 2 computing strategies obtained the historical threshold value from sheet 1 (cell N22). Refer to section 3.6.4.2. for details of threshold value application.

Method 3

As detailed in section 3.2.1.3., Method 3 used the historical mean and standard deviation data as well as the trait values for the calculation of its threshold values (column T). For each record, the threshold value was updated to reflect all inputted trait values up to, and inclusive of that record. This was achieved using the formulae:

=NORMINV(((100-G1)/100),AVERAGE('SHEET1'!N20,I3:I3),'SHEET1'!N21)

for the first record, and:

=NORMINV(((100-G1)/100),AVERAGE('SHEET1'!N20,I3:Ix),
(('SHEET1'!N21+(STDEV(I3:Ix)*COUNT(I3:Ix)))/(COUNT(I3:Ix)+1))

for all following records, where G1 was the % to Select, N20 and N21 were the historical mean and standard deviations, column I was the trait column and x was the row number of the particular record in question.

Method 4

As detailed in section 3.2.1.4., the threshold values for this method used the sample size data and were updated as each record was reached. This was achieved by using the following formulae:

=NORMINV(((100-G1)/100),AVERAGE(N3:Nx,I3:Ix),STDEV(N3:Nx,I3:Ix))

where G was the % to Select, N3:Nx was the sample size selection, I3:Ix were the record trait values, and x was the row number of the particular record in question.

3.6.4.2. Identification of Animals Selected by the Methods

Each method needed to highlight those records whose trait values (Column I) were above or equal to the method threshold value(s) contained within cells:

O2 for Method 1

N22 from sheet 1 for Method 2

T3:Tx for Method 3

W3:Wx for Method 4

This was achieved using the formulae:

=IF(AND(Ix>=threshold value in question),COUNT(Ix)), where column I contained the data set traits, x related to the row in question and “threshold value in question” was replaced by the appropriate cell reference(s), as detailed immediately above. If the record was equal to or above the method threshold value, then it flagged (“1”) for each record, within columns O, R, U and X for Method 1 to 4, respectively; else, it returned “FALSE”.

3.6.4.3. Identification of Target Number of Animals to be Selected

Row 3 and onwards of column P identified those records which were in the top x % of their data set. A flag of “1” was entered when the program identified records, within sheets 2 to 5, as being those selected in sheet 6. This was achieved using the formulae: =VLOOKUP(Bx,'SHEET6'!B3:Lx,11,FALSE), where Bx related to the record number stored in cell B of sheets 2 to 5 and Lx related to the last possible flag in column L of sheet 6. “11” reflected the return of what was entered into the 11th column (column L) in sheet 6, starting at column B; else, it returned “FALSE”.

3.6.4.4. Identification of Correctly Selected Animals

For methods 1 to 4, respectively, where columns O, R, U and X had a flag of “1” within a row, and column P had the same flag, it identified those records within the top x % that had been correctly selected by the methods. Columns Q, S, V and Y flagged “1” where this was the case, by using the formulae: =IF(AND(a3=P3),1), where a is one of columns O, R, U or X.

3.6.5. Programming of the Success Rate

The Success Rate (SR), proportion of target number identified by the program (C/TN) and proportion of those selected that were correct (C/TS) results were stored within sheets 2 to 5. Refer to Appendix 1 for an example of sheets 2 to 5.

For each of the methods, counts of TN, TS and C (refer to section 3.5. for descriptions) were collected in rows 44, 45 and 46, respectively, within columns Q, R, S and T for Methods 1 to 4, respectively. For example, Method 1 formulae would be:

TN (cell Q44) =COUNTIF(P3:Px,1)

TS (cell Q45) =COUNTIF(O3:Ox,1)

C (cell Q46) =COUNTIF(Q3:Qx,1)

where x is the last record row number.

For methods 2, 3 and 4, replace column O with R, U and X, and column Q (within the COUNTIF formulae) with S, V and Y, respectively.

Using the above counts, SR, C/TN and C/TS were calculated for each method, within the same columns, in rows 48, 49 and 50. For example, Method 1 formulae were:

SR (cell Q48)	$= (Q46 * Q46) / (Q44 * Q45)$
C/TN (cell Q49)	$= Q46 / Q44$
C/TS (cell Q50)	$= Q46 / Q45$

3.7. TRANSFORMATION OF SR, C/TN and C/TS RESULTS

Using Minitab, version 10.51 Xtra, Descriptive Statistics, the SR, C/TN and C/TS results for each chapter's (chapters 5 to 8) individual traits were tested to evaluate whether they conformed to a normal distribution. The descriptive statistics returned the P value of the Anderson-Darling Normality Test. Where the P value was < 0.05 , the results were not normally distributed.

Where the data was not normally distributed, a transformation was performed. Where the original data was proportions, the guidelines for transforming such data are:

- If the data is mostly in the range of 0.0 – 0.2, then \sqrt{x} or $\sqrt{x+0.5}$ is recommended.
- If the data is in the range of 0.8 – 1.0, then $\sqrt{1-x}$ or $\sqrt{1.5-x}$ is recommended.
- If the data is in the range of 0.3 – 0.7 then you do not need to transform the data.
- If the range of data is greater than any of these, for example, a range of 0 – 1, then the arcsin transformation is suggested (Parker, 1973).

Since SR, C/TN and C/TS ranged from 0 – 1, the arcsine was the most appropriate form of transformation. Within Minitab, transformation of the results was achieved using the following formulae: $LET\ C2 = 57.297 * ASIN(C1)$ where C2 was the column used to contain the transformed data, and C1 contained the data to be transformed. The range of values to be expected are detailed in table 3.4..

Table 3.4. Arcsine Equivalents of SR, C/TN and C/TS Values

UT Values	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
T Values	0.00	5.74	11.54	17.46	23.58	30.00	36.87	44.43	53.13	64.16	90.00

UT = Untransformed Values, T = Arcsine/Transformed Values

Within the results and discussion sections of chapters 5 to 8, the results of the transformation of data were converted back, for ease of interpretation, to proportions between 0 and 1. This was achieved using the SIN formulae on a scientific calculator. For example, to convert a transformed value of 38.09, SIN 38.09 was entered, and the result of 0.62 was presented.

3.8. STATISTICAL MODELS FOR COMPARISON OF METHODS

Statistical analyses were performed for both transformed (T) and untransformed (UT) data.

3.8.1. General Linear Model

The results from the comparison of methods were obtained using a General Linear Model (GLM) within Minitab. For each SR, C/TN and C/TS, effects and interactions of year (or farm), % to select and method were examined, using the formula:

```
MTB>GLM Y = % to SELECT * METHOD * YEAR;
SUBC>MEANS % to SELECT * METHOD * YEAR.
```

where Y was SR, ASINSR, C/TN, ASINC/TN, C/TS AND ASINC/TS,
YEAR was replaced with FARM for MY.

3.8.2. Tukey 95% Simultaneous Confidence Intervals

Where Method was significant ($P < 0.05$), a Minitab macro, (Whitaker, 1999), was used to ascertain whether any individual method differed significantly from any other. This macro generated Tukey 95% simultaneous confidence intervals.

3.8.3. Tabulation of Results

Within Minitab, a macro (Appendix 2) was written to automatically generate result tables that gave proportions or means for both un-transformed and transformed results of SR, C/TN and C/TS (Appendix 2). The macro was programmed to produce tables of means for the interactions of: Method x Year, Method x % to Select and % to Select x Year, and tables of proportions for the following ranges: 0.90 – 1.00, 1.00 – 0.76, 0.51 – 0.75, 0.26 – 0.50 and 0.00 – 0.25.

NOTE: Ranking of methods is continuous. For example, where two methods have equal first ranking, the following two methods would be ranked second and third.

CHAPTER 4 SAMPLE SIZE SELECTION FOR SELECTED TRAITS

4.1. INTRODUCTION

4.1.1. Sampling from a Normally Distributed Population

Next to the binomial (populations with only two kinds of individuals (e.g. single or twins), the normal distribution was the earliest to be developed. De Moivre published its equations in 1733. In a normal distribution, the variable (e.g. Milk Yield) flows without a break from one individual record to the next. A normal distribution is completely determined by two parameters, (a) the mean, μ , which locates the centre of the distribution and (b) the standard deviation, N , which measures the spread or variation of the individual measurements (Snedecor and Cochran, 1967).

In random samples from normal populations with mean μ and standard deviation N , the sample mean is normally distributed with mean μ and standard deviation (Noether, 1976). The sample mean (\bar{X}) is represented as:

$$\bar{X} = (\sum X)/n$$

where:

X stands for every item successively,

$\sum X$ is the 'sum of X ',

n is the total number of items in the sample.

The range of a sample, dependent as it is on only the two extremes in a sample, usually has a more variable sampling distribution than an estimator based on the whole set of deviations-from-mean in a sample. The sample standard deviation is represented as:

$$s = \sqrt{\frac{\sum (X - \bar{X})^2}{n-1}}$$

where:

\bar{X} is the sample mean

X is each item successively

n is the number of observations in the sample

Here, each deviation is squared, and then the sum of squares ($\sum x^2$) is divided by $n-1$, one less than the sample size. The result is the mean square or sample variance, s^2 . Finally, the extraction of the square root recovers the original scale of measurement (Snedecor and Cochran, 1967).

4.1.2. Sampling and Sample Size

Collecting data is, usually, a costly and timely process; so any experiment used for this purpose should be well designed in order to yield the right information for minimal cost. An important use of statistics is to make inferences about larger groups (the population) on the basis of information obtained from smaller groups (a sample of the population). The extent to which this can be done with any accuracy depends on the adequacy of the sample(s). Samples can be broken down into two basic types: (a) nonprobability – no way of estimating the probability that each individual or element will be included in the sample, (b) probability – each individual has an equal chance of becoming a part of the sample. The basic type of probability sample is the random sample (Downie and Heath, 1974). In terms of probability, random sampling implies that the probability of any particular member being selected is $1/N$, where N denotes the number of individuals in the population (Hoel, 1976).

The sample size to be used depends on the variability of the data, how close to the true mean do you want to be (L) and how confident do you want to be that you have estimated the true mean within the “closeness” defined. Since the normal curve extends from minus infinity to plus infinity, it cannot be guaranteed that \bar{x} lies between the limits $\mu - L$ and $\mu + L$. However, it is possible to make the probability that \bar{x} lies between these limits as large as necessary. In practice, the probability is usually set at between 95% and 99%. For the 95% probability, there is a 95% chance that \bar{x} lies between the limits of $\mu - 1.96N/\sqrt{n}$ and $\mu + 1.96N/\sqrt{n}$. This gives the equation $1.96N/\sqrt{n} = L$ which is solved for n (Snedecor and Cochran, 1967).

Samples may be of any size, ranging from one up to the size of the entire population, but are usually only a small fraction of the entire population (Senter, 1969). When a farmer is selecting for a certain character there is normally a large number of measurements to be made due to the size of his flock/herd. Scott and Roberts (1976) aimed to evaluate methods of calculating an index with a substantially reduced number of measurements needing to be made. When selecting on live weight, the sample size ranged between 5 and 40%, depending on the number of ewes to be donated and the flock size. A sample size of 40% was required when wanting to select the top 30 ewes out of 200, while a sample size of only 5% was required when wanting to select the top 5 ewes out of 1000.

The estimation of minimum sample sizes has also been reported for cattle. Akhtar *et al* (1988) reported that of 1642 dairy herds, a sample size of 80 or less ($\leq 5\%$) dairy herds could be used to obtain the average milk production with precision. In a study to estimate the minimum sample size for comparison of treatments in experiments of consumption and digestibility of cattle in a multitrait analysis, Freitas *et al* (1999) observed a sample size as low as 8% to be sufficient.

4.1.3. Objectives

The aim of this chapter is to research a range of possible sample sizes for suitability of application in methods 1 and 4. Method 1 (and method 4 for its starting threshold value) uses a random sample of the data set in order to calculate its threshold value (section 3.2.).

4.2. MATERIALS AND METHODS

Two procedures were employed to determine an appropriate sample size(s) for use in Chapters 5 to 8. By using two procedures differing perspectives were examined. Procedure A focussed on accuracy and was derived from a published formula. Procedure B examined sample sizes using actual data sets. These procedures were applied to the three traits, Muscle Depth (MD), Milk Yield (MY) and Ovulation Rate (OR).

4.2.1. Principles of Sample Size Selection

4.2.1.1. Procedure A – Sample Size Using Formula

For Procedure A, sample size was determined using the formula:

$$\text{Sample Size} = ((t*N)/L)^2$$

Where:

$t = 1.96$ (obtained from t tables at $P=0.05$)

N = standard deviation for population (the mean of the data set standard deviations for each trait)

L = closeness to the true mean. [e.g. for MD with a mean of 30mm, a L of 1mm indicates the requirement to be within 1mm of the true mean].

(Snedecor and Cochran, 1967)

Procedure A was repeated for the traits MD, MY and OR, and used the mean of the four year/farm means and standard deviations for each trait, as detailed in Table 4.1. Refer to chapter 3, section 3.1 for details of each data set.

Table 4.1. The Averages of the Data Set Trait Mean and Standard Deviations

	Average of Year/Farm Means	Average of Year/Farm Standard Deviations
Muscle (mm)	26.0	2.02
Milk Yield (Litres)	7083.9	1178.19
Ovulation Rate (Count)	2.5	1.28

L was transformed (L_T) to a percentage by using the following formula:

$$L_T = (L/100) * \text{Trait Mean}$$

where L was in mm, litres or a count for MD, MY and OR respectively.

L as a percentage enabled a standardised procedure across the different traits (MD, MY and OR). Sample sizes were examined through a parameter L range of 1 to 50% (Appendix 3), with the focus being on sample sizes of 5 to 50%.

The sample size equation returned the number of animals to be sampled. Referring to Appendix 3, for an example of MD sample size, 5 (4.76 rounded up) animals would be required out of the data set (average MD data set records = 41) to be within 7% of the true mean. This would be equivalent to a sample size of 12%.

4.2.1.2. Procedure B – Sample Size by Application to Data Sets

Procedure B, through a range of sample sizes (5 to 50%), tested whether the true mean of the actual year/farm data sets for each of the traits, could be predicted consistently. This procedure can be justified because the sample size selection for methods 1 and 4 in chapters 5 to 8 used records from a random sample of records in the actual data sets. To determine whether the true mean could be predicted consistently, a one-sample t-test was used. Unlike Procedure A, each year/farm data set was examined individually. The records of the sample sizes were randomly selected using Minitab, version 10.51 Xtra. For each sample size, the procedure (refer to section 4.2.2.2.) was replicated ten times.

Interpretation of Results from t-test Procedure

Counts of where $P < 0.05$, for each of the sample sizes, were stored within an MS Excel spreadsheet, as detailed in section 4.2.2.2.. This count could not exceed 10, since there was only a maximum of 10 replicates for each sample size. The decision of which sample size would be most effective was based on the percentage of instances per sample size of $P < 0.05$.

4.2.2. Computing Strategies

4.2.2.1. Procedure A – Sample Size Selection Using Formula

All Procedure A computing occurred within MS Excel 97. For each year/farm, the mean and standard deviation for the traits were stored within columns B and C, respectively, with averages of the four year/farm means and standard deviations for

each trait stored in column E and the number of records in each data set stored in column D (refer to Appendix 3 for an example spreadsheet).

Calculation of Parameter L

Within column G, the parameter L range of 1 to 50, in an increment of 1, was entered, starting at row 3. Rows 1 and 2 contained header information. Columns H, I and J contained the calculated L (%) of the traits MD, MY and OR, with row 1 containing header information and row 2 containing the trait means, as detailed in Appendix 3.

To calculate L as a % of the trait, the following formulae was required:

$$=SUM(Yx/100)*Y2$$

where Y was the column containing the trait data and x was the row number for the L value in question. Y2 was the trait mean in row 2.

Calculation of the Sample Sizes

The results of the Sample Size formulae were stored in columns L, M and N (refer to section 4.2.1.1.), for MD, MY and OR, respectively.

Within Excel, the following formulae was used:

$$=((1.96*Bx)/Yx)^2$$

where Bx referred to the trait standard deviation stored in Column C, and Yx related to the calculated L as stored in columns H, I and J.

4.2.2.2. Procedure B – Sample Size Selection From Application to Data Sets

Creation of Sample Sizes

The trait data for a specific year/farm was entered into column C1, within Minitab, version 10.51 Xtra.

To select the sample of records from column 1, the following formula was used:

MTB> SAMPLE n C1 C x

Where n was the number of records to select from column C1 for the sample and x was the column number in which to store the selected records. This formula randomly selected records from column 1, as opposed to selecting in a sequential order. The number of records to select ranged from x_1 to x_2 , with ten replicates of each, where x_1 and x_2 were the number of recording making up 5% and 50% of the data set, respectively.

Programming of the TTEST Procedure

The ttest procedure was run by entering the following Minitab command:

TTEST K1 C1-C x

Where K1 contained the mean of the data set within column C1 and C x was the column containing a sample of the data.

4.3. RESULTS

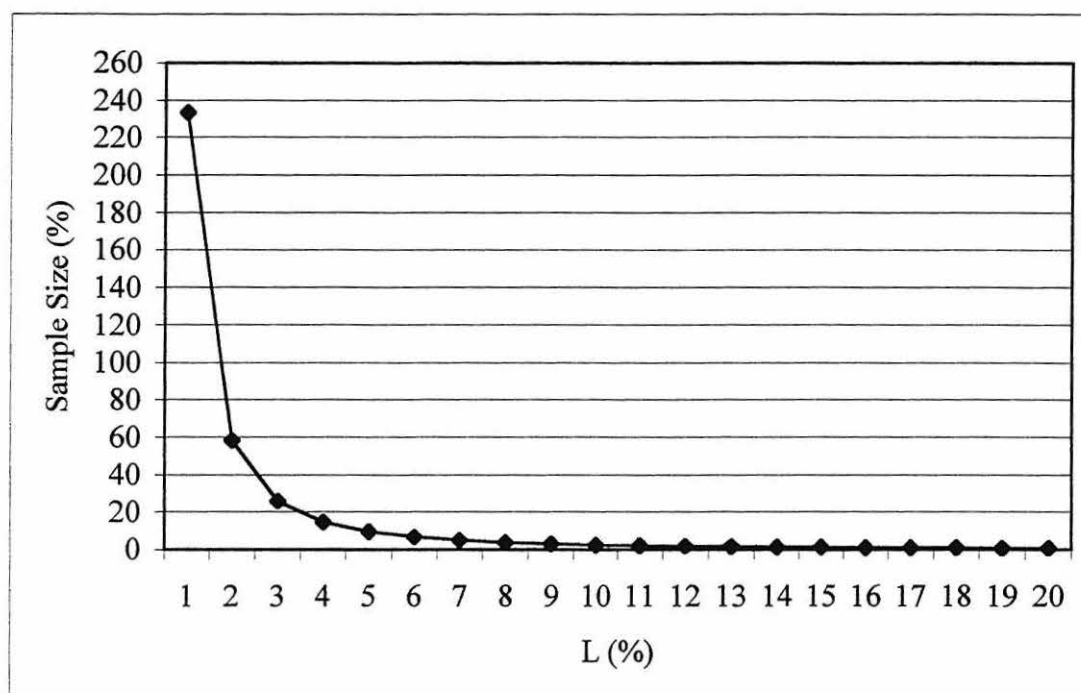
4.3.1. Procedure A – Sample Size Using Formula

The results for all three traits showed the same non-linear relationship. Ovulation Rate (OR) showed a greater range of sample sizes required, while Muscle Depth (MD) showed the least. For all the traits, the sample size decreased as L % was increased.

4.3.1.1. Muscle Depth

Sample sizes of 36 % or less gave accuracy $> \pm 4\%$ of the mean. Indeed, to be $\pm 3\%$ of the true mean, a sample size of 63% would be required. To be ± 4 to 7% of the true mean, sample sizes of 36, 23, 16 and 12% would be required, respectively. For a $L \geq 8\%$, the sample size tended towards an asymptote (refer to Figure 4.1. and Appendix 3). To estimate the mean of a group to $\pm 8\%$ of the true mean, a sample size of 9% would be required. The sample size could be reduced to 5% for an estimate $\pm 11\%$ of the true mean.

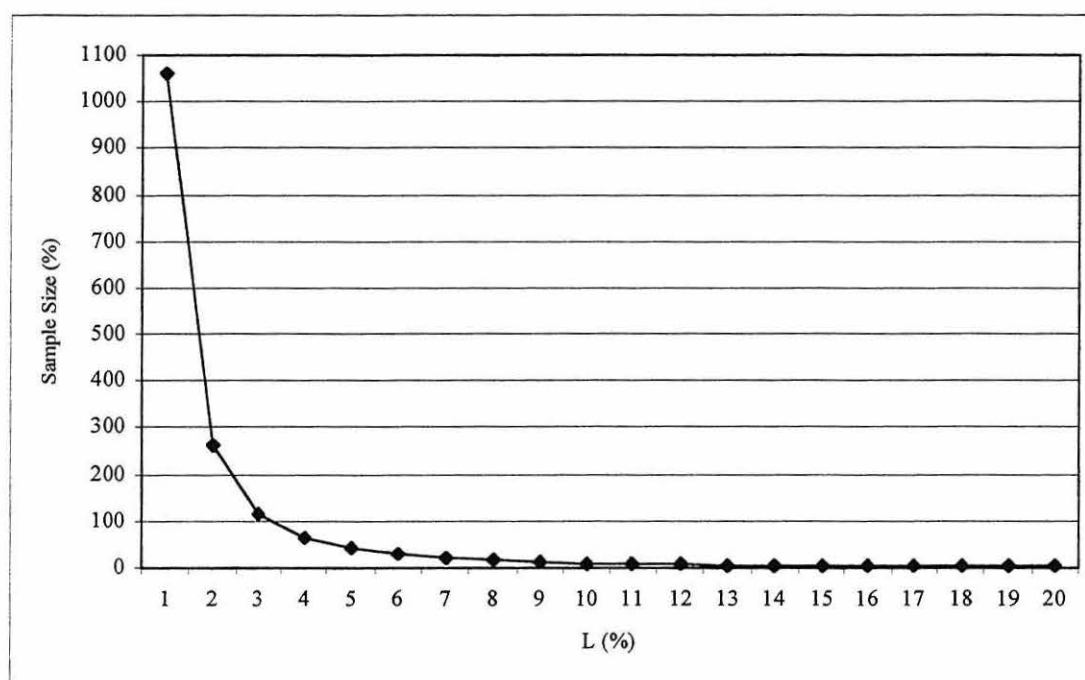
Figure 4.1. The Effect of L (%) on Sample Size (%) for Muscle Depth



4.3.1.2. Milk Yield

For MY, a larger sample size was, in general, required. Sample sizes of 39 % or less gave accuracy $> \pm 5\%$ of the true mean. Indeed, to be $\pm 4\%$ of the true mean, a sample size of 61% would be required. To be ± 5 to 10% of the true mean, sample sizes of 39, 27, 20, 15, 12 and 10% would be required, respectively. For a $L \geq 11\%$, the sample size required tended towards an asymptote (refer to Figure 4.2. and Appendix 3). A sample size of 5% could be used if an estimate $\pm 14\%$ of the true mean could be tolerated.

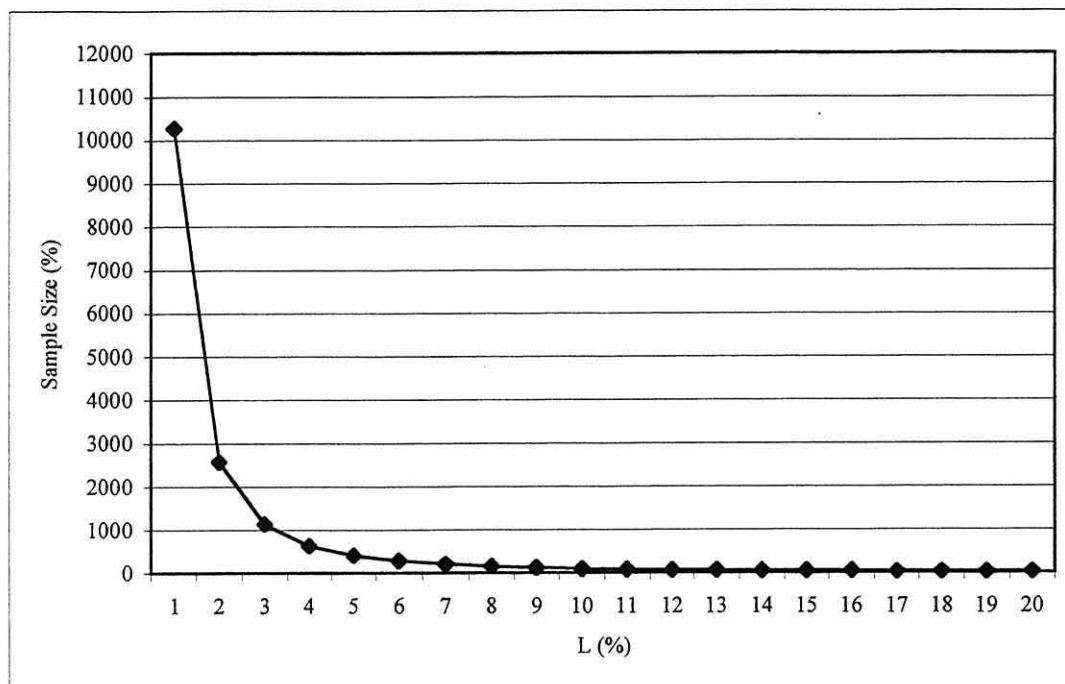
Figure 4.2. The Effect of L (%) on Sample Size (%) for Milk Yield



4.3.1.3. Ovulation Rate

For OR, the sample size decreased from 13200 to 5 % over a L range of 1 to 50%, with a very rapid drop in size over L 1 to 10% (refer to Figure 4.3. and Appendix 3). Because of the high variability of OR, relatively larger sample sizes were required for the same level of accuracy.

Figure 4.3. The Effect of L (%) on Sample Size (%) for Ovulation Rate

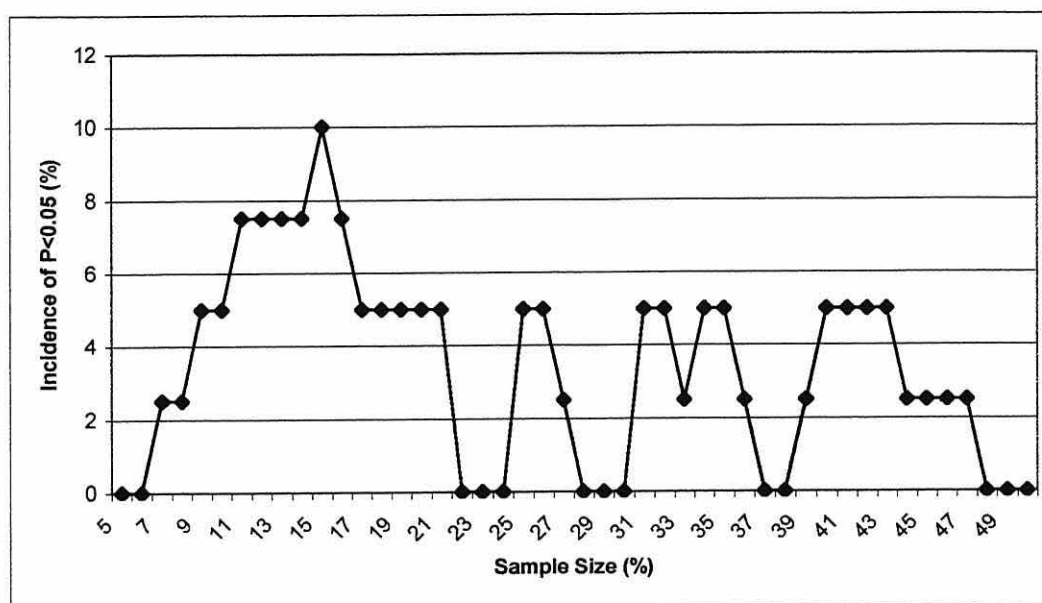


4.3.2. Procedure B – Sample Size by Application to Data Sets

4.3.2.1. Muscle Depth

Across all years, only one sample size (15%) had 10% of instances where estimated mean differed significantly ($P < 0.05$) from the actual mean. All other sample sizes had $\leq 7.5\%$ instance of $P < 0.05$, while 13 of the sample sizes (e.g. 5 and 6%) had no instances of $P < 0.05$. There was no consistent trend across the sample sizes other than all 7.5% and 10% instances of $P < 0.05$ falling in the 11 to 16% range of sample sizes (Figure 4.4 and Appendix 3).

Figure 4.4. The % of Instances of $P<0.05$ for Muscle Depth



4.3.2.2. *Milk Yield*

Across all years, only one sample size (16%) had 10% of instances where estimated mean differed significantly ($P<0.05$) from the actual mean. All other sample sizes had $\leq 7.5\%$ instance of $P<0.05$, while 28 of the sample sizes (e.g. 8 and 9%) had no instances of $P<0.05$. There was no consistent trend across the sample sizes other than all 7.5% and 10% instances of $P<0.05$ falling in the 6 to 26% range of sample sizes (Figure 4.5 and Appendix 3).

4.3.2.3. *Ovulation Rate*

Across all years, there were seven sample sizes (7, 11 – 13, 15, 18 and 20%) that had 10 to 15% of instances where estimated mean differed significantly ($P<0.05$) from the actual mean. All other sample sizes had $\leq 7.5\%$ instance of $P<0.05$, while 10 of the sample sizes (e.g. 24%) had no instances of $P<0.05$. There was no consistent trend across the sample sizes other than all 10% and 15% instances of $P<0.05$ falling in the 7 to 20% range of sample sizes (Figure 4.6 and Appendix 3).

Figure 4.5. The % of Instances of $P < 0.05$ for Milk Yield

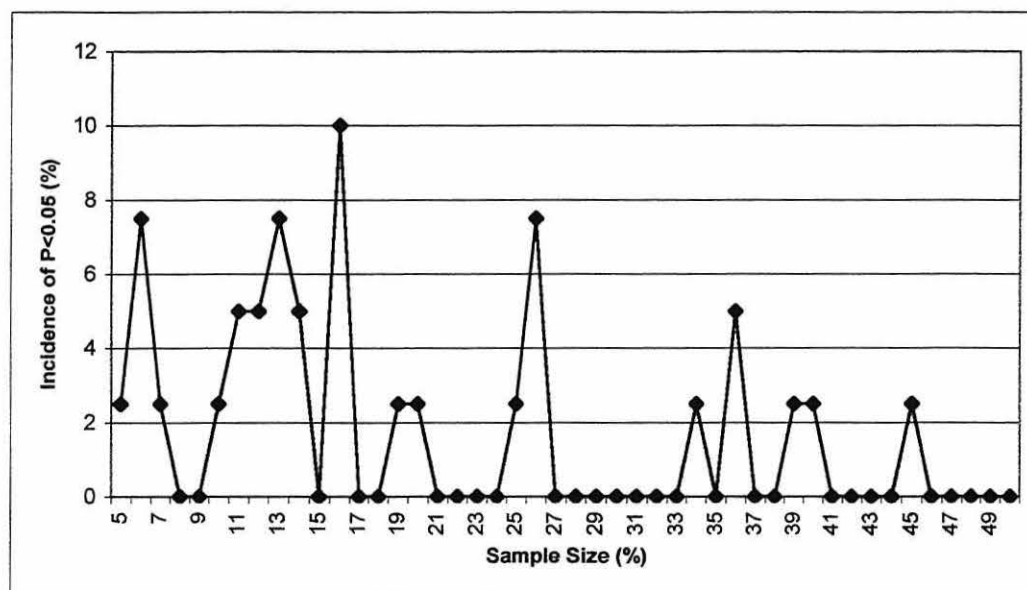
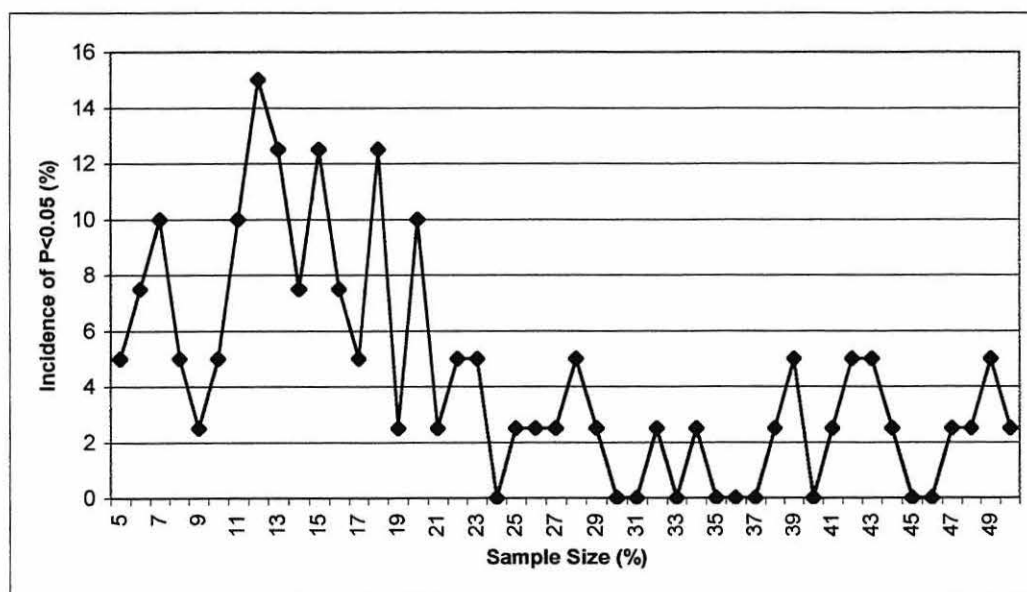


Figure 4.6. The % of Instances of $P < 0.05$ for Ovulation Rate



4.4. DISCUSSION

Procedure A suggested that relatively high sample sizes are required in order to be confident of getting the correct mean. Procedure A gives very precise answers as its answers are derived from an equation. Procedure B was fairly inconclusive but did not suggest any obvious negative effect of using small sample sizes out of what are small data sets.

4.4.1. Muscle Depth

Both procedures showed a wide range of possible sample sizes between 5 and 50%, inclusive. Procedure A's range was less so than Procedure B's. Procedure A identified that by using a sample size of 36%, the sample mean would be within 4% of the true mean (Figure 4.1. and Appendix 3). To be able to decrease L% to 3, the sample size would need to increase substantially to 63%. Furthermore, it would not be possible to obtain a L of 1 or 2% for MD, as the sample sizes required are >100%. The results of Procedure B (Figure 4.4. and Appendix 3) show that the entire range of sample sizes researched (5 to 50%) could be used for MD if the clump of 7.5 and 10% instances of $P < 0.05$ at sample sizes 11 to 16% were accepted. This acceptance would be on the basis that these instances are likely to be a random effect, with a repeat in the procedure resulting in these sample sizes not necessarily having an occurrence of $P < 0.05 \geq 7.5\%$.

Both procedures showed that sample sizes of 5 – 10% could be used as neither of the procedures highlighted any negative effects. Using a sample size of 10% would enable an estimate ± 7 to 8% of the true mean, and would require measuring 4 – 5 animals, from a population of 40. While sampling only 5% (i.e. 2 animals) would be quicker, the sample mean would only be $\pm 11\%$ of the true mean. Therefore, while the MD recording methods would take twice as long, the accuracy of the estimated mean would increase by one third.

4.4.2. Milk Yield

Both procedures showed a wide range of possible sample sizes between 5 and 50%, inclusive. Procedure A's range was less so than Procedure B's. Procedure A identified that by using a sample size of 39%, the sample mean would be within 5% of the true mean (Figure 4.2. and Appendix 3). To be able to decrease L% to 4, the sample size would need to increase substantially to 61%. Furthermore, it would not be possible to obtain a L of ≤ 3 for MY, as the sample sizes required are >100%. The results of Procedure B (Figure 4.5. and Appendix 3) show that the entire range of sample sizes researched (5 to 50%) could be used for MY as there was no obvious

trends to suggest otherwise. Those sample sizes (6, 13, 16, 26%) where the instance of $P < 0.05$ was $\geq 7.5\%$ need not be discounted as it is likely that these results were a random effect that upon repetition of the procedure would not necessarily reoccur.

A sample size of 5% would enable an estimate $\pm 14\%$ of the true mean. The sample size could be increased to 10%, which would enable an estimate $\pm 10\%$ of the true mean. If the L % needed to be lower, then a sample size of 15 or 20% could be employed, which would require 17 to 22 animals to be recorded.

4.4.3. Ovulation Rate

As a result of the standard deviation being very high in relation to the mean, the determination of a suitable sample size has proved difficult (Figures 4.3. and 4.6., and Appendix 3). For this reason, Procedure A did not produce any conclusive results that could be employed in a practical situation. For example, it would not be beneficial to use a sample size of 15% in order to estimate the mean of a group to within 30% of the true mean (Appendix 3). However, the results for Procedure B showed that for OR, there was a range of sample sizes which could be used, although admittedly there was a high incidence of $P < 0.05$. At the lower end of the spectrum of sample sizes, 5 to 10% could be used on the assumption that any instance of $P < 0.05$ was a random effect.

Procedure A, being based on theory, indicated that very large sample sizes would be needed but in practice it would be possible to obtain reliable estimate of the true mean (Procedure B) from the samples. For the OR data sets, sample sizes of 5 to 10% would require recording between 3 to 10 animals. This would be a feasible number of laparoscopies to be performed.

4.4.4. Chapter Conclusions

Reviewing MD, MY and OR results showed how MD and MY results had similar outcomes, while OR results proved less conclusive in their outcome. For MY,

Procedure A trends were similar to those of MD, but the range of L% for sample sizes of 5 to 50% differed slightly in that the range of L was greater (5 to 14%) compared to 4 to 11% for MD. Concerning Procedure B, again MD and MY results were similar, although the two traits differed in those sample sizes that had occurrences of $P < 0.05$ and indeed, quantity of occurrences. MD had 6 sample sizes where the percentage of $P < 0.05$ was higher than 5. For MY, there were only 4 such sample sizes: 6, 13, 16 and 26%. However, as mentioned in sections 4.3.1. to 4.3.3. such occurrences are likely to be a random effect, with the same sample sizes not necessarily having any instances of $P < 0.05$ in future procedure runs. As noted in section 4.3.3., for OR, Procedure A indicated that very large sample sizes would be required in theory, but in practice (Procedure B) smaller sample sizes (5 to 10%) could provide reliable estimates of the true mean from samples.

Finding a sample size which would be suitable for all traits would enable the differing methods within chapter 5 to 8 to be compared more efficiently and effectively. Methods 1 and 4 (for its starting threshold value) require an appropriate sample size in order to calculate the method threshold values over the differing % to Selects. It was not known if any of the procedures differ in their suitability to a particular trait. By keeping all criteria, such as sample size and % to Select, constant, it would ease the comparison of results across the traits. The results for MD, MY and OR indicated that sample sizes of 5 to 10% would be suitable. These sample sizes enabled an estimate of the true mean to be, at the most, $\pm 10\%$ of the true mean (MD and MY). Furthermore, for all three traits, all sample sizes provided a reliable estimate of the mean from the samples (Procedure B).

The question really lies with how close to the true mean the sample mean can be without excessive sampling. If the sample size of 5% was used, the sample means would be an estimated ± 11 and 14% of the true mean (MD and MY, respectively). Using the mean number of records for each example trait, a sample size of 5% would result in just 2, 5 and 4 animals to be recorded for MD, MY and OR, respectively. By using a sample size of 10%, the sample mean estimate only became within ± 7.5 and 10% of the true mean for MD and MY, respectively. This would be the equivalent to

4, 10 and 8 animals required for sampling for MD, MY and OR, respectively. From the results obtained, it would appear that a sample size of 10% was the most suitable for all traits considered. The use of 10% as a sample size falls within the range (5 to 50%) specified by Scott and Roberts (1976) but is higher than those sample sizes reported by Akhtar *et al* (1988) ($\leq 5\%$) and Freitas *et al* (1999) (8%).

In choosing a sample size of 10%, as opposed to any higher sample size %, there are advantages in terms of time and labour. As noted above, the collection of data is both costly and labour intensive. The use of random sampling enables inferences to be made about the population as a whole. Random sampling enables each individual in the population to have an equal chance of becoming a part of the sample and it can provide a reliable estimate of the true mean. Sampling is an effective way of minimising time and labour.

CHAPTER 5 A COMPARISON OF FOUR METHODS TO SELECT ANIMALS WHICH ARE NOT UNIQUELY IDENTIFIABLY TAGGED

5.1. INTRODUCTION

Genetic improvement is an effective strategy for altering the performance of farm animals. While relatively slow compared to some other methods (e.g. improved feeding), it is permanent and cumulative, and furthermore, in most cases, it is highly cost-effective and sustainable. The main opportunities for breeders to accelerate rates of improvement are through choice of the most accurate methods of predicting breeding values (Simm, 1998).

Objective selection depends on having records of performance on animals for selection, or their relatives, or both. In practice, in most Western countries, the cattle and sheep breeders can use recording schemes which are operated by regional (e.g. Welsh Sheep Strategy (WSS)) or national agencies (e.g. SIGNET) which specialise in recording and evaluation. At its simplest, the WSS is encouraging flock monitoring and basing breeding sheep selection on performance records (Anderson, 2001).

Within England and Wales, strategies such as the WSS require that all animals are uniquely identifiable through a tag. This excludes farmers who do not tag each animal with a unique identifier and thus do not record details of their flocks. Hill farmers are reluctant to pay for breeding selection programmes which are technically demanding in terms of cost and time. Sheep farmers in England and Wales do not need to tag animals other than with their flock number (MAFF, 2000). Therefore, within England, Wales and other parts of the world, with particular emphasis on hill farming and rangeland production systems, there still isn't a methodology in place in order to select breeding animals for herds/flocks, based on performance records, where animals are not uniquely identifiable through tagging.

As detailed in the literature review, hill farming occupies 44% of agricultural land in Britain, making it the largest agricultural sector. While the output from hill farming makes up only 8% of the agricultural sector in Britain (Haines, 1987), its contribution to the agricultural industry could be improved through selection of animals for genetic improvement. Furthermore, some 30 to 40 million people within the world heavily

rely on animal rangeland based systems within the arid and semi-arid zones (Sandford, 1983). Again, rangeland production systems too could benefit from a selection programme which could be used for animals which are not uniquely identifiable through tagging.

The aim of this chapter was to examine four methods which calculated threshold values as the basis of selection. Method 1 (and method 4 for its starting threshold) used a random sample of the data set to calculate a mean and standard deviation, and hence the threshold value. Method 2 (and method 3 for its starting threshold) used a historical mean and standard deviation to calculate the threshold value. Methods 3 and 4 updated the threshold value as each record was reached (section 3.2.). Those animals that were above or on the threshold value for the particular trait in question were within the top x % to be selected.

5.2. MATERIALS AND METHODS

The four methods, as defined in sections 3.2 and 5.1, were evaluated over a range of % to Selects (5, 15, 25, 35 and 45 % to Select) (section 3.3), using example data sets of Muscle Depth (MD), Milk Yield (MY) and Ovulation Rate (OR), as described in section 3.1. The evaluation of the methods, computer strategies, transformation of the results and statistical models for comparison of the methods are as detailed in sections 3.5, 3.6, 3.7 and 3.8, respectively. The sample size (10%) used for methods 1 and 4 is discussed in Chapter 4.

5.3. RESULTS

The success rate (SR), proportion of the target number identified by the program (C/TN) and proportion of those selected that were correct (C/TS) were tested for normal distribution using the Anderson-Darling test (section 3.7). None of the variables had a normal distribution ($P < 0.05$) (Appendix 4). Therefore, descriptive results are shown for transformed (T) data. The data was transformed using arcsine (section 3.7). Any marked differences between un-transformed (UT) and T data are detailed in the results section. Both UT and T data are displayed within the tables but

the graphs display the T results only. Further tabulated results are presented in Appendix 5.

All results are rounded up to 2 decimal places. This can result in slight discrepancies in the T data, for example: $SR = 0.85$, $C/TN = 0.86$ and $C/TS = 1.00$, which prior to rounding up were $SR = 0.853$, $C/TN = 0.856$ and $C/TS = 0.996$.

5.3.1. Muscle Depth

5.3.1.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of % to Select x Method. The results are shown in Table 5.1, and the range of SR values is shown in Figure 5.1.

Method 4 (0.78) gave the highest mean Success Rate (SR), while methods 1, 2 and 3 SR were lower at 0.63, 0.62 and 0.75, respectively ($P < 0.05$). Method 4 was higher than all other methods but was not significantly better than method 3 ($P < 0.05$). Method 4 had a higher proportion of observations (0.31) of SR within the range of 0.90 to 1.00, while method 1 had the least (0.20).

Overall, method 4 gave the highest SR (1992 = 0.85, 1994 = 0.76) but methods 2 and 3 were significantly higher for the years 1991 (0.85) and 1993 (0.79), respectively. Furthermore, a % to Select of 45 gave the highest SR for the years 1992 (0.88), 1993 (0.71) and 1994 (0.91), while a % to Select of 15 gave the highest SR for the year 1991 (0.92), ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were elevated in comparison to UT, and for UT, method 3 was significantly higher for the year 1992, while for T, method 4 was significantly higher ($P < 0.05$) (Appendix 5).

Table 5.1. Success Rate for the Four Methods for Muscle Depth

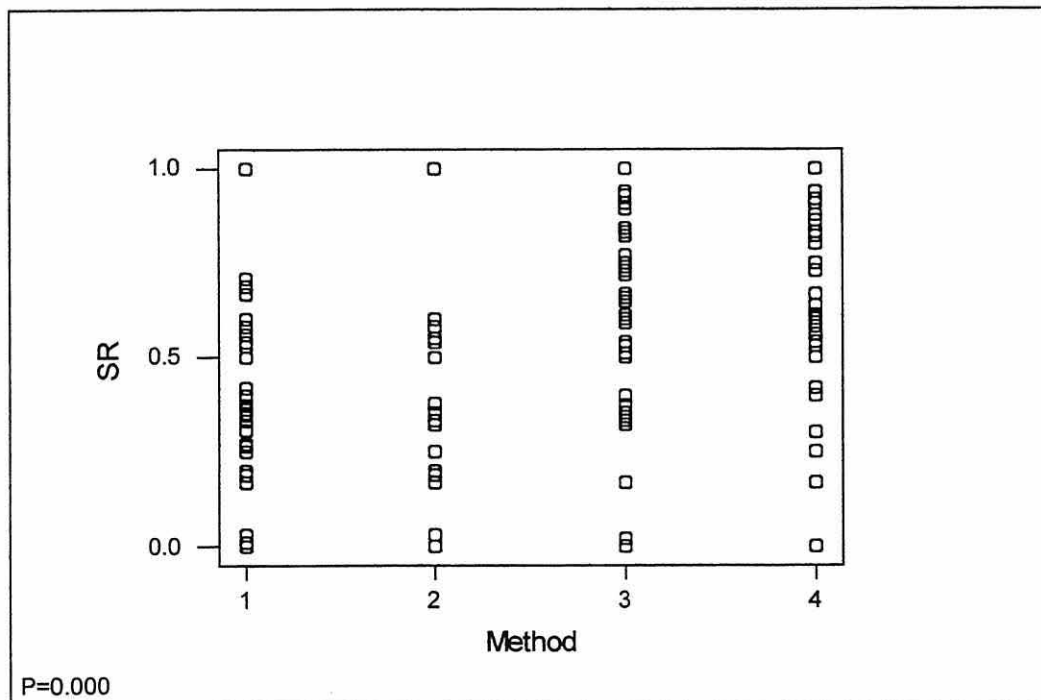
% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	28.32 (8.10)	32.44 (6.30)	39.71 (6.66)	43.29 (6.26)	51.06 (7.10)	38.96 (3.14)
	T (B)	0.47	0.54	0.64	0.69	0.78	0.63
	UT	0.38 (0.09)	0.48 (0.07)	0.56 (0.07)	0.62 (0.06)	0.68 (0.06)	0.54 (0.03)
2	T (A)	29.67 (9.02)	48.69 (9.49)	36.19 (7.00)	34.11 (1.59)	42.86 (5.92)	38.30 (3.22)
	T (B)	0.49	0.75	0.59	0.56	0.68	0.62
	UT	0.37 (0.09)	0.60 (0.09)	0.51 (0.07)	0.56 (0.02)	0.62 (0.05)	0.53 (0.03)
3	T (A)	52.99 (9.09)	49.76 (7.62)	45.92 (4.43)	38.85 (2.68)	55.41 (5.31)	48.59 (2.80)
	T (B)	0.80	0.76	0.72	0.63	0.82	0.75
	UT	0.66 (0.09)	0.66 (0.07)	0.69 (0.05)	0.62 (0.03)	0.77 (0.05)	0.68 (0.03)
4	T (A)	52.56 (9.94)	58.25 (7.34)	50.99 (5.61)	35.52 (1.10)	58.12 (5.76)	51.09 (3.03)
	T (B)	0.79	0.85	0.78	0.58	0.85	0.78
	UT	0.63 (0.10)	0.75 (0.07)	0.72 (0.05)	0.58 (0.01)	0.78 (0.05)	0.69 (0.03)
ALL	T (A)	40.89 (4.67)	47.28 (3.97)	43.20 (3.12)	37.94 (1.78)	51.86 (3.04)	44.23 (1.55)
	T (B)	0.65	0.73	0.68	0.61	0.79	0.70
	UT	0.51 (0.05)	0.62 (0.04)	0.62 (0.03)	0.59 (0.02)	0.71 (0.03)	0.61 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 8.53, 10.14 and 26.33, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.10 and 0.26, respectively.

Figure 5.1. Success Rate for the Four Methods for Muscle Depth



5.3.1.2. *Proportion of the Target Number Identified by the Program (C/TN)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method and % to Select x Method x Year. The results are shown in Table 5.2, and the range of C/TN values is shown in Figure 5.2.

Method 2 (0.95) gave the highest mean C/TN, while methods 1, 3 and 4 were lower at 0.85, 0.81 and 0.79, respectively ($P < 0.05$). Method 2 was significantly better than all other methods ($P < 0.05$). Method 2 had a higher proportion of observations (0.71) of C/TN within the range of 0.90 to 1.00, while method 4 had the least (0.32).

Overall, method 2 (1991 = 0.85, 1992 and 1993 = 1.00) gave the highest C/TN but it was significantly lower ($P < 0.05$) than method 1 (0.84) for the year 1994. Furthermore, a % to Select of 5 gave the highest C/TN for the years 1992 (1.00) and 1993 (0.97) while % to Selects 15 and 45 gave the highest C/TN for the years 1991 (0.94) and 1994 (0.94), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were elevated in comparison to UT, and for UT, a % to Select of 45 was significantly higher for the year 1993, while for T, a % to Select of 5 was significantly higher ($P < 0.05$) (Appendix 5).

Figure 5.2. C/TN for the Four Methods for Muscle Depth

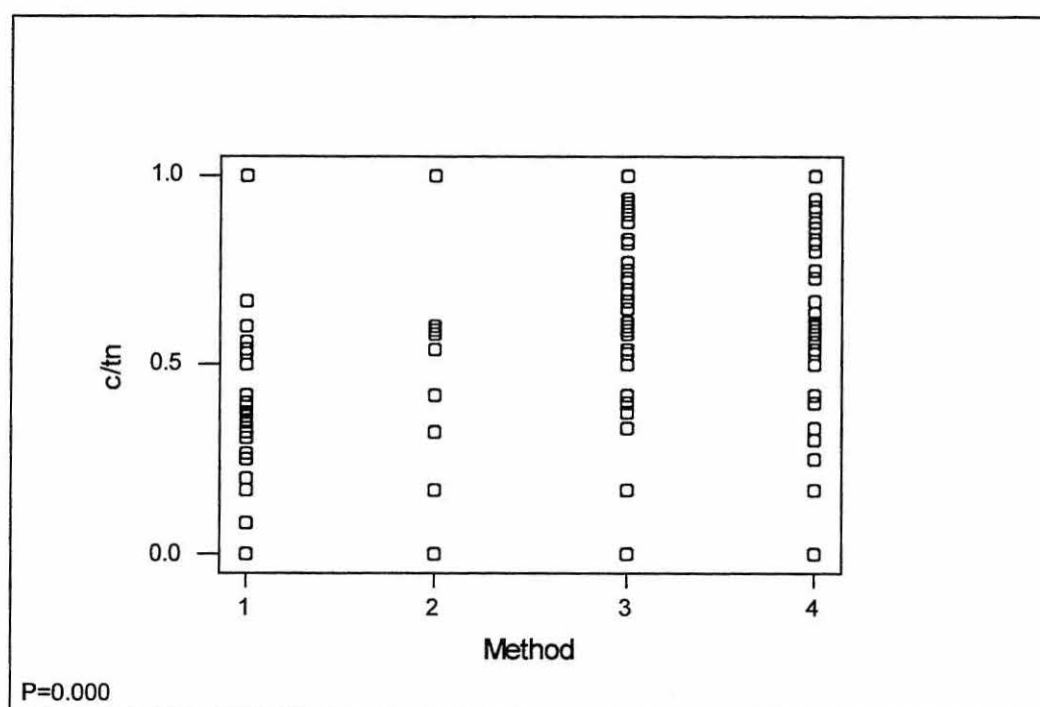


Table 5.2. C/TN for the Four Methods for Muscle Depth

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1 T (A)	58.74 (10.57)	54.45 (9.30)	57.79 (8.55)	55.78 (7.94)	62.55 (8.12)	57.86 (3.91)
T (B)	0.85	0.81	0.85	0.83	0.89	0.85
UT	0.67 (0.11)	0.66 (0.09)	0.71 (0.08)	0.71 (0.07)	0.76 (0.07)	0.70 (0.04)
2 T (A)	69.34 (9.26)	84.99 (5.01)	72.65 (6.68)	61.51 (7.43)	73.00 (6.51)	72.30 (3.21)
T (B)	0.94	1.00	0.95	0.88	0.96	0.95
UT	0.78 (0.10)	0.95 (0.05)	0.86 (0.05)	0.77 (0.06)	0.87 (0.05)	0.85 (0.03)
3 T (A)	64.92 (9.65)	54.69 (7.65)	53.75 (5.49)	40.32 (2.45)	57.57 (5.01)	54.25 (2.98)
T (B)	0.91	0.82	0.81	0.65	0.84	0.81
UT	0.74 (0.10)	0.71 (0.07)	0.75 (0.05)	0.64 (0.03)	0.79 (0.04)	0.73 (0.03)
4 T (A)	56.15 (10.02)	58.25 (7.34)	50.99 (5.61)	35.52 (1.10)	58.12 (5.76)	51.81 (3.05)
T (B)	0.83	0.85	0.78	0.58	0.85	0.79
UT	0.66 (0.10)	0.75 (0.07)	0.72 (0.05)	0.58 (0.01)	0.78 (0.05)	0.70 (0.03)
ALL T (A)	62.29 (4.28)	63.10 (4.00)	58.79 (3.43)	48.28 (3.05)	62.81 (3.24)	59.05 (1.71)
T (B)	0.88	0.89	0.85	0.75	0.89	0.86
UT	0.71 (0.05)	0.77 (0.04)	0.76 (0.03)	0.67 (0.03)	0.80 (0.03)	0.74 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 9.78, 11.63 and 30.18, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.09, 0.11 and 0.29, respectively.

5.3.1.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method, % to Select x Year and % to Select x Method x Year. The results are shown in Table 5.3, and the range of C/TS values is shown in Figure 5.3.

Method 4 (1.00) gave the highest mean C/TS, while methods 1, 2 and 3 C/TS were lower at 0.90, 0.79 and 0.98, respectively ($P < 0.05$). Overall, method 4 gave the highest C/TS (1992 and 1994 = 1.00, 1993 = 0.99), but it was significantly lower ($P < 0.05$) than method 2 for the year 1991 (1.00). All methods differed significantly ($P < 0.05$). Method 4 had a higher proportion of observations (0.96) of C/TS within the range of 0.90 to 1.00 while method 2 had the least (0.44).

There were marked differences between UT and T data. T C/TS results were elevated in comparison to UT, and for UT, the interaction of % to Select x Method was significant ($P < 0.05$). Furthermore, method 3 was significantly higher for the year 1993, while for T, method 4 was significantly higher ($P < 0.05$). For UT data, methods 3 and 4 did not differ significantly (Appendix 5).

Figure 5.3. C/TS for the Four Methods for Muscle Depth

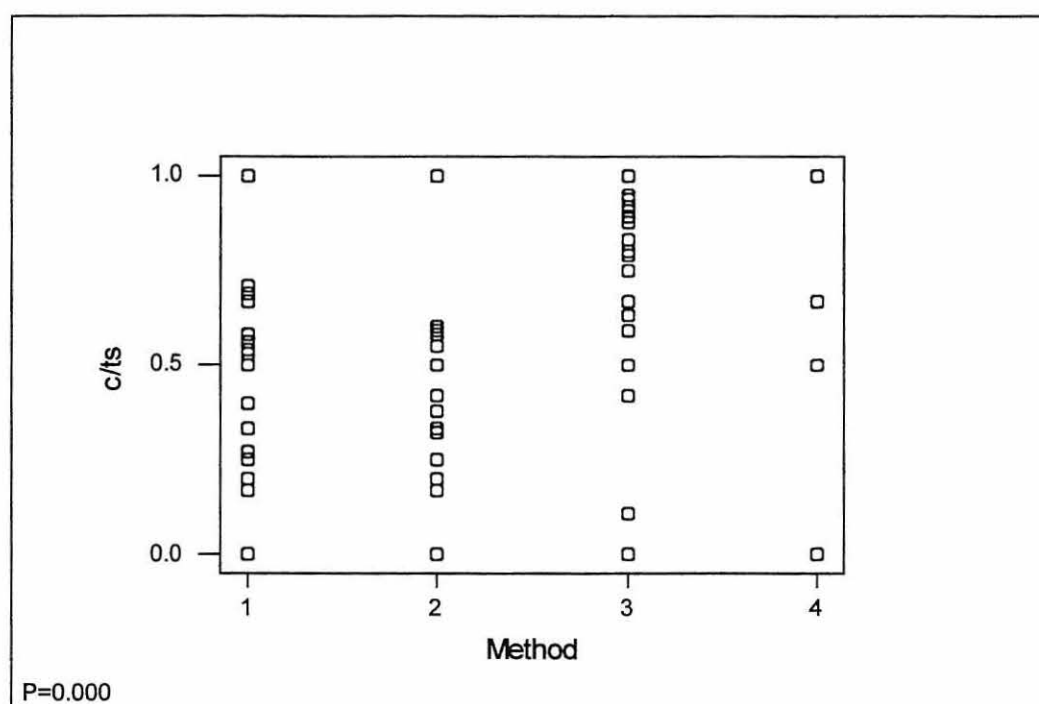


Table 5.3. C/TS for the Four Methods for Muscle Depth

% to Select Method	5	15	25	35	45	ALL
	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1 T (A)	37.08 (9.53)	63.48 (8.01)	67.16 (7.73)	74.59 (5.93)	78.51 (5.14)	64.16 (3.63)
T (B)	0.60	0.89	0.92	0.96	0.98	0.90
UT	0.46 (0.10)	0.77 (0.07)	0.81 (0.07)	0.89 (0.04)	0.92 (0.03)	0.77 (0.03)
2 T (A)	44.71 (10.34)	49.19 (9.33)	50.41 (9.02)	59.67 (6.91)	57.48 (7.42)	52.29 (3.84)
T (B)	0.70	0.76	0.77	0.86	0.84	0.79
UT	0.53 (0.11)	0.61 (0.09)	0.63 (0.08)	0.77 (0.05)	0.73 (0.06)	0.65 (0.04)
3 T (A)	72.45 (7.22)	75.85 (6.17)	74.36 (5.10)	83.68 (3.67)	82.72 (3.75)	77.81 (2.39)
T (B)	0.95	0.97	0.96	0.99	0.99	0.98
UT	0.85 (0.07)	0.90 (0.06)	0.91 (0.04)	0.96 (0.02)	0.96 (0.03)	0.92 (0.02)
4 T (A)	77.63 (6.94)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	87.53 (1.46)
T (B)	0.98	1.00	1.00	1.00	1.00	1.00
UT	0.89 (0.07)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.98 (0.01)
ALL T (A)	57.97 (4.74)	69.63 (3.86)	70.48 (3.63)	76.99 (2.79)	77.18 (2.83)	70.45 (1.67)
T (B)	0.85	0.94	0.94	0.97	0.97	0.94
UT	0.68 (0.05)	0.82 (0.04)	0.83 (0.03)	0.91 (0.02)	0.91 (0.02)	0.83 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 8.49, 10.09 and 26.19, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

5.3.2. Milk Yield

5.3.2.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Farm and their interactions were observed. The results are shown in Table 5.4, and the range of SR values is shown in Figure 5.4.

Method 4 (0.86) gave the highest mean SR, while methods 1, 2 and 3 were lower at 0.78, 0.60 and 0.82, respectively ($P < 0.05$). Method 4 was higher than all other methods but was not significantly better than method 3 ($P < 0.05$). Method 4 had a higher proportion of observations (0.37) of SR within the range of 0.90 and 1.00. The proportion of SR within this range decreased with lowering method number, with the exception of method 2 which was lower at just 0.05.

Overall, method 4 gave the highest SR (farms B = 0.87, D = 0.86) but it was significantly lower ($P < 0.05$) than methods 1 (0.85) and 3 (0.89) for farms C and A,

respectively. Furthermore, method 4 gave the highest SR for % to Selects 5 (0.66), 15 (0.88), 25 (0.91) and 35 (0.88). However, it was significantly lower ($P<0.05$) than method 3 (0.91) at 45 % to Select.

A % to Select of 45 gave the highest SR for the farms A (0.83) and D (0.84), while % to Select of 25 gave the highest SR for the farms B (0.90) and C (0.90), respectively ($P<0.05$).

Marked differences between UT and T data were seen. T SR results were elevated in comparison to UT, and for UT, method 1 was significantly higher for the % to Select of 5, while for T, method 4 was significantly higher ($P<0.05$) (Appendix 5).

Figure 5.4. Success Rate for the Four Methods for Milk Yield

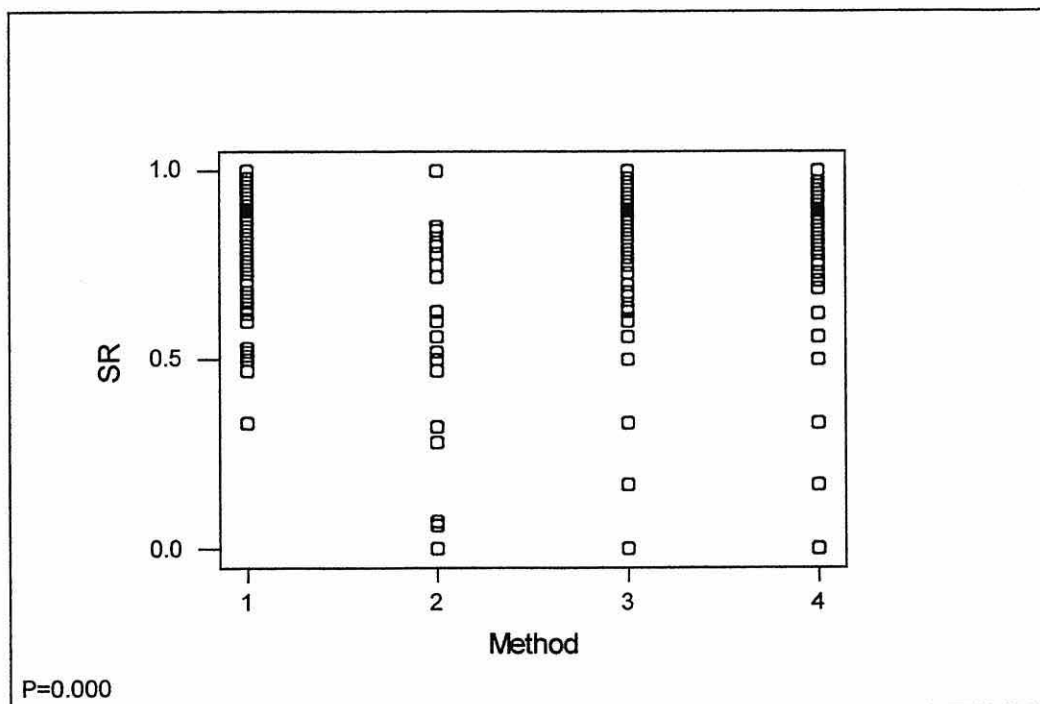


Table 5.4. Success Rate for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	41.44 (4.86)	53.75 (2.95)	54.23 (4.00)	52.59 (3.44)	55.36 (3.66)	51.47 (1.77)
	T (B)	0.66	0.81	0.81	0.79	0.82	0.78
	UT	0.62 (0.06)	0.79 (0.03)	0.78 (0.04)	0.77 (0.04)	0.80 (0.04)	0.75 (0.02)
2	T (A)	23.71 (4.61)	31.18 (4.53)	43.53 (7.98)	39.99 (3.79)	45.06 (3.36)	36.69 (2.41)
	T (B)	0.40	0.52	0.69	0.64	0.71	0.60
	UT	0.38 (0.07)	0.50 (0.07)	0.59 (0.09)	0.62 (0.05)	0.69 (0.04)	0.56 (0.03)
3	T (A)	31.21 (5.00)	55.90 (2.66)	61.68 (3.10)	61.05 (2.53)	65.09 (2.22)	54.99 (1.98)
	T (B)	0.52	0.83	0.88	0.88	0.91	0.82
	UT	0.48 (0.06)	0.81 (0.03)	0.86 (0.02)	0.86 (0.02)	0.90 (0.02)	0.78 (0.02)
4	T (A)	41.48 (5.60)	61.79 (2.70)	65.35 (3.09)	61.33 (2.30)	64.22 (2.37)	58.83 (1.80)
	T (B)	0.66	0.88	0.91	0.88	0.90	0.86
	UT	0.62 (0.07)	0.87 (0.02)	0.89 (0.02)	0.87 (0.02)	0.89 (0.02)	0.82 (0.02)
ALL	T (A)	34.46 (2.63)	50.65 (2.18)	56.20 (2.64)	53.74 (1.86)	57.43 (1.77)	50.50 (1.10)
	T (B)	0.57	0.77	0.83	0.81	0.84	0.77
	UT	0.53 (0.03)	0.74 (0.03)	0.78 (0.03)	0.78 (0.02)	0.82 (0.02)	0.73 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 4.41, 5.25 and 13.62, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.05 and 0.14, respectively.

5.3.2.2. Proportion of the Target Number Identified by the Program (C/TN)

Significant effects ($P < 0.05$) of Method, % to Select and Farm and their interactions were observed, with the exception of the interaction of % to Select x Method x Farm. The results are shown in Table 5.5, and the range of C/TN values is shown in Figure 5.5.

Method 2 (0.93) gave the highest mean C/TN, while methods 1, 3 and 4 were lower at 0.84, 0.89 and 0.91, respectively ($P < 0.05$). Method 2 was higher than all other methods but was not significantly better than method 4 ($P < 0.05$). Method 2 had a higher proportion of observations (0.75) of C/TN within the range of 0.90 to 1.00 while method 1 had the least (0.34).

Overall, method 2 gave the highest C/TN for farms A (1.00), B (1.00) and C (1.00), but it was significantly lower ($P < 0.05$) than method 4 for farm D (0.87). Furthermore, method 4 gave the highest C/TN for % to Selects 15 (0.95) and 25 (0.93), but it was

significantly lower ($P < 0.05$) than method 2 at 5 (0.92), 35 (0.93) and 45 (0.95) % to Selects, respectively.

A % to Select of 15 gave the highest C/TN for the farms B (0.98) and C (0.99), while a % to Select 45 gave the highest C/TN for the farms A (0.95) and D (0.86), respectively ($P < 0.05$).

There were marked differences between UT and T data. T C/TN results were elevated in comparison to UT. For UT, method 4 gave the highest mean C/TN, but method 3 was significantly higher for the % to Selects of 35 and 45 ($P < 0.05$) (Appendix 5).

Figure 5.5. C/TN for the Four Methods for Milk Yield

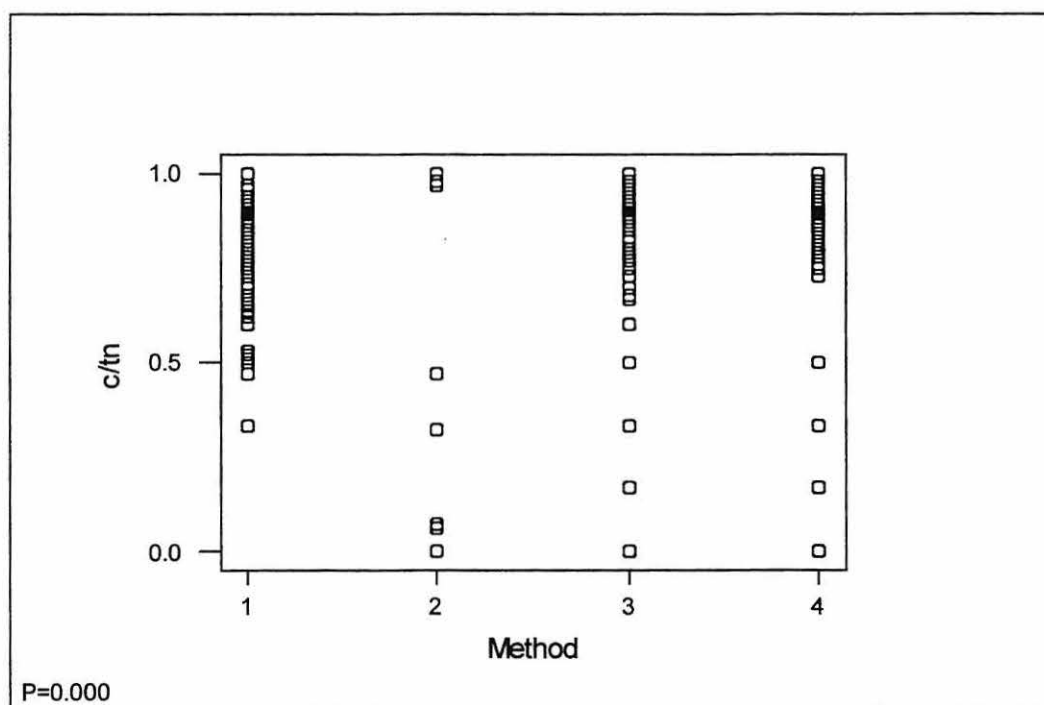


Table 5.5. C/TN for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	56.65 (8.06)	63.65 (5.61)	56.27 (4.82)	52.59 (3.44)	56.07 (4.02)	57.05 (2.40)
	T (B)	0.84	0.90	0.83	0.79	0.83	0.84
	UT	0.72 (0.07)	0.83 (0.04)	0.79 (0.04)	0.77 (0.04)	0.80 (0.04)	0.78 (0.02)
2	T (A)	67.50 (10.06)	68.36 (9.68)	68.50 (9.61)	68.65 (7.60)	71.64 (6.61)	68.93 (3.85)
	T (B)	0.92	0.93	0.93	0.93	0.95	0.93
	UT	0.75 (0.11)	0.76 (0.10)	0.77 (0.10)	0.82 (0.07)	0.86 (0.06)	0.79 (0.04)
3	T (A)	43.33 (7.84)	65.94 (4.05)	67.40 (3.85)	65.61 (3.62)	69.47 (3.17)	62.35 (2.36)
	T (B)	0.69	0.91	0.92	0.91	0.94	0.89
	UT	0.59 (0.08)	0.88 (0.03)	0.89 (0.02)	0.88 (0.03)	0.91 (0.02)	0.83 (0.02)
4	T (A)	57.74 (8.34)	72.69 (4.26)	68.64 (3.76)	63.40 (3.05)	65.46 (2.59)	65.59 (2.19)
	T (B)	0.85	0.95	0.93	0.89	0.91	0.91
	UT	0.72 (0.08)	0.92 (0.02)	0.90 (0.02)	0.87 (0.02)	0.90 (0.02)	0.86 (0.02)
ALL	T (A)	56.30 (4.34)	67.66 (3.11)	65.20 (3.01)	62.56 (2.46)	65.66 (2.26)	63.48 (1.40)
	T (B)	0.83	0.92	0.91	0.89	0.91	0.89
	UT	0.69 (0.04)	0.85 (0.03)	0.84 (0.03)	0.84 (0.02)	0.87 (0.02)	0.82 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.87, 6.98 and 18.12, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.06 and 0.16, respectively.

5.3.2.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Farm and their interactions were observed. The results are shown in Table 5.6, and the range of C/TS values is shown in Figure 5.6.

Methods 1 (0.99) and 4 (0.99) gave the highest mean C/TS, while methods 2 and 3 were lower at 0.79 and 0.98, respectively ($P < 0.05$). Methods 1 and 4 were higher than the other methods but were not significantly better than method 3 ($P < 0.05$). Method 1 had a higher proportion of observations (0.89) of C/TS within the range of 0.90 and 1.00, while method 2 had the least (0.25).

Overall, method 1 gave the highest C/TS (farms A = 1.00, C = 0.98, D = 1.00) but it was significantly lower ($P < 0.05$) than method 3 (1.00) for farm B. Furthermore, method 1 gave the highest C/TS for all % to Selects 5 (0.96), 15 (0.98), 25 (1.00), 35 (1.00) and 45 (1.00).

A % to Select of 15 gave the highest C/TS for the farm D (1.00). However, a % to Select of 25 gave the highest C/TS for the farms A (0.96) and B (1.00), while a % to Select of 45 gave the highest C/TS for the farm C (0.99), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TS results were elevated in comparison to UT, and for UT, a % to Select of 15 was significantly higher for the farm A ($P < 0.05$) (Appendix 5).

Figure 5.6. C/TS for the Four Methods for Milk Yield

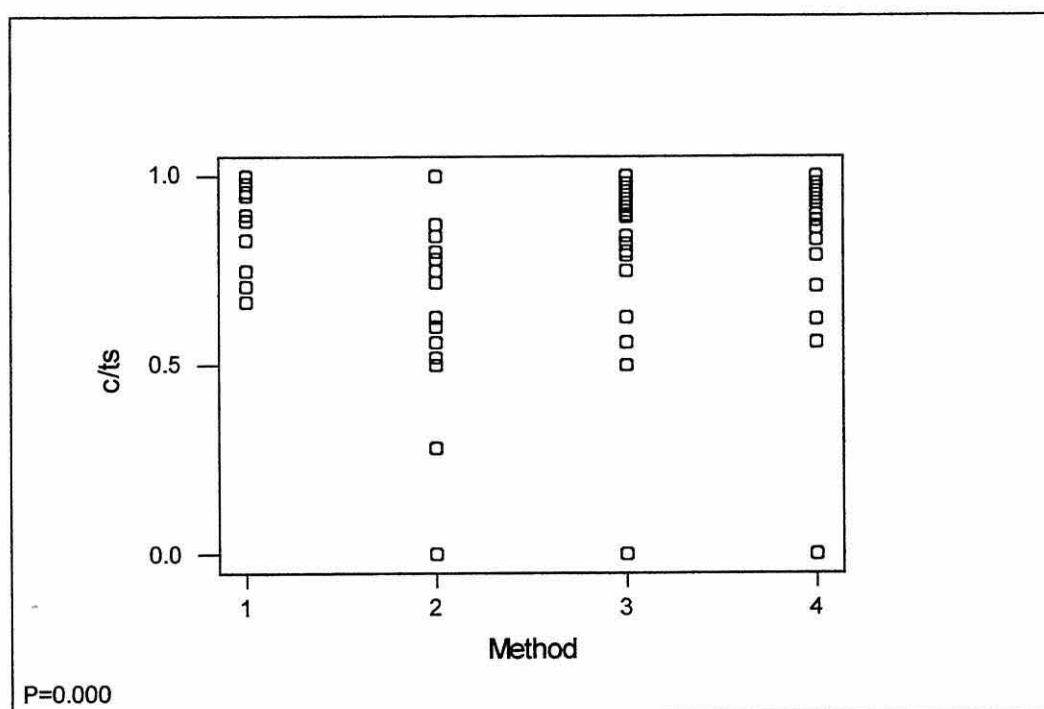


Table 5.6. C/TS for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	74.79 (5.13)	80.10 (3.45)	87.97 (1.39)	90.00 (0.00)	89.28 (0.72)	84.43 (1.41)
	T (B)	0.96	0.99	1.00	1.00	1.00	1.00
	UT	0.91 (0.03)	0.96 (0.01)	0.99 (0.003)	1.00 (0.00)	1.00 (0.001)	0.97 (0.01)
2	T (A)	23.71 (4.61)	52.82 (5.84)	65.03 (6.54)	58.58 (5.20)	61.12 (4.90)	52.25 (2.90)
	T (B)	0.40	0.80	0.91	0.85	0.88	0.79
	UT	0.38 (0.07)	0.73 (0.05)	0.82 (0.05)	0.80 (0.04)	0.83 (0.04)	0.72 (0.03)
3	T (A)	69.31 (7.45)	76.11 (4.27)	81.81 (3.19)	80.74 (2.18)	81.97 (1.99)	77.99 (1.95)
	T (B)	0.94	0.97	0.99	0.99	0.99	0.98
	UT	0.83 (0.07)	0.93 (0.02)	0.97 (0.01)	0.98 (0.01)	0.98 (0.01)	0.94 (0.02)
4	T (A)	66.78 (6.91)	78.31 (3.65)	85.79 (2.28)	85.97 (1.82)	86.83 (1.44)	80.74 (1.86)
	T (B)	0.92	0.98	1.00	1.00	1.00	0.99
	UT	0.83 (0.07)	0.95 (0.02)	0.99 (0.01)	0.99 (0.004)	0.99 (0.003)	0.95 (0.01)
ALL	T (A)	58.65 (3.95)	71.84 (2.56)	80.15 (2.20)	78.82 (2.10)	79.80 (1.94)	73.85 (1.26)
	T (B)	0.85	0.95	0.99	0.98	0.98	0.96
	UT	0.74 (0.04)	0.89 (0.02)	0.94 (0.01)	0.94 (0.01)	0.95 (0.01)	0.89 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 3.85, 4.58 and 11.88, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.03, 0.04 and 0.09, respectively.

5.3.3. Ovulation Rates

5.3.3.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of Method x % to Select x Year. The results are shown in Table 5.7, and the range of SR values is shown in Figure 5.7.

Method 2 (0.73) gave the highest mean SR, while methods 1, 3 and 4 were lower at 0.64, 0.63 and 0.60, respectively ($P < 0.05$). Method 2 was higher than all other methods but was not significantly better than method 1 ($P < 0.05$). Method 2 had a higher proportion of observations (0.35) of SR within the range of 0.90 to 1.00, while method 4 had the least (0.10).

Overall, method 2 gave the highest SR (1988 = 0.90) but it was significantly lower ($P < 0.05$) than methods 1 (1991 = 0.83) and 3 (1989 = 0.59, 1992 = 0.81). Furthermore, method 2 gave the highest SR for % to Selects 5 (0.97), 15 (0.94) and 45 (0.71). However, it was significantly lower ($P < 0.05$) than method 1 at 25 (0.63)

and 35 (0.68) % to Selects, respectively.

A % to Select of 15 gave the highest SR for the years 1991 (0.88) and 1992 (0.91), while % to Selects of 5 and 45 gave the highest SR for the years 1989 (0.72) and 1988 (0.85), respectively ($P < 0.05$).

There were marked differences between UT and T data. T SR results were elevated in comparison to UT. Method alone was not significant ($P > 0.05$) for UT. For UT, method 3 was significantly higher for % to Selects 25 and 35 ($P < 0.05$) (Appendix 5).

Figure 5.7. Success Rate for the Four Methods for Ovulation Rate

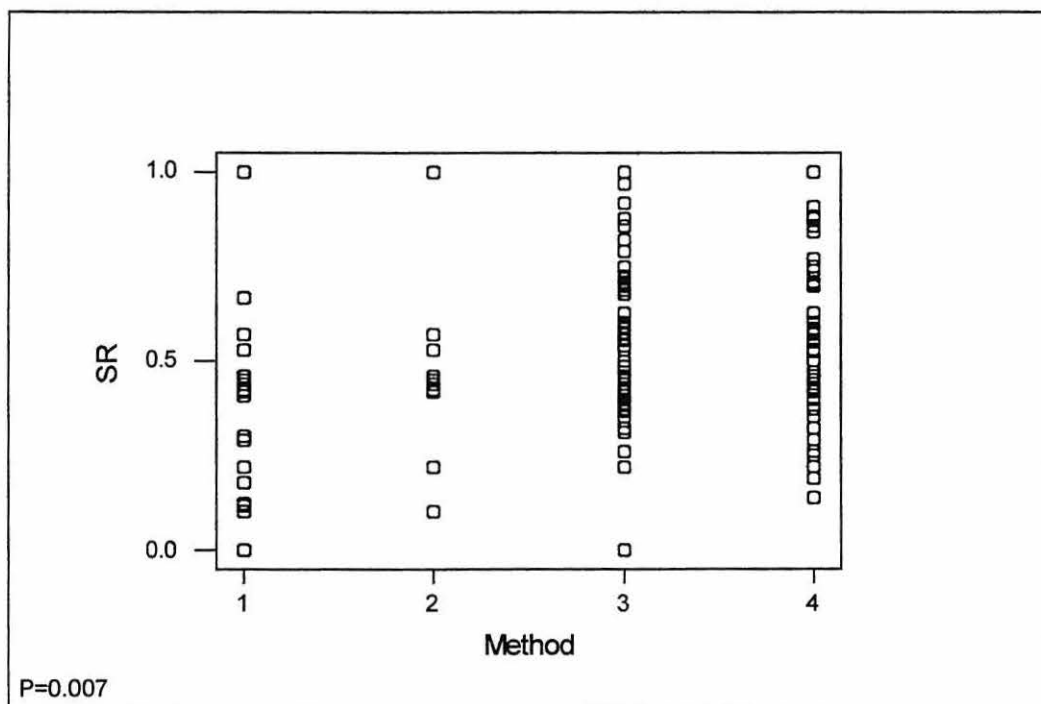


Table 5.7. Success Rate for the Four Methods for Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	34.84 (7.35)	47.93 (9.68)	39.25 (8.97)	42.96 (8.41)	35.79 (5.42)	40.15 (3.57)
	T (B)	0.57	0.74	0.63	0.68	0.58	0.64
	UT	0.49 (0.08)	0.58 (0.10)	0.50 (0.09)	0.56 (0.08)	0.53 (0.05)	0.53 (0.03)
2	T (A)	76.19 (6.18)	70.65 (8.65)	22.33 (1.46)	20.62 (2.23)	45.23 (6.69)	47.00 (3.63)
	T(B)	0.97	0.94	0.38	0.35	0.71	0.73
	UT	0.89 (0.05)	0.80 (0.09)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.61 (0.03)
3	T (A)	52.08 (6.79)	36.48 (6.11)	33.28 (4.04)	37.71 (4.81)	34.64 (2.80)	38.84 (2.36)
	T (B)	0.79	0.59	0.55	0.61	0.57	0.63
	UT	0.71 (0.07)	0.53 (0.06)	0.52 (0.05)	0.57 (0.05)	0.56 (0.03)	0.58 (0.02)
4	T (A)	46.40 (6.58)	34.72 (5.45)	31.21 (3.55)	38.15 (5.65)	34.36 (3.94)	36.97 (2.32)
	T (B)	0.72	0.57	0.52	0.62	0.56	0.60
	UT	0.65 (0.07)	0.53 (0.07)	0.50 (0.05)	0.56 (0.05)	0.54 (0.04)	0.56 (0.02)
ALL	T (A)	52.38 (3.80)	47.44 (4.16)	31.52 (2.69)	34.86 (2.99)	37.51 (2.48)	40.74 (1.52)
	T (B)	0.79	0.74	0.52	0.57	0.61	0.65
	UT	0.68 (0.04)	0.61 (0.04)	0.48 (0.03)	0.51 (0.03)	0.56 (0.02)	0.57 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.85, 9.34 and 24.23, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

5.3.3.2. Proportion of the Target Number Identified by the Program (C/TN)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of Method x % to Select x Year. The results are shown in Table 5.8, and the range of C/TN values is shown in Figure 5.8.

Method 2 (0.73) gave the highest mean C/TN, while methods 1, 3 and 4 were lower at 0.72, 0.64 and 0.64, respectively ($P < 0.05$). Although significant, none of the methods differed significantly. Method 1 had a higher proportion of observations (0.36) of C/TN within the range of 0.90 to 1.00, while methods 3 and 4 had the least (0.15).

Overall, method 2 gave the highest C/TN (1988 = 0.90) but it was significantly lower ($P < 0.05$) than methods 1 (1991 = 0.89, 1992 = 0.90) and 3 (1989 = 0.61). Furthermore, method 2 gave the highest C/TN for % to Selects 5 (0.97), 15 (0.94) and 45 (0.71). However, it was significantly lower ($P < 0.05$) than method 1 at 25 (0.63) and 35 (0.73), and method 3 (0.79) at 25 % to Select, respectively.

A % to Select of 5 gave the highest C/TN for the years 1989 (0.74), 1991 (0.91) and 1992 (1.00), while % to Select of 45 gave the highest C/TN for the year 1988 (0.85) ($P < 0.05$).

There were marked differences between UT and T data. T C/TN results were elevated in comparison to UT. Method alone was not significant ($P > 0.05$) for UT. For UT, method 1 was significantly higher for a % to Select of 25 ($P < 0.05$) (Appendix 5).

Figure 5.8. C/TN for the Four Methods for Ovulation Rate

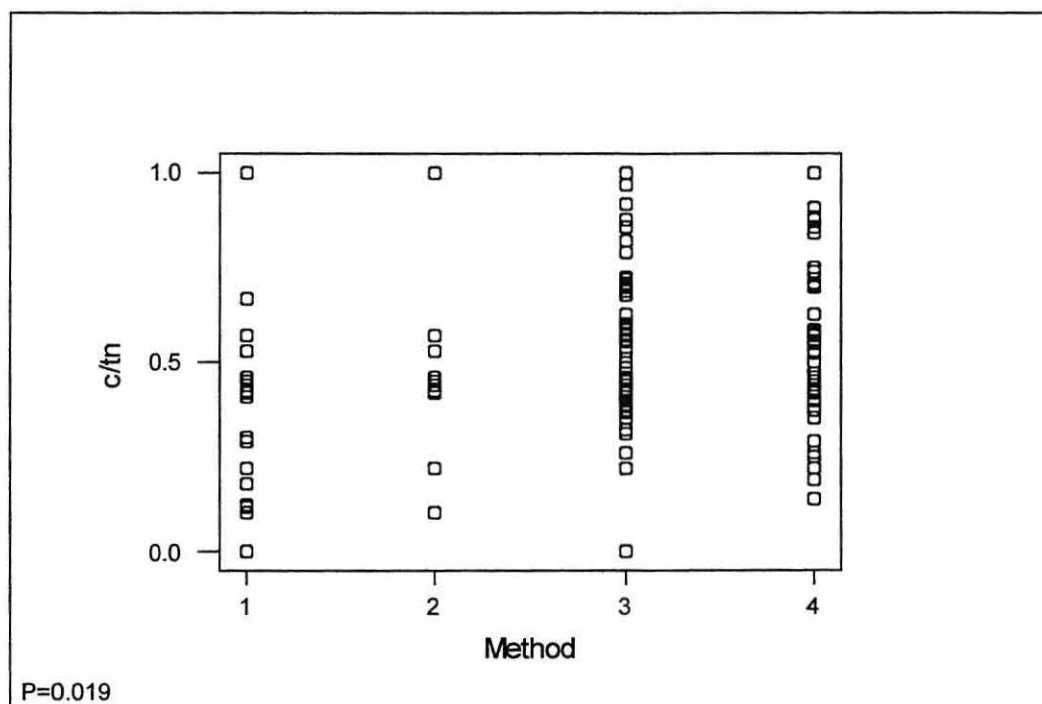


Table 5.8. C/TN for the Four Methods for Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	57.31 (8.78)	52.00 (9.89)	39.25 (8.97)	46.59 (8.87)	35.79 (5.42)	46.19 (3.82)
	T (B)	0.84	0.79	0.63	0.73	0.58	0.72
	UT	0.70 (0.09)	0.62 (0.10)	0.50 (0.09)	0.59 (0.09)	0.53 (0.05)	0.59 (0.04)
2	T (A)	76.19 (6.18)	70.65 (8.65)	22.33 (1.46)	20.62 (2.22)	45.23 (6.69)	47.00 (3.63)
	T (B)	0.97	0.94	0.38	0.71	0.71	0.73
	UT	0.89 (0.05)	0.80 (0.09)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.61 (0.03)
3	T (A)	57.99 (7.37)	36.48 (6.11)	33.28 (4.04)	37.71 (4.81)	34.64 (2.80)	40.02 (2.52)
	T (B)	0.85	0.59	0.55	0.57	0.57	0.64
	UT	0.75 (0.07)	0.53 (0.06)	0.52 (0.05)	0.57 (0.05)	0.56 (0.03)	0.59 (0.03)
4	T (A)	57.42 (7.48)	37.19 (6.41)	31.21 (3.55)	38.15 (5.65)	34.36 (3.94)	39.67 (2.65)
	T (B)	0.84	0.60	0.52	0.56	0.56	0.64
	UT	0.74 (0.07)	0.54 (0.07)	0.50 (0.05)	0.56 (0.05)	0.54 (0.04)	0.58 (0.03)
ALL	T (A)	62.23 (3.80)	49.08 (4.24)	31.52 (2.69)	35.76 (3.11)	37.51 (2.48)	43.22 (1.61)
	T (B)	0.88	0.76	0.52	0.61	0.61	0.68
	UT	0.77 (0.04)	0.62 (0.04)	0.48 (0.03)	0.52 (0.03)	0.56 (0.02)	0.59 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.74, 9.20 and 23.89, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.23, respectively.

5.3.3.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Year were seen and their interactions were observed, with the exception of the interactions of % to Select x Year and Method x % to Select x Year. The results are shown in Table 5.9, and the range of C/TS values is shown in Figure 5.9.

Methods 2 (1.00), 3 (1.00) and 4 (1.00) gave the highest mean C/TS, while method 1 was lower at 0.99 ($P < 0.05$). Although significant, none of the methods differed significantly. Method 2 had a higher proportion of observations (1.00) of C/TS within the range of 0.90 to 1.00, while method 1 had the least (0.90). The year 1988 C/TS results showed that all methods achieved a C/TS of 1.00. Method 2 achieved a C/TS of 1.00 for all years. There weren't any marked differences between UT and T data (Appendix 5).

Figure 5.9. C/TS for the Four Methods for Ovulation Rate

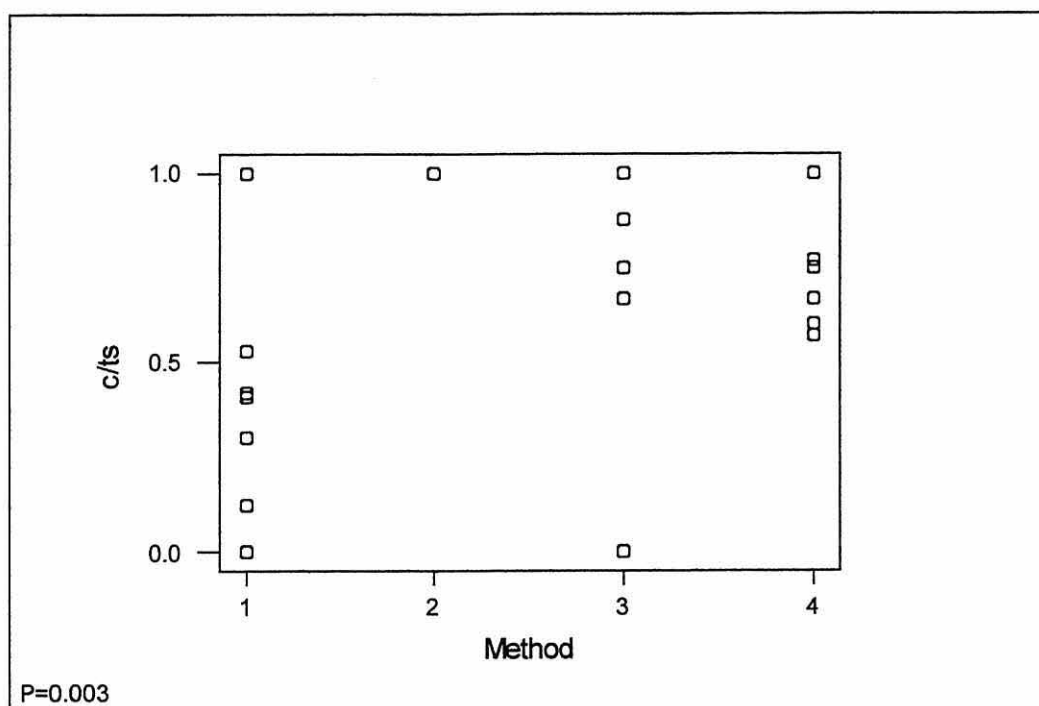


Table 5.9. C/TS for the Four Methods for Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1	T (A)	61.91 (9.47)	85.93 (4.07)	90.00 (0.00)	86.38 (3.62)	90.00 (0.00)	82.84 (2.44)
	T (B)	0.88	1.00	1.00	1.00	1.00	0.99
	UT	0.72 (0.10)	0.96 (0.04)	1.00 (0.00)	0.97 (0.03)	1.00 (0.00)	0.93 (0.02)
2	T (A)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)
	T (B)	1.00	1.00	1.00	1.00	1.00	1.00
	UT	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
3	T (A)	76.97 (6.54)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	87.40 (1.40)
	T (B)	0.97	1.00	1.00	1.00	1.00	1.00
	UT	0.89 (0.06)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.98 (0.01)
4	T (A)	75.04 (0.00)	87.52 (2.48)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	86.51 (1.39)
	T (B)	0.97	1.00	1.00	1.00	1.00	1.00
	UT	0.90 (0.04)	0.99 (0.01)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.98 (0.01)
ALL	T (A)	75.98 (3.38)	88.36 (1.18)	90.00 (0.00)	89.10 (0.91)	90.00 (0.00)	86.69 (0.79)
	T (B)	0.97	1.00	1.00	1.00	1.00	1.00
	UT	0.88 (0.03)	0.99 (0.01)	1.00 (0.00)	0.99 (0.01)	1.00 (0.01)	0.97 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 4.95, 5.89 and 15.29, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.05 and 0.14, respectively.

5.4. DISCUSSION

5.4.1. Success Rates of the Methods

5.4.1.1. Muscle Depth and Milk Yield

The results indicated that methods 3 and 4 were significantly better than methods 1 and 2 ($P < 0.001$), except for MY where method 3 was not significantly better than method 1. Overall, method 4 gave the highest SR. This result was as expected, since this method used the sample size threshold of the actual data sets, and hence, was logically more likely to produce better SR. This was because the possibility of erroneous means and standard deviations, as introduced, for example, by using historical data, was reduced somewhat. Furthermore, it was also expected that methods 4 and 3 would give better SR than methods 1 and 2, since the threshold value within these methods was updated as each trait value was entered into the program, enabling a more accurate threshold value as the procedure advanced.

Overall, with the exception of method 2's mean SR value which was 2% lower, the SR results for MY were higher than those for MD (Table 5.10). The difference between MY and MD in SR results ranged from 2% (method 2) to 15% (method 1). When compared to MD, both methods 3 and 4 had better MY results by some 7% and 8%, respectively. These higher results for MY were due to the higher number of SR values within the higher range of possible values (0.76 – 1.00). Indeed, for methods 1 to 4, the proportions of MY SR within this range were 0.54, 0.30, 0.71 and 0.81, while the proportions of MD SR within the same range were considerably lower (0.20, 0.21, 0.36 and 0.42). The nature of the MD values, in part, resulted in these lower proportions. MD data sets and historical data had coefficients of variation of 8 and 9.5, respectively. These were within the lower range of values reported (Morris, 1999). When the data is less variable, it results in large groups of the same value. For example, 64% of the MD values for 1991 were immediately bordering, by one whole number, the data set mean. This, combined with the varied starting thresholds for method 1 (section 5.4.2) and the historical threshold (section 5.4.3.), resulted in methods 1 and 2 having the lower proportions within the range of 0.76 to 1.00. The results did not indicate any negative effect of variation for MY.

The highest proportions of MD SR were found within the range of 0.50 to 0.75.

However, MD (24%) had a 1% higher proportion of SR of 1.00 than MY (23%). Methods 1 and 2 had the highest number of SR at the lower end (0.00) of the spectrum. A SR of 1.00 can only be achieved when the proportion of the target number being identified by the program (C/TN) equals the proportion of those selected that were correct (C/TS). The results would suggest that the differences between C/TN and C/TS were more marked, in many cases, for MD, but at the same time, there was a higher frequency of C/TN = C/TS. This can be seen by comparing Figures 5.1 and 5.4. Methods 1, 3 and 4 show a greater range of results for MD, and MY has a larger proportion of results above 0.50. Clearly, the low number of SR values of 1.00 for MY results from the high proportion of values that fall immediately below 1.00 (methods 1, 3 and 4 in particular).

5.4.1.2. *Ovulation Rate*

The results indicated that method 2 was significantly better than Methods 1, 3 and 4 ($P=0.007$). This was unexpected, since this method used the historical data to produce its threshold. It was expected that methods 4 and 3 would achieve better overall means than methods 1 and 2 but methods 1 and 2 were some 1% and 10% better, respectively, than method 3, while the same methods were 4% and 13% better, respectively, than method 4. Method 2 SR results had less range (refer to Figure 5.7) than any of the other methods, and it was the higher number of SR of 1.00 (35%), compared to that for methods 1 (27%), 3 and 4 (both 8.75%) that resulted in the overall highest mean. The trend in SR values across all methods was similar, if not the same, as that for MD. All methods had a high percentage of values within the range of 0.40 to 0.60, with method 2 having the most (50%) and method 1 having the least (41%).

Updating the threshold value as each value was entered caused the SR to have a larger range. Method 3 and 4 not only had a high percentage of values in the 0.40 to 0.60 range, but they also both fared better than methods 1 and 2 in the 0.50 to 0.70 range by some 31% and 21%, respectively. However, the updating of the threshold value resulted in threshold values that did not enable a SR of 1.00 to be achieved in many

instances.

All of the above OR findings were mainly due to the large groups of identical values. Like MD, this can be attributed to the variability of the data. However, unlike MD, OR had an extremely high variability, with the true data sets having coefficients of variation between 48% to 56%. This is higher than the coefficient of variation range (20-40%) reported by Morris (1999).

5.4.2. Effects of Methods 1 and 4 Starting Values on the SR

The differences in C/TN and C/TS resulted from both the variability of the data (refer to sections 5.4.1.1 and 5.4.1.2) and, in the case of methods 1 and 4, the randomly sorted sample of the data sets in order to calculate the starting threshold value. As with all other calculated thresholds, these thresholds took into account the % to Select.

Of the 32 randomly sorted data sets for method 1 (and method 4 starting threshold) threshold calculation (for both MD and MY), three of them included the lowest possible value. All three instances occurred in MD 1993, and with the threshold being calculated using the lowest values but not the highest values, the threshold values were lower than the actual threshold meaning that the method over selected records. A further three contained the highest possible value (MD 1991, MY Farms A and C). For MD, this resulted in the threshold values for the year 1991 being too high in 70% of instances.

For MY, the lack of lower range values and the presence of the highest values in the sample, would explain why method 1 thresholds were higher than the true data set thresholds in 86% of cases. It also helps explain why method 1 did not achieve such high SR results as those for methods 3 and 4. However, the resultant threshold value did not hinder method 3 in achieving a high mean SR (Table 5.4) Furthermore, such observations did not result in a low MY mean SR value for method 1 when compared to MD or OR. Indeed, the mean SR for MY method 1 (0.78) was the same as what was achieved by the highest mean SR (method 4) for MD, and was higher than any of

the mean SR results for OR.

For OR, the random samples of the data sets to get methods 1 and 4 started, had a different result, with all but one data sheet having the lowest possible value, and 5 out of 16 instances having the highest value. In general, the random samples gave a good representation of all OR values, which explained why 51% and 49% of the thresholds were higher and lower than the true threshold, respectively. This aided method 1 in obtaining the second highest mean SR for OR.

For all traits (MD, MY and OR), the findings show how the use of random sampling can alter the performance of method 1 (and 4 to a lesser extent). Both method 1 and 4 were inconsistent across the different years and farms, with the greatest difference in SR between the years/farms for method 1 being some 27%, 16% and 34% for MD, MY and OR, respectively. For method 4, the greatest differences were lower, at 12%, 3% and 23% for MD, MY and OR, respectively. Clearly, the updating of the threshold as each value is entered lessened the inconsistency in method 4's performance. For method 1, the least inconsistency was observed for MY. This could be due to the nature of the MY data. The MY coefficient of variations were within the acknowledged range of 20-25% (Mead *et al*, 1993; Morris, 1999) and this, combined with larger data sets (section 3.1.) and a greater range of values, could have provided more reliable samples.

5.4.3. Effects of Historical Data on the Success Rate of Methods 2 and 3

The ranking of the methods was inconsistent across the different years/farms. The three main reasons for this were: method 1 starting random sample (section 5.4.2.), the data set coefficient of variations (sections 5.4.1.1 and 5.4.1.2) and the differences between the data set and historical means and standard deviations.

5.4.3.1. Muscle Depth

With an exception to the years 1991 and 1994, method 2 had the lowest SR as a result of conflicting TN and TS results. The years 1992 and 1993 clearly had higher means

and an upper range of values in their data sets than 1991 and 1994 (Table 3.1.) This resulted, for 1992 and 1993, in the historical threshold values being lower than the true data set threshold; meaning that method 2 was more likely to over select.

For the years 1991 and 1994, the historical thresholds were similar, across all % to Selects, to the true thresholds calculated by method 3, using the actual data sets. In those instances where the historical mean and standard deviation were higher than the true threshold, it resulted in the initial threshold values for method 3 being high. Once the true data set records were used in the threshold calculations, the threshold started to decrease in value. However, it did not necessarily decrease sufficiently enough to enable a good SR to be sought for the particular MD value that was being referenced. This showed the effect of using historical data to get the method started, for the next threshold value might have been low enough for some MDs to be selected, but the MD being referenced was of a high value. Inspection of the random sorting for each of the data sheets, for the differing years, indicated a good sort of the data. In these instances, the random sort would not have had a detrimental effect on the methods (Appendix 6).

5.4.3.2. Milk Yield

The lower results of MY, compared to MD, for method 2 were due to the differences between the data set and historical thresholds of each MY data set. The average difference between the data set true thresholds and the historical threshold for MD was only 6%, while for MY the thresholds differed on average by 15.5%.

For three of the farms (A, B and C), the historical threshold at all % to Selects was lower than the true threshold. These threshold values were low enough to cause the method to over select to the extent that poor SR resulted. Of all the results obtained for MY method 2, only 1 instance of a SR of 1.00 was achieved. In contrast, for farm D, at all % to Selects, the historical threshold was higher than the true threshold value. Indeed, at 5 % to Select, the historical threshold was 54.5% greater than the data set mean and 18% greater than the true threshold value. This high percentage for farm D, and the lower values for the other farms, is reflected in the results, with method 2 only

achieving a mean SR of 0.19.

The most evident finding for effect of farm was for farm D, where the historical mean was considerably higher, by some 11%, than that of the true data set. This resulted in a poor SR for method 2 (0.19) because the method under selected. However, this did not negatively affect method 3, which achieved a mean SR of 0.81.

5.4.3.3. Ovulation Rate

The above findings for MD and MY, concerning the differences between the true and historical thresholds, differ to those for OR. Unlike MD and MY, as detailed in section 5.4.1.2., method 2 achieved the highest mean SR out of all the methods. Examination of the historical threshold values at each % to Select for each year showed that where a SR of 1.00 was achieved, the historical threshold was less than one whole number below the actual number of records which should be selected (TN). With the OR values being whole numbers, it was not possible for the method to over select when the historical threshold was suitably matched to the data set in question.

Of the four years, only for 1989 did the SR prove to be poor for method 2, with the method having the lowest mean SR. This was due to the historical data being too high to select many of the records. The mean SR over the % to Selects for method 2, 1989, was only 0.32. In contrast, for 1988, the SR was the highest mean SR, with method 2 gaining the second highest mean SR for both 1991 and 1992. Indeed, for 5, 15 and 45 % to Select, method 2 achieved a mean SR of 1.00 for the year 1988. These results were due to the historical data being very close to that of the actual data set at these % to Selects. It was the significantly higher result of method 2, compared to all other methods, for the year 1988, that resulted in the overall mean SR being some 9% better than the next best method (method 1).

For all traits (MD, MY and OR), the findings show how using historical data hindered the calculation of a fair threshold value. While the historical data was consistent throughout, the fluctuations in the year/farm data identified the importance of using historical records that were closely related to the flock/herd in question in order for method 2 (and 3 to a lesser extent) to perform consistently.

5.4.4. Effects of % to Select on SR

There were clear differences to be seen with the interactions of % to Select x Year/Farm. It would be expected that the higher the % to Select, the better the SR. This was the case for the years 1992, 1993, 1994 (MD), farms A, D (MY), and 1988 (OR), where these years/farms showed better SR results at 45 % to Select. For MD, this was not the case for the year 1991, where the better SR results, by far, were achieved at 15 % to Select (method 2). Due to the low variability of the MD data and the historical threshold being too high, method 2 was unable to correctly select a large proportion of the correct data at higher % to selects. However, method 2 succeeded in the 1991 data set due to the historical mean and standard deviation being very similar to those of the actual data set. In a similar fashion, SR results for farms B and C (MY) and years 1991 and 1992 (OR) were better at 25 % to Select, and 1989 (OR) at 5 % to Select due to the true threshold value being nearer the correct number of animals to be selected (TN). The findings for MD would indicate that a % to Select of 45 could provide the best SR results, while for MY and OR, in 50% of cases, the % to Select could be ≤ 25 .

5.4.5. Chapter Conclusions

In general, the results were as expected, particularly so for MD and MY. It was expected that methods 3 and 4 would perform better than methods 1 and 2. For MD and MY, the procedure of updating the threshold value as each trait value was recorded proved effective in obtaining more accuracy, and hence higher mean SRs than when not updating (Table 5.10). For both MD and MY, method 4 achieved the highest mean SR, and this was a result of both the use of a sample of the data set to initiate the method and the updating of the threshold values. Method 3 results showed that by updating the threshold values, the use of historical data can be used to obtain a high SR within 3% and 4% of the results obtained for method 4 for MD and MY, respectively.

For OR, the high mean SR result (0.73), compared to 0.62 and 0.60 for MD and MY, respectively, for method 2 was a result of the historical data providing threshold values over the range of % to Selects which were more accurately matched to the actual data set in question. The overall SR mean of 0.73 was boosted by 35% of SRs being 1.00,

and this itself was helped by OR values being whole numbers (section 5.4.2.). However, an element of caution should be given to these results. While these results show that the historical data used was appropriate for an overall high mean SR, where the historical data was not appropriate for a particular year, the results were considerably poorer (section 5.4.3.3.). For OR, method 1 could be used with more accuracy than methods 3 and 4, if the historical data obtained for method 2 was inappropriate. The skewed nature of the OR distribution affected the calculated thresholds for methods 3 and 4, causing the methods to fluctuate considerably; resulting in SR values of 1.00 being uncommon. Similarly, method 1 could be used with more accuracy than method 2 for MD and MY if a drop in SR of 15% and 8% for MD and MY, respectively, was acceptable (Table 5.10).

Table 5.10 summarises the mean SR results for MD, MY and OR across the four methods. Two further areas of investigations have resulted from the findings of this chapter.

1. The historical mean and standard deviation values clearly had an affect on the results. By exchanging the values that were used for this chapter, with a mean and standard deviation that was based on the minimum and maximum values of the actual data set in question, it would be possible to see if method 2 (and method 3 less so) could improve in its results. This option would be a fairly quick procedure in practice. This investigation is reported upon in Chapter 6.
2. Using the Anderson Darling Normality Test within Minitab version 10Xtra, it was found that the raw OR values were not normally distributed (Appendix 4). Two possible transformations of the raw data, square root and log(10) have been identified and this investigation is reported upon in Chapter 7.

Furthermore, as detailed within section 2.2 of the literature review, there are a number of environmental factors that can affect an animal's performance. Chapter 8 explores the effects of applying correction factors to MD and MY for dam-age, ram-age and rearing type (MD), and lactation number and breed type (MY).

Table 5.10. A Summary of the Success Rates for Muscle Depth, Milk Yield and Ovulation Rate over the Four Methods

Methods		Muscle Depth	Milk Yield	Ovulation Rate
1	T	0.63	0.78	0.64
2	T	0.62	0.60	0.73
3	T	0.75	0.82	0.63
4	T	0.78	0.86	0.60

CHAPTER 6 A REFINEMENT OF METHODS 2 AND 3 IN THE COMPARISON OF FOUR METHODS TO SELECT ANIMALS WHICH ARE NOT UNIQUELY IDENTIFIABLY TAGGED

6.1. INTRODUCTION

In the previous chapter, methods 2 and 3 used historical data (section 3.1.1.1, 3.1.2.1 and 3.1.3.1) in order to calculate the method thresholds. For method 2, the threshold value calculated using the historical data, was used. Method 3 used the threshold value as calculated for method 2 in order to get the method started, and then updated the threshold value as each animal was recorded. The results of chapter 5 identified an effect of historical values which was not unexpected. The historical values used were based on previous years' records. An alternative to the use of historical data would be the calculation of means and standard deviations, and hence threshold values, based on the minimum and maximum values of the actual data sets in use. In practice, a farmer could select animals likely to have the minimum and maximum trait value.

The use of minimum and maximum values can be justified when the characteristics of the normal distribution curve are examined. Using the characteristics of the normal distribution curve, it is possible to obtain the minimum and maximum data set values. A normal distribution is symmetrical and has the same relative proportions of scores falling between particular values of the numbers involved (Clegg, 1988).

Statistically, the mean \pm 3 standard deviations (SD) contains 99.87% of the data set values. Therefore, both minimum and maximum values can be estimated from a knowledge of the values of the data in the areas under the normal curve which are greater than 3 SD, i.e., the top or low 0.13% (Clegg, 1988). Conversely, SD can be estimated if the minimum and maximum values are known.

The aim of this chapter was to investigate the effects of changing from the historical data used in Chapter 5, to using minimum and maximum values of the data set in question for the calculation of the mean and standard deviations for methods 2 and 3. The discussion section will compare the methods, with the emphasis being on the comparison of the results for methods 2 and 3 from both this chapter and chapter 5.

6.2. MATERIALS AND METHODS

All materials and methods were the same as those detailed in chapter 3 and section 5.2 of chapter 5, with the exception of the origin of values for the calculation of the historical mean, standard deviation and hence threshold value used for methods 2 and 3 (refer to Appendix 1). This chapter used the minimum and maximum values of the specific trait data set in question. Methods 2 and 3 have been denoted as 2M and 3M, to distinguish them as modified (M) versions to those of chapter 5.

6.2.1. Computing Strategies

The minimum and maximum values were stored in sheet 1 within cells J20 and J21, and used the formulae: =MIN(H3:Hx) and =MAX(H3:Hx), where x was the final animal row of data. In order to calculate the mean and standard deviation, the following formulae were used within cells M20 and M21: =(J20+J21)/2 and =(J21-J20)/6, respectively. The threshold value was calculated in the same manner as that detailed in chapter 3.

6.2.2. Data Set for Comparison of Methods Across Chapter 5 and Current Chapter

For the purposes of comparing the methods in chapter 5 with the current chapter, the data sets for statistical analysis contained all results for chapter 5 in addition to the results for methods 2M and 3M for the current chapter. All statistical models for the comparison of methods are detailed in section 3.6 of chapter 3.

6.3. RESULTS

The success rate (SR), proportion of the target number identified by the program (C/TN) and proportion of those selected that were correct (C/TS) were tested for normal distribution using the Anderson-Darling test (section 3.7). None of the variables had a normal distribution ($P < 0.05$) (Appendix 4). Therefore, descriptive results are shown for transformed (T) data. The data was transformed using arcsine (section 3.7). Any marked differences between un-transformed (UT) and T data are detailed in the results section. Both UT and T data are displayed within the tables but the graphs display the T results only. Further tabulated results are presented in

Appendix 5.

All results are rounded up to 2 decimal places. This can result in slight discrepancies in the T data (see Section 5.3).

6.3.1. Muscle Depth

6.3.1.1. Success Rate

Significant effects ($P < 0.05$) of Method and Year were observed. Significant effects ($P < 0.05$) of all possible interactions were observed, with the exception of the interaction of % to Select x Method. The results are shown in Table 6.1, and the range of SR values is shown in Figure 6.1.

Comparing methods for chapters 5 and 6, method 3M's (0.68) mean Success Rate (SR) ranked third below methods 3 and 4, while method 2M (0.63) ranked joint fourth with method 1 ($P < 0.05$). Method 2M differed significantly from method 4 ($P < 0.05$). Methods 2M (0.17) and 3M (0.14) had the least SR within the range of 0.90 to 1.00.

Method 2M gave the highest SR for the year 1991 (0.76) ($P < 0.05$) while method 3M did not have the highest SR for any of the years. Neither method 2M or 3M achieved the highest SR at any % to Select. A % to Select of 15 gave the highest SR for the years 1991 (0.85) and 1993 (0.75), while % to Selects of 5 and 25 gave the highest SR for the years 1992 (0.99) and 1994 (0.81), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were higher than UT. For UT, significant differences were observed for both % to Select and the interactions of % to Select x Method ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the refinement of the methods did not result in either method 2 and 2M or 3 and 3M significantly differing in SR ($P > 0.05$).

Figure 6.1. Success Rate for Methods 2M and 3M for Muscle Depth

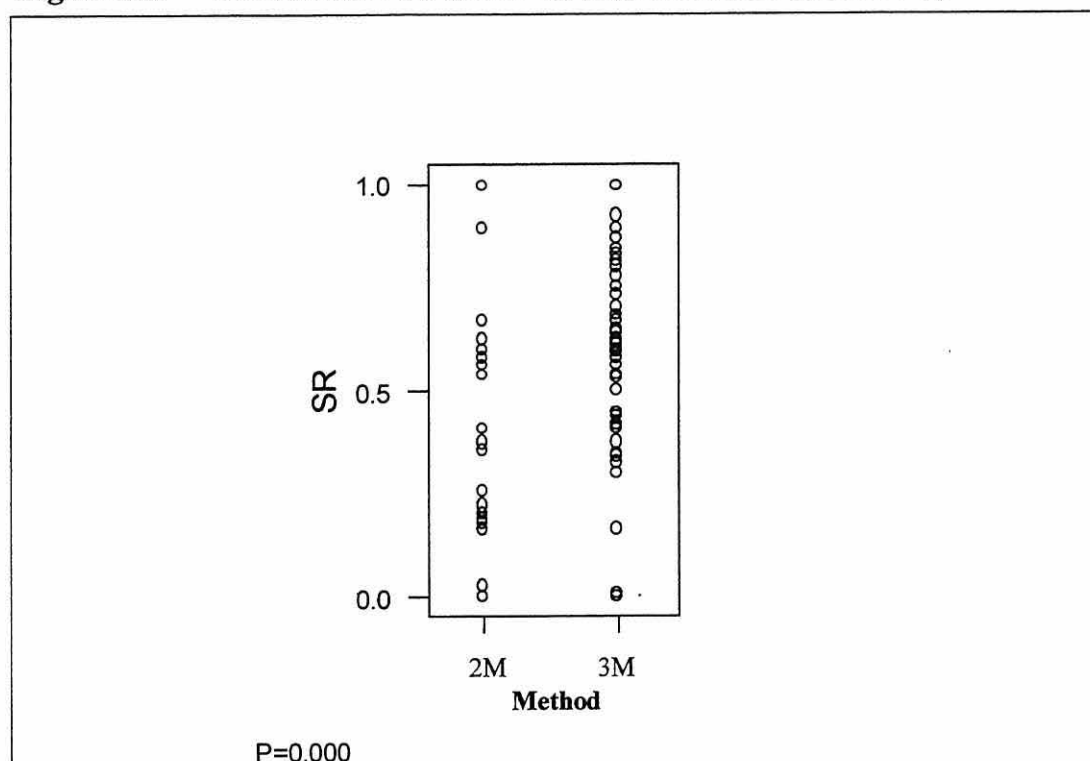


Table 6.1. Success Rate for Methods 2M and 3M for Muscle Depth

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	35.74 (4.14)	45.26 (3.80)	43.12 (3.13)	37.35 (4.03)	32.72 (0.73)	38.76 (3.37)
T (B)	0.58	0.71	0.68	0.61	0.54	0.63
UT	0.48 (0.04)	0.62 (0.04)	0.62 (0.03)	0.50 (0.04)	0.53 (0.01)	0.55 (0.03)
3M T (A)	47.23 (4.59)	44.53 (3.55)	40.80 (1.65)	34.99 (1.54)	46.72 (2.08)	42.85 (2.92)
T (B)	0.73	0.70	0.65	0.57	0.73	0.68
UT	0.59 (0.05)	0.62 (0.04)	0.64 (0.02)	0.56 (0.02)	0.70 (0.02)	0.62 (0.03)
Mean T (B) SR results for Methods 1, 2, 3 and 4 were 0.63, 0.62, 0.75 and 0.78, respectively (Table 5.1)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 8.34, 9.91 and 25.73, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.10 and 0.26, respectively.

6.3.1.2. *Proportion of the Target Number Identified by the Program (C/TN)*

Significant effects ($P < 0.05$) of Method and % to Select were observed. Significant effects ($P < 0.05$) of all possible interactions were observed, with the exception of the interaction of % to Select x Method, and % to Select x Method x Year. The results are shown in Table 6.2, and the range of C/TN values is shown in Figure 6.2.

Comparing methods for chapters 5 and 6, methods 2M and 3M both achieved a mean C/TN of 0.73, and ranked joint fifth ($P < 0.05$). Methods 1 and 2M, and 1 and 3M differed significantly from each other ($P < 0.05$). Method 2M had the same proportion (0.32) of C/TN within the range of 0.90 to 1.00 as method 4, while method 3M had 0.24.

Method 2M (0.93) gave the highest C/TN for the year 1991 while method 3M did not have the highest C/TN for any of the years. Furthermore, a % to Select of 5 gave the highest C/TN for the years 1992 (1.00) and 1993 (0.91). A % to Select of 15 gave the highest C/TN for the years 1991 (0.94) and 1994 (0.89), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were higher than UT. For UT, significant differences were not observed for either % to Select or Method ($P > 0.05$). Furthermore, for UT, a % to Select of 45 gave the highest C/TN for the year 1994 ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the refinement of the methods resulted in method 2M mean C/TN significantly decreasing by 22% when compared to method 2 ($P < 0.05$).

Figure 6.2. C/TN for Methods 2M and 3M for Muscle Depth

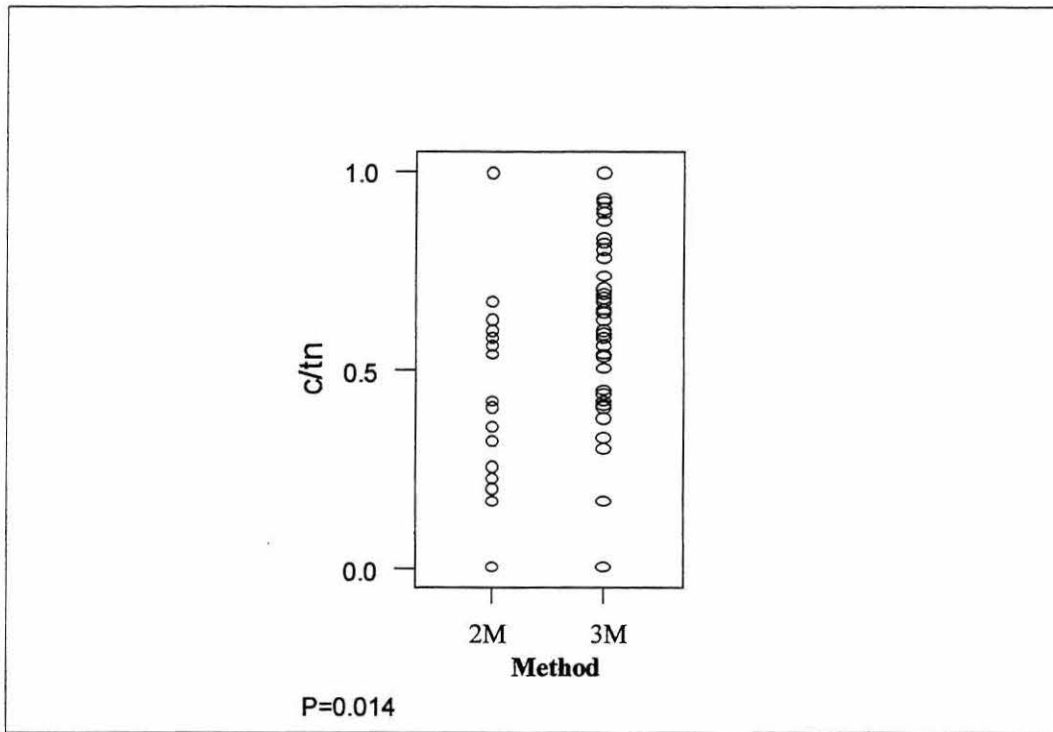


Table 6.2. C/TN for Methods 2M and 3M for Muscle Depth

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M	T (A)	69.34 (4.63)	52.54 (4.47)	44.06 (2.99)	37.87 (3.98)	32.84 (0.49)	47.33 (3.90)
	T (B)	0.94	0.79	0.69	0.61	0.54	0.73
	UT	0.78 (0.05)	0.65 (0.04)	0.63 (0.03)	0.51 (0.04)	0.54 (0.01)	0.62 (0.04)
3M	T (A)	56.13 (5.03)	49.80 (3.92)	42.97 (1.67)	36.07 (1.48)	48.35 (1.95)	46.66 (3.18)
	T (B)	0.83	0.76	0.68	0.59	0.75	0.73
	UT	0.66 (0.05)	0.65 (0.04)	0.66 (0.02)	0.58 (0.02)	0.72 (0.02)	0.65 (0.03)
Mean T (B) C/TN results for Methods 1, 2, 3 and 4 were 0.85, 0.95, 0.81 and 0.79, respectively (Table 5.2)							

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 9.89, 11.76 and 30.53, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.10, 0.11 and 0.30, respectively.

6.3.1.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method, Method x Year and % to Select x Method x Year. The results are shown in Table 6.3, and the range of C/TS values is shown in Figure 6.3.

Comparing methods for chapters 5 and 6, methods 2M (0.98) and 3M (0.98) mean C/TS ranked joint second with method 3, below method 4 ($P<0.05$). Neither methods 2M and 3M, nor 3M and 4 differed significantly from each other ($P>0.05$). Methods 2M and 3M had 0.79 and 0.85, respectively, of C/TS within the range of 0.90 to 1.00, below method 4 (0.96).

Furthermore, a % to Select of 35 gave the highest C/TS for the years 1992 (1.00) and 1993 (1.00). For 1992, 45 % to Select had the same result as 35 % to Select. A % to Select of 25 gave the highest C/TS for the year 1991 (1.00), while a % to Select of 45 gave the highest C/TS for the year 1994 (0.99) ($P<0.05$).

There weren't any marked differences between UT and T data (Appendix 5). When compared to the results of chapter 5, the refinement of the methods resulted in method 2M mean C/TS significantly increasing by 19% when compared to method 2 ($P<0.05$).

Figure 6.3. C/TS for Methods 2M and 3M for Muscle Depth

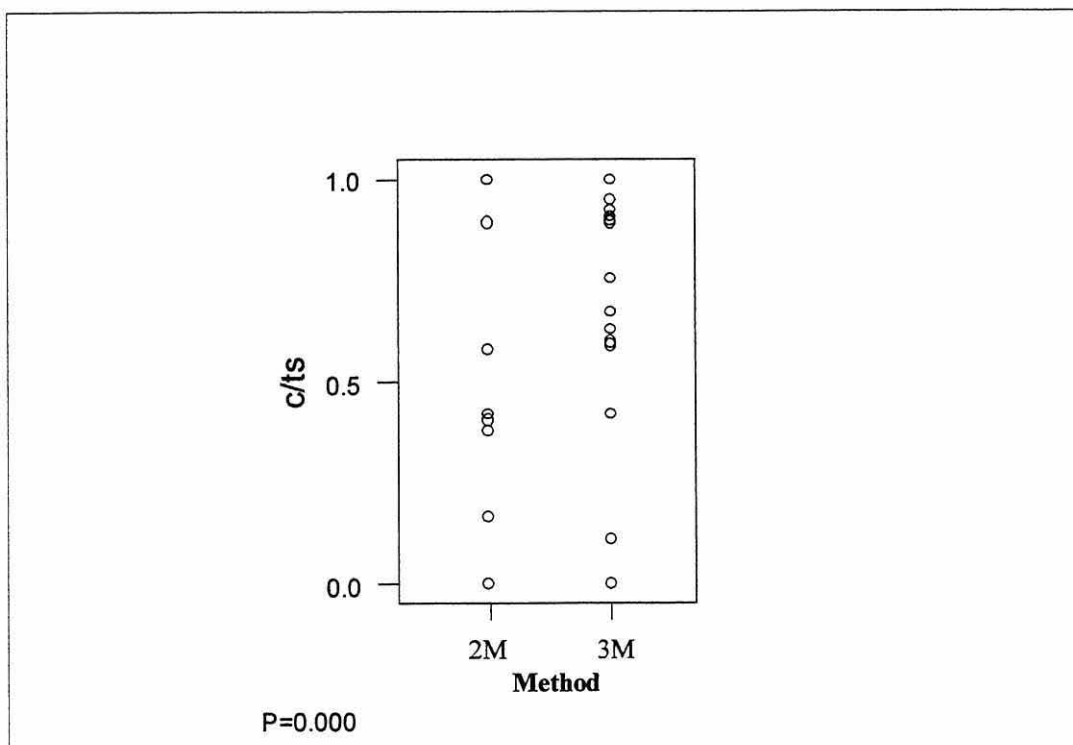


Table 6.3. C/TS for Methods 2M and 3M for Muscle Depth

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M	T (A)	50.78 (4.52)	78.21 (2.73)	85.93 (2.04)	86.59 (1.70)	86.59 (1.70)	77.62 (3.19)
	T (B)	0.77	0.98	1.00	1.00	1.00	0.98
	UT	0.63 (0.04)	0.92 (0.03)	0.96 (0.02)	0.97 (0.01)	0.97 (0.01)	0.89 (0.03)
3M	T (A)	66.85 (4.18)	80.08 (2.97)	83.04 (2.17)	85.29 (1.72)	83.88 (1.85)	79.83 (2.79)
	T (B)	0.92	0.98	0.99	1.00	0.99	0.98
	UT	0.79 (0.04)	0.92 (0.03)	0.95 (0.02)	0.97 (0.01)	0.96 (0.01)	0.92 (0.03)
Mean T (B) C/TS results for Methods 1, 2, 3 and 4 were 0.90, 0.79, 0.98 and 1.00, respectively (Table 5.3)							

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 8.40, 9.99 and 25.92, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

6.3.2. Milk Yield

6.3.2.1. Success Rate

Significant effects ($P < 0.05$) of Method and % to Select were observed. Significant effects ($P < 0.05$) of all possible interactions were observed. The results are shown in Table 6.4, and the range of SR values is shown in Figure 6.4.

Comparing methods for chapters 5 and 6, method 3M's (0.85) mean SR ranked second below method 4, while method 2M (0.72) ranked fifth ($P < 0.05$). Methods 3M and 4 did not differ significantly from each other ($P > 0.05$). Method 3M had a higher proportion (0.40) of SR within the range of 0.90 and 1.00, while method 2M had the least (0.05).

Method 3M gave the highest SR for the farms A (0.87) and D (0.86) while method 2M did not have the highest SR for any of the farms. Method 3M gave the highest SR for % to Selects 25 (0.92), 35 (0.90) and 45 (0.91) while method 2M did not have the highest SR for any of the % to Selects ($P < 0.05$).

A % to Select of 45 gave the highest SRs for the farms A (0.84) and D (0.93), while % to Selects of 15 and 25 gave the highest SRs for the farms B (0.88) and C (0.90), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were higher than UT. For UT, Method 1 gave the highest mean SR at a % to Select of 5 ($P < 0.05$) (Appendix 5).

When compared to chapter 5 results, the refinement of the methods resulted in method 2M mean SR significantly increasing by 12% when compared to method 2 ($P < 0.05$).

Figure 6.4. Success Rate for Methods 2M and 3M for Milk Yield

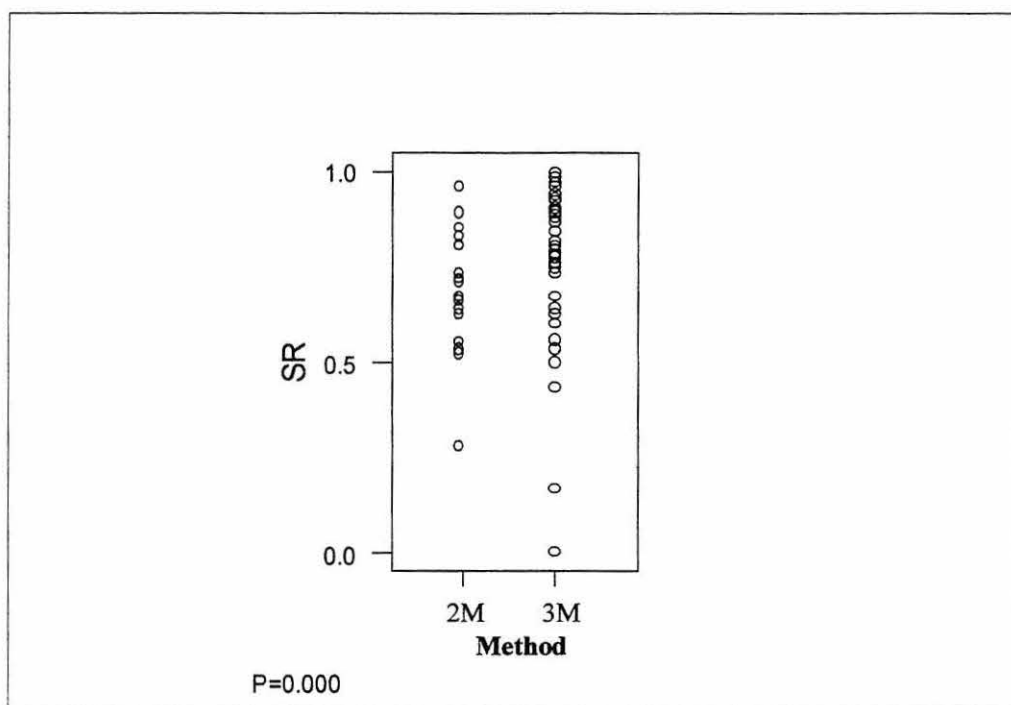


Table 6.4. Success Rate for Methods 2M and 3M for Milk Yield

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	39.54 (2.09)	46.58 (1.44)	45.26 (0.65)	48.16 (1.05)	52.64 (1.94)	46.44 (1.59)
T (B)	0.64	0.73	0.71	0.74	0.79	0.72
UT	0.61 (0.03)	0.71 (0.02)	0.71 (0.01)	0.74 (0.01)	0.77 (0.02)	0.71 (0.02)
3M T (A)	35.96 (2.34)	55.83 (0.94)	67.66 (1.39)	64.68 (0.97)	65.23 (0.99)	57.87 (2.02)
T (B)	0.59	0.83	0.92	0.90	0.91	0.85
UT	0.55 (0.03)	0.82 (0.01)	0.91 (0.01)	0.90 (0.01)	0.90 (0.01)	0.82 (0.02)
Mean T (B) SR results for Methods 1, 2, 3 and 4 were 0.78, 0.60, 0.82 and 0.86, respectively (Table 5.4)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 4.32, 5.14 and 13.34, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.04, 0.05 and 0.14, respectively.

6.3.2.2. *Proportion of the Target Number Identified by the Program (C/TN)*

Significant effects ($P < 0.05$) of Method, % to Select and Farm and their interactions were observed, with the exception of the interactions of % to Select x Method and % to Select x Method x Farm. The results are shown in Table 6.5, and the range of C/TN values is shown in Figure 6.5.

Comparing methods for chapters 5 and 6, methods 3M (0.93) and 2M (0.92) mean C/TN ranked equal first and second, respectively ($P < 0.05$). Neither methods 2M and 3M, 2M and 4, nor 3M and 4 differed significantly from each other ($P > 0.05$). Method 3M had a higher proportion (0.67) of C/TN within the range of 0.90 to 1.00 while method 2M had fewer at 0.50.

Overall, method 3M gave the highest C/TN ($A = 0.91$, $B = 0.97$) but it was significantly lower ($P < 0.05$) than method 2M for farms C (1.00) and D (1.00), respectively.

A % to Select of 45 gave the highest C/TN for the farm D (0.97). A % to Select of 5 gave the highest C/TN for farm A (0.87) and 15 % to Select gave the highest C/TN for the farms B (0.97) and C (0.99), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were higher than UT. For UT, significant differences were observed for % to Select x Method ($P > 0.05$). For UT, a % to Select of 45 gave the highest mean C/TN for farm A ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the refinement of the methods resulted in method 3M mean C/TN significantly increasing by 4% when compared to method 3 ($P < 0.05$).

Table 6.5. C/TN for Methods 2M and 3M for Milk Yield

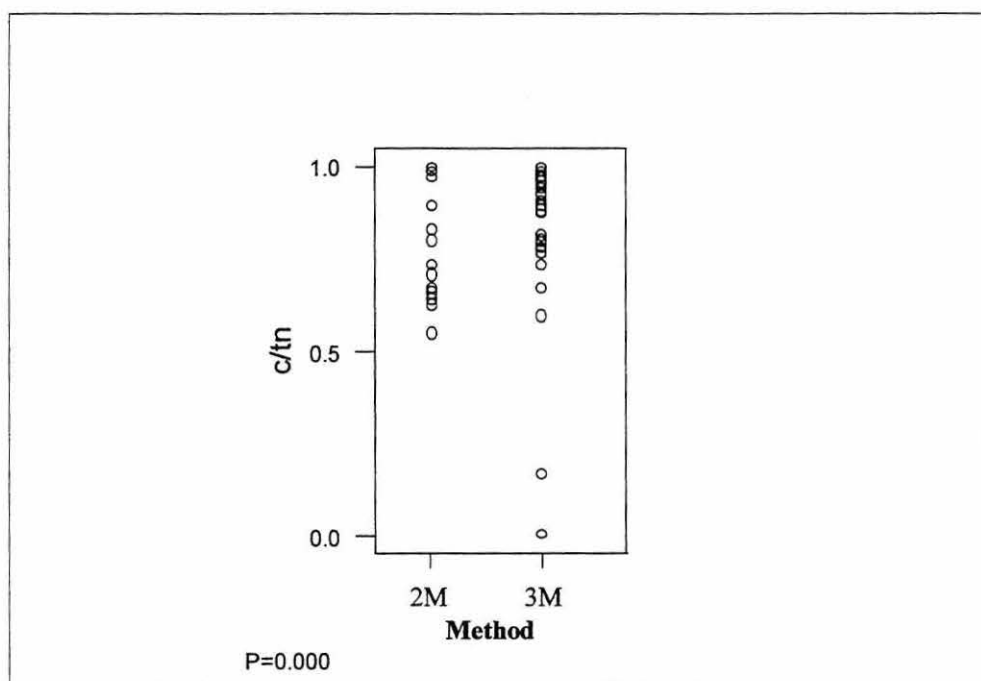
% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	72.31 (2.29)	72.44 (2.38)	65.47 (3.17)	61.57 (2.84)	61.78 (3.00)	66.71 (2.75)
T (B)	0.95	0.95	0.91	0.88	0.88	0.92
UT	0.91 (0.01)	0.90 (0.01)	0.83 (0.02)	0.81 (0.02)	0.81 (0.02)	0.85 (0.02)
3M T (A)	62.45 (3.93)	70.13 (1.63)	73.94 (1.62)	68.90 (1.44)	68.60 (1.37)	68.80 (2.21)
T (B)	0.89	0.94	0.96	0.93	0.93	0.93
UT	0.77 (0.04)	0.92 (0.01)	0.94 (0.01)	0.91 (0.01)	0.91 (0.01)	0.89 (0.02)
Mean T (B) C/TN results for Methods 1, 2, 3 and 4 were 0.84, 0.93, 0.89 and 0.91, respectively (Table 5.5)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.76, 6.85 and 17.78, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.06 and 0.16, respectively.

Figure 6.5. C/TN for Methods 2M and 3M for Milk Yield



6.3.2.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Farm and their interactions were observed, with the exception of the interactions of % to Select x Method. The results are shown in Table 6.6, and the range of C/TS values is shown in Figure 6.6.

Comparing methods for chapters 5 and 6, methods 3M (0.96) and 2M (0.93) mean C/TS ranked third and fourth, respectively. Methods 1 and 4 (0.99) jointly ranked first ($P<0.05$). Method 3M had a proportion of 0.72 of C/TS within the range of 0.90 and 1.00, while method 2M had fewer at 0.55.

Method 2M gave a C/TS of 1.00 for farms A and B. Method 3M did not have the highest C/TS for any of the farms ($P<0.05$). A % to Select of 45 gave the highest C/TS for the farms C (0.99) and D (0.99), while % to Selects of 25 and 35 gave the highest C/TS for the farms B (1.00) and A (1.00), respectively ($P<0.05$).

Marked differences between UT and T data were seen. T C/TS results were higher than UT. For UT, significant differences were not observed for % to Select x Method ($P>0.05$) (Appendix 5).

When compared to the results of chapter 5, the refinement of the methods resulted in method 2M mean C/TS significantly increasing by 14% when compared to method 2 ($P<0.05$).

Figure 6.6. C/TS for Methods 2M and 3M for Milk Yield

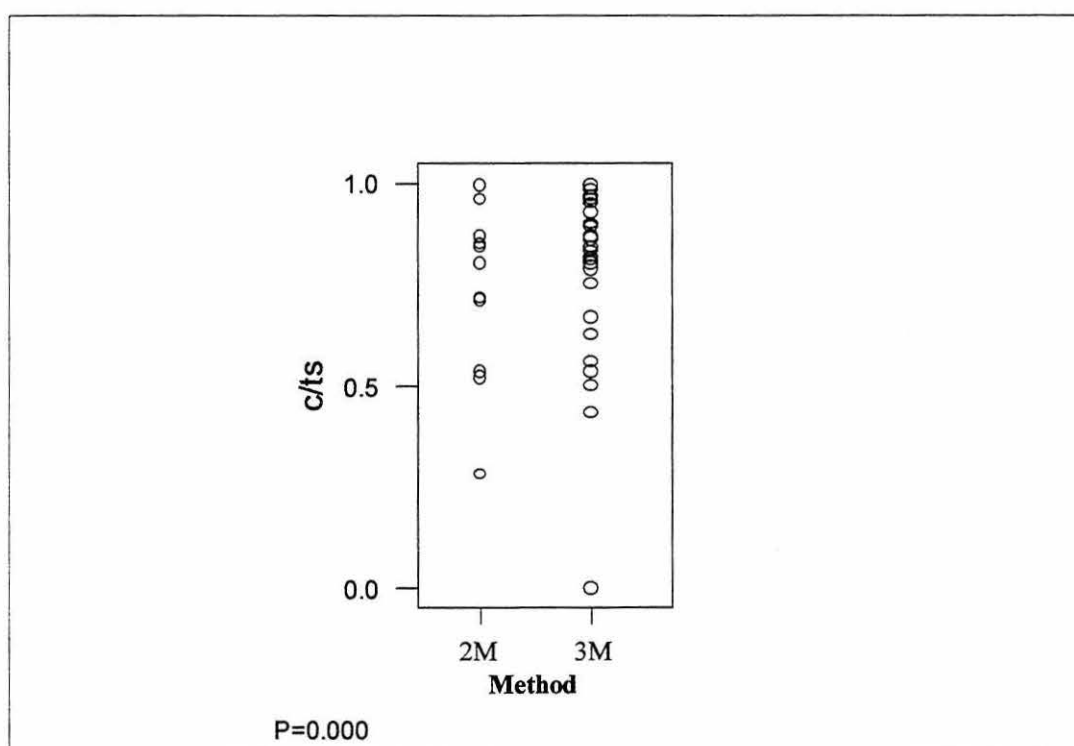


Table 6.6. C/TS for Methods 2M and 3M for Milk Yield

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	57.24 (4.30)	64.14 (3.40)	69.80 (2.63)	73.84 (2.09)	78.55 (1.60)	68.71 (3.03)
T (B)	0.84	0.90	0.94	0.96	0.98	0.93
UT	0.70 (0.04)	0.81 (0.03)	0.88 (0.02)	0.92 (0.01)	0.96 (0.01)	0.85 (0.02)
3M T (A)	54.95 (3.80)	70.49 (2.27)	82.24 (1.54)	81.89 (1.08)	82.07 (0.94)	74.33 (2.52)
T (B)	0.82	0.94	0.99	0.99	0.99	0.96
UT	0.71 (0.04)	0.90 (0.01)	0.97 (0.01)	0.98 (0.00)	0.98 (0.00)	0.91 (0.02)
Mean T (B) C/TS results for Methods 1, 2, 3 and 4 were 0.99, 0.79, 0.98 and 0.99, respectively (Table 5.6)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 3.82, 4.54 and 11.80, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.03, 0.04 and 0.09, respectively.

6.3.3. Ovulation Rates

6.3.3.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 6.7, and the range of SR values is shown in Figure 6.7.

Comparing methods for chapters 5 and 6 methods 3M (0.59) and 2M (0.24) mean SR ranked fifth and sixth, respectively ($P < 0.05$). Methods 1 and 2M, 2M and 3M, and 2M and 4 differed significantly from each other ($P < 0.05$). Method 3M had a proportion of 0.09 of SR within the range of 0.90 to 1.00, while method 2M had fewer at 0.05.

Method 3M gave the highest SR at 5 % to Select (0.79) and for the year 1989 (0.60), while method 2M did not have the highest SR for any of the % to Selects or years ($P < 0.05$). A % to Select of 5 gave the highest SR for the years 1989 (0.73) and 1992 (0.88), while % to Selects of 15 and 45 gave the highest SR for the years 1991 (0.63) and 1988 (0.59), respectively ($P < 0.05$).

T SR results were higher, except for method 3M, in comparison to UT. When compared to the results of chapter 5, the refinement of the methods resulted in method

2M mean SR significantly decreasing by 49% when compared to method 2 ($P < 0.05$).

Table 6.7. Success Rate for Methods 2M and 3M for Ovulation Rate

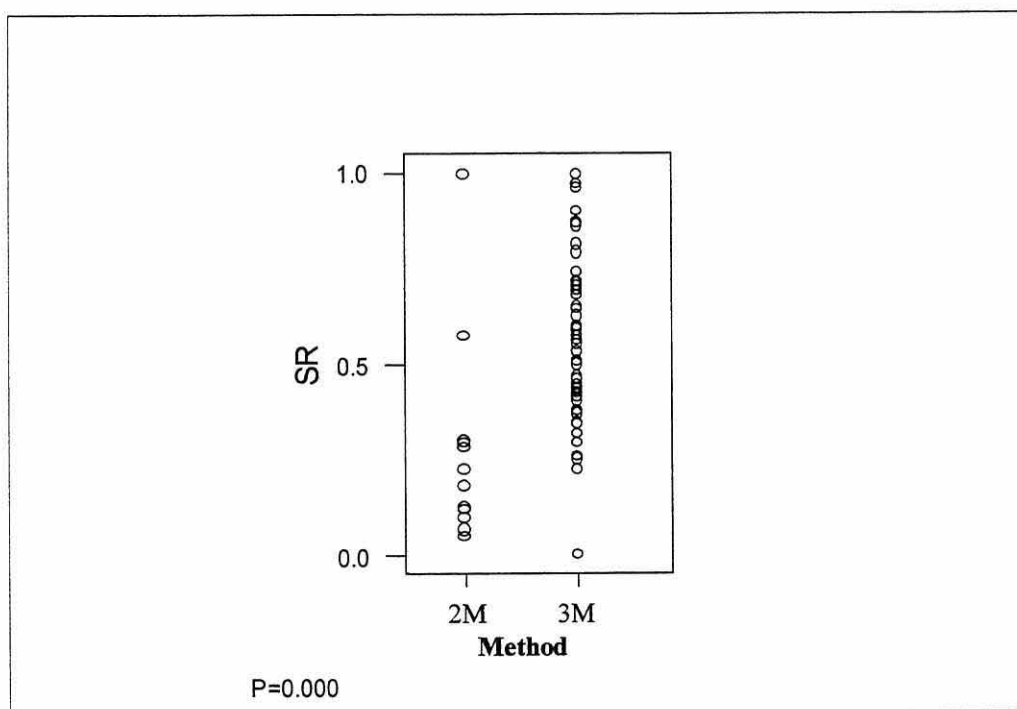
% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	39.54 (3.88)	10.99 (0.57)	8.28 (0.48)	6.34 (0.36)	5.75 (0.37)	14.18 (2.37)
T (B)	0.64	0.19	0.14	0.11	0.10	0.24
UT	0.54 (0.04)	0.19 (0.01)	0.14 (0.01)	0.11 (0.01)	0.10 (0.01)	0.22 (0.03)
3M T (A)	52.35 (3.45)	30.92 (1.96)	34.53 (2.47)	31.25 (1.40)	31.55 (1.05)	36.12 (2.41)
T (B)	0.79	0.51	0.57	0.52	0.52	0.59
UT	0.71 (0.03)	0.49 (0.03)	0.53 (0.03)	0.51 (0.02)	0.52 (0.01)	0.55 (0.03)
Mean T (B) SR results for Methods 1, 2, 3 and 4 were 0.64, 0.73, 0.63 and 0.60, respectively (Table 5.7)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across the years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.79, 9.26 and 24.04, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

Figure 6.7. Success Rate for Methods 2M and 3M for Ovulation Rate



6.3.3.2. Proportion of the Target Number Identified by the Program (C/TN)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method and Method x % to Select x Year. The results are shown in Table 6.8, and the range of

C/TN values is shown in Figure 6.8.

Comparing methods for chapters 5 and 6, methods 3M (0.61) and 2M (0.24) mean C/TN ranked fourth and fifth, respectively ($P < 0.05$). Methods 1 and 2M, 2M and 3M, and 3M and 4 differed significantly from each other ($P < 0.05$). Method 3M had a proportion of 0.11 of C/TN within the range of 0.90 to 1.00, while method 2M had fewer at 0.05.

Method 3M gave the highest C/TN for the year 1989 (0.62) while method 2M did not have the highest C/TN for any of the years ($P < 0.05$). A % to Select of 5 gave the highest C/TN for the years 1989 (0.75), 1991 (0.73) and 1992 (1.00), while % to Select of 45 gave the highest C/TN for the year 1988 (0.59) ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were higher than UT. For UT, methods 1 and 3M differed significantly from each other ($P < 0.05$). For UT, method 3M gave the highest mean C/TN for 1988 ($P < 0.05$) (Appendix 5). When compared to chapter 5 results, the refinement of the methods resulted in method 2M mean C/TN significantly decreasing by 49% when compared to method 2 ($P < 0.05$).

Figure 6.8. C/TN for Methods 2M and 3M for Ovulation Rate

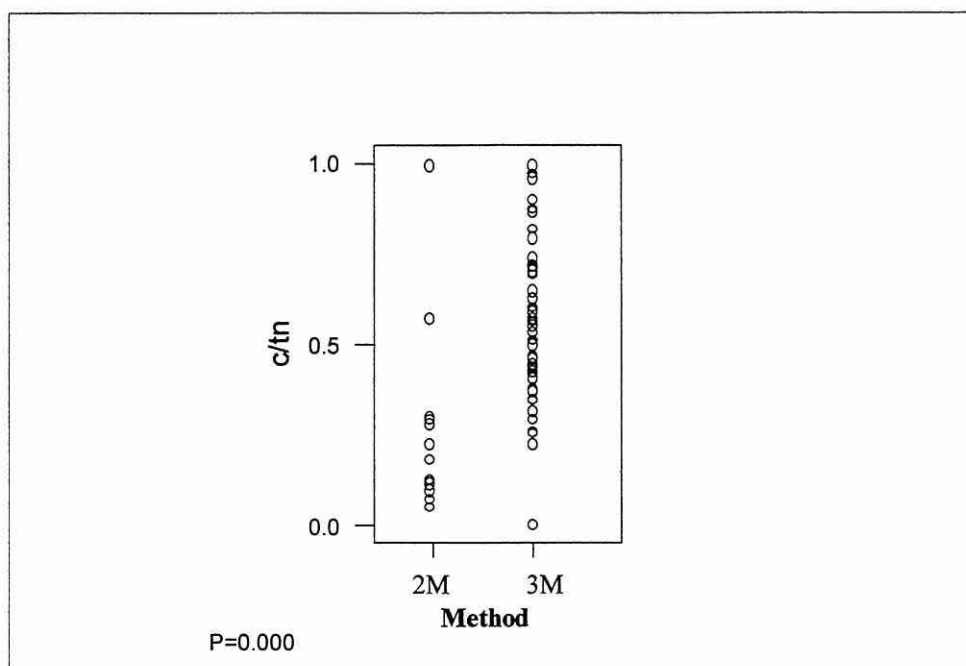


Table 6.8. C/TN for Methods 2M and 3M for Ovulation Rate

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	39.54 (3.88)	10.99 (0.57)	8.28 (0.48)	6.34 (0.36)	5.75 (0.37)	14.18 (2.37)
T (B)	0.64	0.19	0.14	0.11	0.10	0.24
UT	0.54 (0.04)	0.19 (0.01)	0.14 (0.01)	0.11 (0.01)	0.10 (0.01)	0.22 (0.03)
3M T (A)	58.35 (3.73)	30.92 (1.96)	34.53 (2.47)	31.25 (1.40)	31.55 (1.05)	37.32 (2.63)
T (B)	0.85	0.51	0.57	0.52	0.52	0.61
UT	0.75 (0.04)	0.49 (0.03)	0.53 (0.03)	0.51 (0.02)	0.52 (0.01)	0.56 (0.03)
Mean T (B) C/TN results for Methods 1, 2, 3 and 4 were 0.72, 0.73, 0.64 and 0.64, respectively (Table 5.8)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.65, 9.10 and 23.62, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.23, respectively.

6.3.3.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of % to Select x Year and Method x % to Select x Year. The results are shown in Table 6.9, and the range of C/TS values is shown in Figure 6.9.

Methods 2M (1.00) and 3M (1.00) mean C/TS ranked joint first with methods 2, 3 and 4 ($P < 0.05$). Methods 1 and 2M differed significantly from each other ($P < 0.05$). Method 2M had a higher proportion (1.00) of C/TS within the range of 0.90 to 1.00, while method 3M had fewer at 0.95.

The year 1988 C/TS results showed that all methods achieved a C/TS of 1.00 ($P < 0.05$). Methods 2M and 3M achieved a C/TS of 1.00 for all years and % to Selects, except for method 3M at 5 % to Select ($P < 0.05$). Furthermore, all methods at % to Selects of 25, 35 and 45 achieved a C/TS of 1.00.

There weren't any marked differences between UT and T data (Appendix 5). When compared to the results of chapter 5, the refinement of the methods did not result in either method 2 or 3 significantly differing in C/TS.

Figure 6.9. C/TS for Methods 2M and 3M for Ovulation Rate

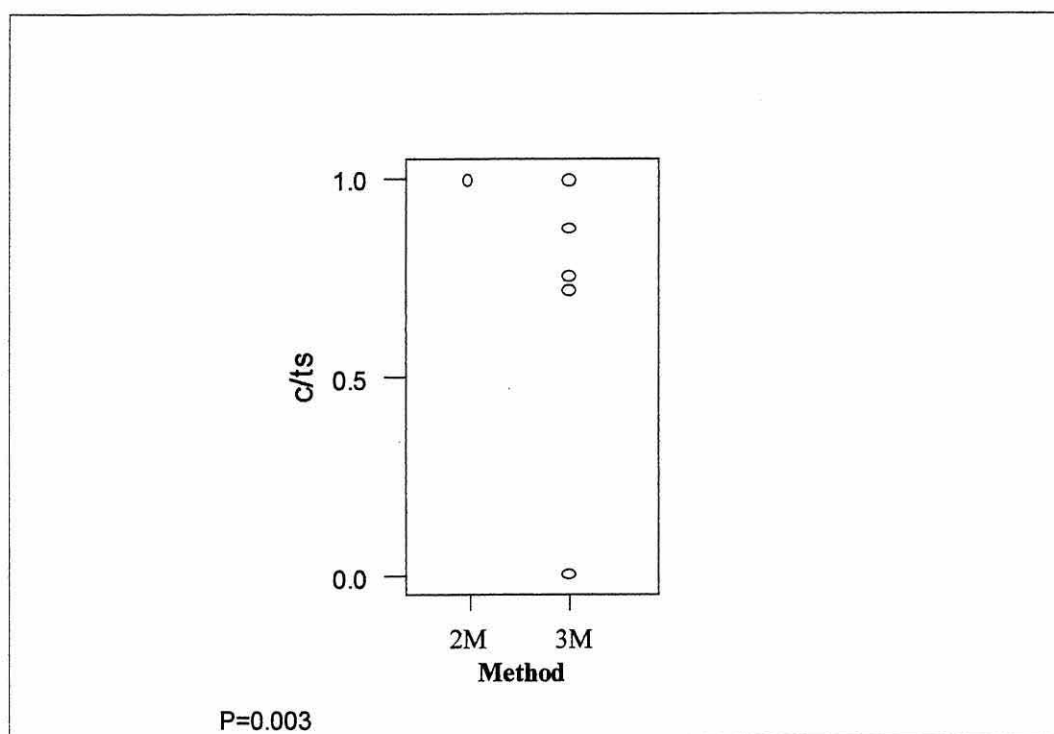


Table 6.9. C/TS for Methods 2M and 3M for Ovulation Rate

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
2M T (A)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)
T (B)	1.00	1.00	1.00	1.00	1.00	1.00
UT	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
3M T (A)	77.23 (3.22)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	87.45 (1.54)
T (B)	0.97	1.00	1.00	1.00	1.00	1.00
UT	0.90 (3.08)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.98 (0.01)
Mean T (B) C/TS results for Methods 1, 2, 3 and 4 were 0.99, 1.00, 1.00 and 1.00, respectively (Table 5.9)						

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 4.93, 5.86 and 15.22, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.05 and 0.14, respectively.

6.4. DISCUSSION

The purpose of this experiment was to investigate the effects of changing from using historical data, as used in Chapter 5, to using minimum and maximum values of the data set in question for the calculation of the mean and standard deviations for methods 2M and 3M.

6.4.1. Comparison of Methods 2M and 3M Verses Methods 2 and 3

For MD, a comparison of methods 2 and 3, and 2M and 3M showed no significant difference between the methods. The results for MD showed a slight improvement with method 2M improving on method 2 by 1%. The refinement of the historical data could have reduced the possible error attached to historical values used in chapter 5, in that it created threshold values that were based on the actual data sets in question. This created historical thresholds that were closer to the data set true threshold, and hence, the method was less likely to over or under select. When comparing the difference between the true and historical thresholds for chapter 5 (mean of 6%) and this chapter (mean of 2%), it was not surprising that method 2M achieved a better SR than method 2. This was particularly apparent for the years 1992 and 1993, as in general, due to their high mean and upper range of values relative to the chapter 5 historical threshold, the results for these years were poorer in chapter 5.

It was expected that any effect of Year/Farm x Method would have decreased due to the threshold values being based on the actual year/farm for each data set. This was not the case for MD or OR, which showed significant differences ($P < 0.05$) (ranging from 0.62 to 0.75 (MD); 0.43 to 0.61 (OR)) between the methods across the years. Examination of the data sets identified the reason as being the grouping of the data. For method 2M, while the years 1992 and 1993 (MD), and 1988 and 1992 (OR) had the same minimum and maximum trait data for the calculation of their respective threshold values, 1993 performed less well (0.62) than 1992 (0.75) and 1988 performed less well (0.43) than 1992 (0.61) for MD and OR, respectively. This was due to the higher number of values, for 1993, in the upper range of MD, and lower number of values, for 1988, in the upper range of OR, resulting in the methods over and under selecting, respectively.

Compared to the range of SR results for method 2, the refinement for MD showed a wider spread of values, with more SR values within the higher ranges (0.5 to 1.0) of SR. However, both method 2M and 3M results indicated that the proportion of values of SR of 1.00 were lower than for methods 2 and 3, by some 4 and 7%, respectively.

For MD, while method 3M performed better than methods 1 and 2M, its overall mean SR was negatively affected by the use of the minimum and maximum values of the data set, with a drop in mean SR by 7% when compared to method 3. This finding was most likely due to the lower coefficient of variation for each of the historical thresholds. Compared to chapter 5's historical threshold coefficient of variation (9.5), the refinement calculations resulted in lower coefficient of variations, ranging from 5.3 to 6.9. This effectively meant that more threshold values calculated throughout processing for method 3M were not as varied as in chapter 5, meaning that the threshold value did not vary enough to capture relevant MDs. In contrast to method 2M, method 3M results showed that the proportion of SR values in the higher ranges (0.5 to 1.0) of SR decreased when compared to method 3, but the amount within the range of 0.4 to 0.6 increased.

The results for MY showed a positive effect of refinement. Both methods 2M and 3M significantly ($P < 0.05$) improved mean SR values compared to methods 2 and 3, respectively. The refinement of the historical data for MY created historical thresholds that were more in line with the true threshold; with the difference between the true and historical thresholds decreasing from 10% to 4%. The refinement of methodology enabled, in the case of MY, for means and standard deviations to be very similar to that of the true data values. This would explain why method 2M improved on method 2 by 12%. Furthermore, the range of SR results shifted, with fewer SR values within the lower range (0 to 0.5), but more within the upper range (0.5 to 1.0). For method 3M, the proportion of values of SR of 1.00 did not differ to method 3, but for method 2M, the refinement meant that while the overall mean SR improved, there weren't any SRs of 1.00; a drop of 5%, compared to method 2.

Within chapter 5, the mean SR results for methods 2 and 3 for MD were 2% higher and 7% lower than those for MY, respectively. The effect of using a refinement to the

methods has shown that MY gained higher mean SR for both methods, and that the difference in results between the traits had increased by 9% and 17%, for methods 2M and 3M, respectively. This clearly indicated that the refinement of methods was more beneficial for MY. Furthermore, of these two methods and traits, method 2M for MY benefited the most, as the mean SR increased significantly enough to bring the value more in line with the other methods for that trait.

The MY results showed that method 3M performed better, because of the refinement, than method 3 by 3%. While the improvement in method 3M was less so than that for method 2M, the mean SR of 0.85 was only 1% less than that for method 4 (0.86). The gap between methods 3M and 4 was effectively less than methods 3 and 4. The range of SR values shifted in the same way as that for method 2M.

For OR, refinement of methods 2M and 3M had a significant ($P < 0.05$), negative, effect, with both methods obtaining lower mean SR results by 49% and 4%, respectively. In contrast to both the findings of MD and MY, refinement of the methods resulted in the difference between the true and historical thresholds for OR to increase from 8% to 27%. This was likely to be due to the lowering coefficient of variation, which decreased from 49%, within Chapter 5, to a range of 25% to 27.3% for this chapter. With the true data sets having coefficients of variation ranging from 48 to 56%, it was not surprising that the threshold values differed more between the true data set thresholds and the historical thresholds for this chapter. A comparison of methods 2, 3, 2M and 3M showed significant differences within methods 2 and 2M, but not methods 3 and 3M. It was not unexpected that method 2M would achieve a lower mean SR than method 3M; but it was surprising that by using the true data to obtain the minimum and maximum values, such a negative effect would arise. The significant drop in mean SR for method 2M resulted in the method going from achieving the highest mean SR, in chapter 5, to having the lowest in this chapter. A comparison of Figures 5.7 and 6.7 does not immediately identify any great change in the clusters for methods 2M or 3M. Indeed, for method 3M, there was only a small shift in SR values towards the lower values, as reflected in the 4% decrease in mean SR. However, for method 2M, the proportion of SR values in the lower end of the spectrum (0 to 0.25) increased by 60%, while the proportion of SRs of 1.00 decreased

by 30%.

The OR results showed that Method 3M performed less well than method 3, by 4%. The findings were the same as for method 2M, but due to the updating of the threshold values throughout the method, the negative effect was less so.

6.4.2. Comparison of Methods 2M and 3M Versus Methods 1 and 4

For MD and MY, the results indicated that the effect of altering the calculation for the historical mean and standard deviation did not significantly improve either methods 2M or 3M to be more favourable than method 4. For MD, the underlying reason for methods 2M and 3M not improving enough to rank first, was that the proportion of the target number that was identified by the program (C/TN) decreased by 22 and 8% for methods 2M and 3M, respectively. This was reflected in the lowering percentage of C/TN within the range of 0.9 to 1.0, where methods 2M and 3M decreased within this range by 39 and 14%, respectively. Furthermore, the percentage of SR within the same range (0.9 to 1.0) also decreased for methods 2M and 3M, by 4 and 10%, respectively. However, even though method 2M did not improve on method 2 enough to rank first, its increase in SR by 1% was due to the 19% increase in the proportion of those selected being correct (C/TS). For C/TS, there was a 35% increase in its results ranging within the range of 0.9 to 1.0.

Unlike MD, the modification to the methods had a more positive effect for MY. Methods 2M and 3M increased in SR by 12 and 3%, respectively, with method 3M having a SR (0.85) that was 1% lower than that of method 4 (0.86), which ranked first. Of the three traits (MD, MY and OR), MY data was the most normally distributed. For MY, the use of minimum and maximum values for the calculation of the mean and standard deviation could be used with knowledge that data was not clumped at either end of the spectrum. When using the minimum and maximum values for method 3M, for this trait, it would not be possible to achieve a better SR than method 4, which also updates its threshold value as each animal is entered. Therefore, that method 3M achieved a SR which was only 1% lower than method 4, should indicate that for normally distributed data, the use of minimum and maximum values,

within an updating threshold value regime, would achieve a SR of almost equal standing to that for method 4.

Within chapter 5, method 2 for OR ranked first with a SR of 0.73, but the refinement of the method resulted in this method decreasing in SR (0.24) by 49%. The modification to the method has resulted in method 2M ranking fourth, with methods 1 and 4 changing from rankings of 2 and 4, to 1 and 2, respectively. Method 3M did not alter in ranking to that of method 3. The underlying reason for the significant change for method 2M is that the OR data was not normally distributed, with most of the OR values being within the lower range of the OR scale. For example, for the year 1991, the minimum and maximum OR values were 1 and 10. Over a range of % to Select of 5 to 45, these values resulted in threshold values ranging from 7.97 to 5.69, inclusive. For that year, 92% of the OR values were within the range of 1 to 4, inclusive, meaning that only 8 of the OR data had any chance of being selected by method 2M. Method 3M's decrease by 4%, when compared to method 3, was less extreme than that of method 2M due to the threshold updating as each record was entered. Indeed, method 3M (0.59) was only 1% lower than method 4 (0.60).

6.4.3. Chapter Conclusions

The results for MY showed a positive, significant effect of refinement on both methods 2M and 3M by 12% and 3%, respectively. For MD, there was no significant difference between the results of the refinement and those of Chapter 5. Indeed, method 2M improved on method 2 by only 1% while method 3M decreased by 6% when compared to method 3. For both MD and MY, none of the improvements in SR observed for methods 2M or 3M were sufficient enough to be better than method 4, which ranked first within chapter 5 and this chapter. The ranking of 3 for method 1 remained the same across this chapter and chapter 5.

For OR, however, there was a negative, significant, effect on the refinement of methods 2M and 3M, with the methods decreasing by 49% and 4% when compared to methods 2 and 3, respectively. In practice, for OR, the application of the refinement to the methods would not be appropriate. It would not be possible for a farmer to

objectively select animals that have minimum/maximum OR values without the use of laparoscopy or historical data, which in themselves rather defeat the use of refinement. Furthermore, the results indicated that methods 2M and 3M would not be ideal for OR, as the results implied that choosing the lowest and highest was not a sensible strategy if the data is likely to be skewed. The distribution of the OR values indicates that the data should be transformed. This will be examined in Chapter 7.

In summary, the findings of this chapter, compared to those of chapter 5 can be expressed with the following rankings:

MD: $4 > 3 > 3M > 1 = 2M > 2$

MY: $4 > 3M > 3 > 1 > * 2M > * 2$

OR: $2 > 1 > 3 > 4 > 3M > * 2M$

Where: M represents those methods refined within the current chapter. All other entries relate to the results of chapter 5.

*** indicates a significant difference between the methods either side of its entry**

CHAPTER 7 A COMPARISON OF FOUR METHODS TO SELECT NON-UNIQUELY TAGGED ANIMALS USING TRANSFORMED OVULATION RATE DATA

7.1. INTRODUCTION

Ovulation rate (OR), in part, affects the number of lambs born in a sheep flock. Other factors such as environmental effects on fertilisation and embryo survival, and ewes lambing per ewe exposed can also cause low lambing rates; a major issue in the sheep industry as a whole (Bunge *et al*, 1993). Reproductive rate is a major factor affecting financial returns from sheep production systems (Ap Dewi *et al*, 1996). Lamberson and Thomas (1982) and Hanrahan (1987) observed that OR has a higher repeatability and heritability than litter size, and that therefore the selection of ewes on the basis of OR rather than litter size would result in a more rapid improvement of prolificacy.

It is characteristic of many traits of importance in farm animals which are influenced by many genes, such as live weights, milk yields (MY) and muscle depths (MD), to have a distribution of performance which follows a smooth bell-shaped, normal, distribution. Where animals' phenotypes for traits fall into a small number of categories then it is not unusual for the trait to have a non-normal distribution. Although there are many genes and environmental factors influencing OR, most ewes have either 0, 1, 2 or 3 lambs (Simm, 1998) and OR can therefore be considered to be a categorical trait.

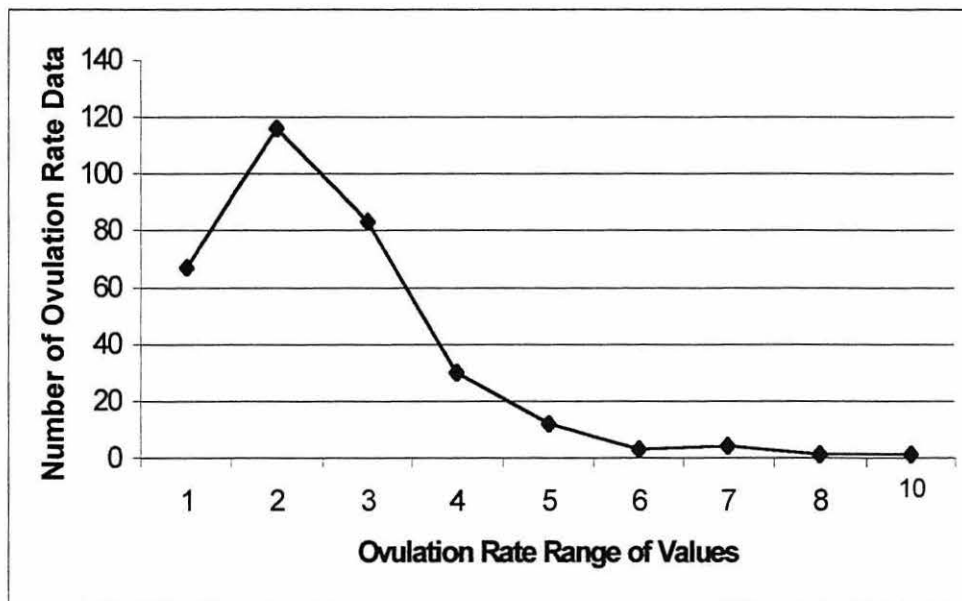
Of the three traits examined in chapter 5 (MD, MY and OR), the OR trait data was not found to be normally distributed. This was not unexpected, for 84% of the data was of 1 – 3 OR, while 13% were OR values of 4 and 5, and 3% were of extreme values of 6 to 10 OR (Figure 7.1.). Using the Anderson-Darling test for normality (Minitab version 10Xtra), the P value for the individual years and all years combined was <0.001. The Anderson-Darling test is designed to identify non-normal distributions, and thus $P < 0.05$ refers to a distribution which is significantly not normal. In such circumstances of non-normality, it is possible to use a transformation to get the data into a normal distribution (Dowdy and Wearden, 1983).

A transformation replaces each observed value by another value, for example, $x = \log$

y. It is essential that any transformation preserves the order of the data values; thus, if y_1 and y_2 are transformed to x_1 and x_2 respectively and $y_1 < y_2$, then $x_1 < x_2$. With the order of the observations not changed by the transformation used, any conclusion about differences in the transformed data are also true for the original data (Dowdy and Wearden, 1983).

For OR, there are several transformations which could be used including $\log(10)$ (L) and square root ($\sqrt{\cdot}$). Parker (1973) noted that data in the form of small, whole numbered counts tend to have a variance proportional to their mean, and that an appropriate transformation to render the variances independent of the mean is $\sqrt{\cdot}$. The OR data ranged from 1 to 10 (Table 3.3.), and thus can be considered for $\sqrt{\cdot}$. The L transformation can be used when the graph has a parabolic shape (Dowdy and Wearden, 1983). Appendix 7 illustrates such a shape, using the OR data for all of the years.

Figure 7.1. Frequency Distribution of Ovulation Rate Data (Across All Years)



The aim of this chapter was to investigate the effects of transforming the original OR data on the success of the four selection methods described in chapter 3. The original OR data is described in section 3.1.3. The data was transformed using L and $\sqrt{\cdot}$.

7.2. MATERIALS AND METHODS

The four methods, as defined in section 3.2 and 5.1, were evaluated over a range of % to Selects (5, 15, 25, 35 and 45 % to Select) (section 3.3). All materials and methods were the same as those detailed in chapter 3 and section 5.2. of chapter 5, with the exception of only using example data sets of OR (section 3.1.), the transformation of the trait OR values (section 7.2.1.1.), the origin of the historical data (section 7.2.1.2.) and the data present for comparison of methods across chapter 5 and current chapter (section 7.2.2.). For each year, two sets of transformation of OR data were applied: one set using log (base 10), the other using square root ($\sqrt{}$). The original OR value was replaced with the transformed value.

The four methods have been denoted as $1\sqrt{}$, $2\sqrt{}$, $3\sqrt{}$, $4\sqrt{}$ and 1L, 2L, 3L and 4L to distinguish them as using transformed data using $\sqrt{}$ and L, respectively, to that of chapter 5. The transformed data were then used in the model described in section 3.6.

7.2.1. Computing Strategies

7.2.1.1. Transformation of OR Values

In order to replace the original OR values, the values from a single sheet were copied to a spare sheet's column A, within the Excel template. For each value, an adjacent cell calculated the L or $\sqrt{}$, by using the appropriate formulae: =LOG10(Ax) or =SQRT(Ax), where x was the row in question. The transformed values were then copied to the sheet from where the original OR values came from. This procedure was repeated for each sheet in turn.

7.2.1.2. Transformation of Historical Data

The historical data mean was transformed using the same formula: =LOG10(Ax) or =SQRT(Ax) as that stated in section 7.2.1.1. The historical data standard deviation was obtained using the historical mean and standard deviation. The following formula was used to obtain the standard deviation, replacing SQRT with LOG10 where appropriate:

$$=((\text{SQRT}(x+sd))-(\text{SQRT}(x-sd)))/2$$

where x = mean and sd = standard deviation of untransformed data. Here, two standard deviations either side of the mean were used ($x+sd$, and $x-sd$), thus, the above formula ends with “/2”.

7.2.2. Data Set for Comparison of Methods Across Chapter 5 and Current Chapter

For the purposes of comparing the methods in chapter 5 with the current chapter, a separate statistical analysis containing all OR results for chapter 5, $\sqrt{}$ and L was performed. All statistical models for the comparison of methods are detailed in section 3.8. of chapter 3.

7.3. RESULTS

The success rate (SR), proportion of the target number identified by the program (C/TN) and proportion of those selected that were correct (C/TS) were tested for normal distribution using the Anderson-Darling test (section 3.7). None of the variables had a normal distribution ($P < 0.05$) (Appendix 4). Therefore, descriptive results are shown for transformed (T) data. The data was transformed using arcsine (section 3.7). Any marked differences between un-transformed (UT) and T data are detailed in the results section. Both UT and T data are displayed within the tables but the graphs display the T results only. Further tabulated results are presented in Appendix 5.

All results are rounded up to 2 decimal places. This can result in slight discrepancies in the T data (see Section 5.3).

7.3.1. Square Root Transformation of OR

7.3.1.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 7.1, and the range of SR values is shown in Figure 7.2.

Methods $3\sqrt{}$ (0.72) and $4\sqrt{}$ (0.72) gave the highest mean SR, while methods $1\sqrt{}$ and $2\sqrt{}$ were lower at 0.64 and 0.47, respectively ($P < 0.05$). Methods $3\sqrt{}$ and $4\sqrt{}$ were higher than methods $1\sqrt{}$ and $2\sqrt{}$ but were not significantly better than method $1\sqrt{}$. Method $1\sqrt{}$ had a higher proportion of observations (0.26) of SR within the range 0.90 to 1.00, while method $2\sqrt{}$ had the least (0.10). Method $4\sqrt{}$ gave the highest mean SR for the year 1992 (0.86) but methods $1\sqrt{}$ and $3\sqrt{}$ were significantly better for the years 1988 (method $3\sqrt{} = 0.73$), 1989 (method $3\sqrt{} = 0.66$) and 1991 (method $1\sqrt{} = 0.83$) ($P < 0.05$). Method $4\sqrt{}$ achieved the highest mean SR at % to Selects 15 (0.74 (equal to method $1\sqrt{}$)), 25 (0.63) and 35 (0.75), while methods $2\sqrt{}$ and $3\sqrt{}$ achieved the highest at 45 (0.71) and 5 (0.84) % to Select, respectively ($P < 0.05$). A different % to Select gave the highest mean SR for each year ($P < 0.05$).

Differences between UT and T data were seen. T SR results were higher than UT. For UT, method $3\sqrt{}$ was 1% higher than method $4\sqrt{}$ (Appendix 5).

When compared to the results of chapter 5, the $\sqrt{}$ transformation of the OR data resulted in methods $3\sqrt{}$ and $4\sqrt{}$ improving on methods 3 and 4 SR by 9 and 12%, respectively. Method $1\sqrt{}$ was not affected by the transformation. Compared to method 2, method $2\sqrt{}$ was significantly lower, by 26% ($P < 0.05$).

Figure 7.2. Success Rate for the Four Methods for Square Root Transformed Ovulation Rate

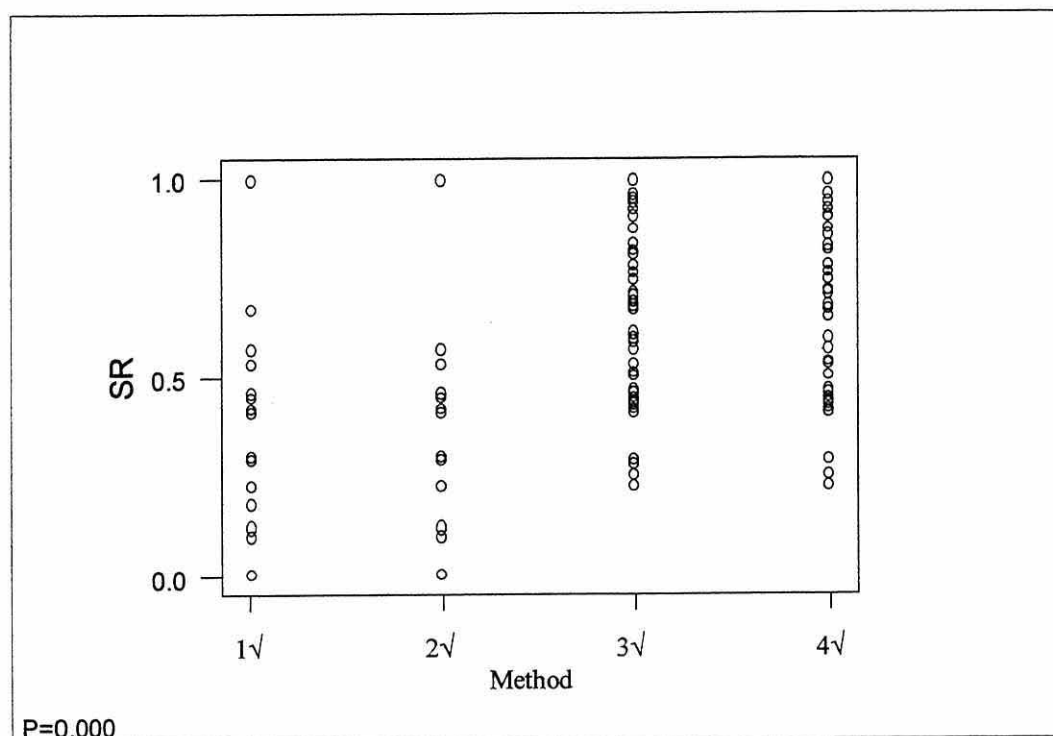


Table 7.1. Success Rate for the Four Methods for Square Root Transformed Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1√	T (A)	34.82 (7.35)	47.93 (9.68)	35.59 (8.31)	45.41 (7.88)	35.91 (5.41)	39.93 (3.48)
	T (B)	0.57	0.74	0.58	0.71	0.59	0.64
	UT	0.49 (0.08)	0.58 (0.10)	0.47 (0.08)	0.60 (0.07)	0.54 (0.05)	0.54 (0.03)
2√	T (A)	35.40 (8.73)	18.19 (1.83)	22.28 (1.44)	20.35 (2.21)	45.35 (6.67)	28.35 (2.52)
	T (B)	0.58	0.31	0.38	0.35	0.71	0.47
	UT	0.46 (0.09)	0.31 (0.03)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.43 (0.03)
3√	T (A)	56.98 (6.92)	44.11 (5.27)	37.58 (3.93)	45.96 (4.88)	44.06 (5.40)	45.74 (2.44)
	T (B)	0.84	0.70	0.61	0.72	0.69	0.72
	UT	0.75 (0.06)	0.65 (0.06)	0.59 (0.05)	0.68 (0.05)	0.64 (0.05)	0.66 (0.02)
4√	T (A)	50.54 (6.11)	47.62 (7.13)	39.15 (5.18)	48.87 (6.01)	43.45 (5.95)	45.92 (2.70)
	T (B)	0.77	0.74	0.63	0.75	0.69	0.72
	UT	0.71 (0.06)	0.65 (0.08)	0.59 (0.05)	0.69 (0.06)	0.62 (0.05)	0.65 (0.03)
ALL	T (A)	44.44 (3.78)	39.46 (3.59)	33.65 (2.73)	40.19 (3.10)	42.19 (2.91)	39.99 (1.46)
	T (B)	0.70	0.63	0.55	0.64	0.67	0.64
	UT	0.60 (0.04)	0.55 (0.04)	0.51 (0.03)	0.58 (0.03)	0.61 (0.02)	0.57 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.52, 8.94 and 23.21, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.07, 0.09 and 0.22, respectively.

7.3.1.2. Proportion of the Target Number Identified (C/TN)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 7.2, and the range of C/TN values is shown in Figure 7.3.

Method 4 $\sqrt{}$ (0.75) gave the highest mean C/TN, while methods 1 $\sqrt{}$, 2 $\sqrt{}$ and 3 $\sqrt{}$ were lower at 0.73, 0.47 and 0.74, respectively ($P < 0.05$). Method 4 $\sqrt{}$ was higher than all other methods but was not significantly better than methods 1 $\sqrt{}$ and 3 $\sqrt{}$. Method 1 $\sqrt{}$ had a higher proportion of observations (0.36) of C/TN within the range 0.90 to 1.00, while method 2 $\sqrt{}$ had the least (0.10).

Method 3 $\sqrt{}$ gave the highest mean C/TN for the years 1988 (0.74) and 1989 (0.66) but methods 1 $\sqrt{}$ and 4 $\sqrt{}$ were significantly better for the years 1991 (0.89) and 1992 (0.92), respectively ($P < 0.05$). Method 1 $\sqrt{}$ achieved the highest mean C/TN at % to Selects 15 (0.79) and 25 (0.63 (Method 4 $\sqrt{}$ also)), while methods 2 $\sqrt{}$, 3 $\sqrt{}$ and 4 $\sqrt{}$ achieved the highest at 5 (Method 3 $\sqrt{}$ = 0.88), 35 (Method 4 $\sqrt{}$ = 0.76) and 45 (Methods 2 $\sqrt{}$ and 3 $\sqrt{}$ = 0.71) % to Select ($P < 0.05$). A % to Select of 5 gave the highest mean C/TN for the years 1991 (0.83) and 1992 (1.00), while 45 and 25 % to Select were higher for the years 1988 (0.96) and 1989 (0.68), respectively ($P < 0.05$). T C/TN results were higher than UT (Appendix 5).

When compared to the results of chapter 5, the $\sqrt{}$ transformation of the OR data resulted in methods 1 $\sqrt{}$, 3 $\sqrt{}$ and 4 $\sqrt{}$ increasing C/TN by 1, 10 and 11%, respectively. Method 2 $\sqrt{}$'s decrease from 0.73 (chapter 5) to 0.47 was significant ($P < 0.05$).

Figure 7.3. C/TN for the Four Methods for Square Root Transformed Ovulation Rate

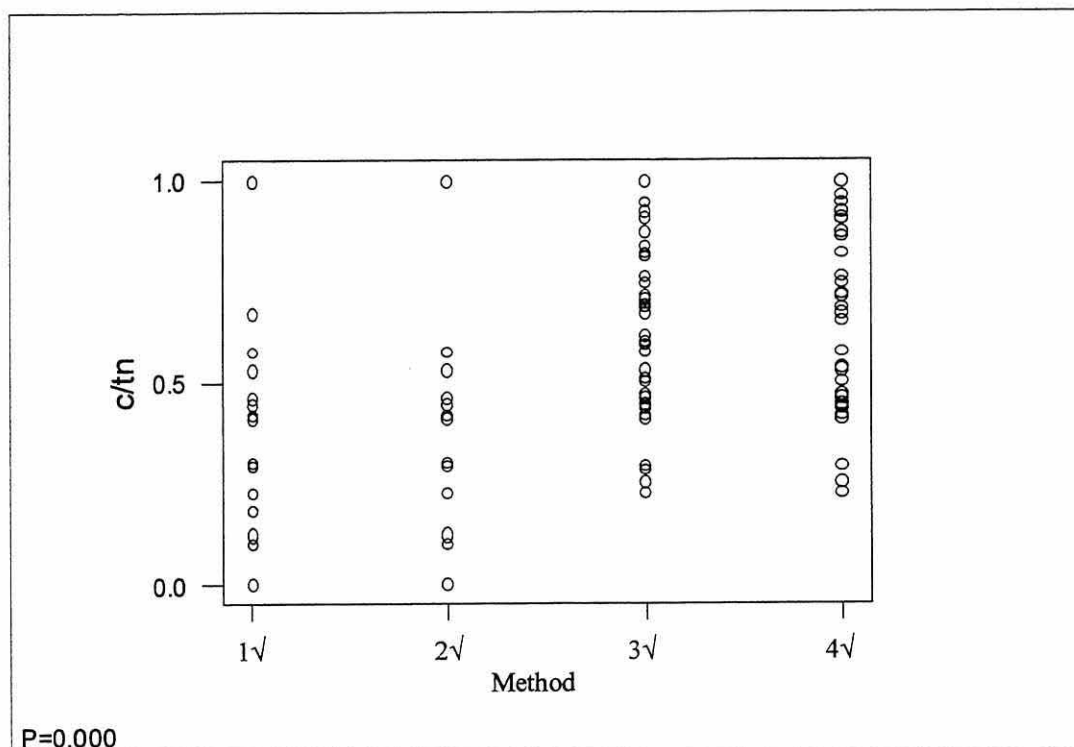


Table 7.2. C/TN for the Four Methods for Square Root Transformed Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1√	T (A)	57.31 (8.78)	52.00 (9.89)	39.21 (8.29)	49.03 (8.29)	35.91 (5.41)	46.69 (3.77)
	T (B)	0.84	0.79	0.63	0.75	0.59	0.73
	UT	0.70 (0.09)	0.62 (0.10)	0.50 (0.09)	0.63 (0.08)	0.54 (0.05)	0.60 (0.04)
2√	T (A)	35.40 (8.73)	18.19 (1.83)	22.28 (1.44)	20.35 (2.21)	45.35 (6.67)	28.35 (2.52)
	T (B)	0.58	0.31	0.38	0.35	0.71	0.47
	UT	0.46 (0.09)	0.31 (0.03)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.43 (0.03)
3√	T (A)	61.99 (7.41)	45.64 (5.87)	37.58 (3.93)	46.98 (5.35)	45.20 (5.89)	47.48 (2.68)
	T (B)	0.88	0.71	0.61	0.73	0.71	0.74
	UT	0.78 (0.06)	0.66 (0.06)	0.59 (0.05)	0.68 (0.05)	0.65 (0.05)	0.67 (0.02)
4√	T (A)	58.87 (7.17)	48.74 (7.60)	39.15 (5.18)	49.89 (6.36)	43.45 (5.95)	48.22 (2.93)
	T (B)	0.86	0.75	0.63	0.76	0.69	0.75
	UT	0.76 (0.07)	0.66 (0.08)	0.59 (0.05)	0.69 (0.06)	0.62 (0.05)	0.66 (0.03)
ALL	T (A)	53.39 (4.15)	41.39 (3.80)	34.55 (2.87)	41.61 (3.30)	42.48 (2.97)	42.68 (1.57)
	T (B)	0.80	0.66	0.57	0.66	0.67	0.68
	UT	0.68 (0.04)	0.56 (0.04)	0.51 (0.03)	0.59 (0.03)	0.61 (0.03)	0.59 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.53, 8.95 and 23.25, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.07, 0.08 and 0.22, respectively.

7.3.1.3. *Proportion of those Selected that were Correct (C/TS)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 7.3, and the range of C/TS values is shown in Figure 7.4.

Methods 2√ (1.00), 3√ (1.00) and 4√ (1.00) gave the highest mean C/TS, while method 1√ was lower at 0.99 ($P < 0.05$). Method 3√ had a higher proportion of observations (0.97) of C/TS within the range of 0.90 to 1.00, while method 1√ had the least (0.87). All methods gave a mean C/TS of 1.00 for all years, except for methods 1√ (0.99) and 2√ (0.95) for the year 1989, method 1√ (0.99) for the year 1991 and methods 1√ (0.94) and 4√ (0.99) for the year 1992 ($P < 0.05$). Furthermore, all % to Selects gave a mean C/TS of 1.00 for the years 1988 and 1991, except for 5 (0.97) % to Select for 1991 ($P < 0.05$). A mean C/TS of 1.00 was also achieved at 15, 25 and 35 % to Select for 1989 and 25 and 45 % to Select for 1992 ($P < 0.05$). The C/TS results were higher than UT (Appendix 5).

When compared to the results of chapter 5, none of the methods were affected by the transformation.

Figure 7.4. C/TS for the Four Methods for Square Root Transformed Ovulation Rate

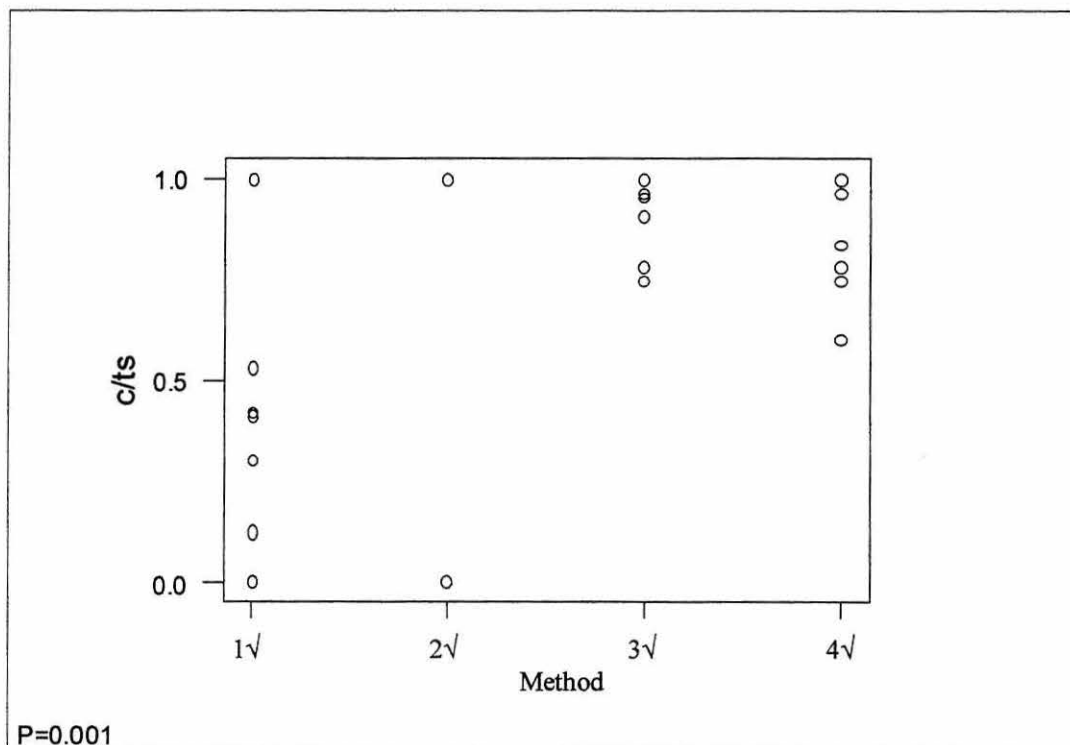


Table 7.3. C/TS for the Four Methods for Square Root Transformed Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1√	T (A)	61.89 (9.47)	85.93 (4.07)	86.38 (3.62)	86.38 (3.62)	84.38 (5.62)	80.99 (2.72)
	T (B)	0.88	1.00	1.00	1.00	0.99	0.99
	UT	0.72 (0.09)	0.96 (0.04)	0.97 (0.03)	0.97 (0.03)	0.94 (0.06)	0.91 (0.03)
2√	T (A)	67.50 (10.01)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	85.50 (2.21)
	T (B)	0.92	1.00	1.00	1.00	1.00	1.00
	UT	0.75 (0.11)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.95 (0.02)
3√	T (A)	84.99 (3.42)	88.47 (1.53)	90.00 (0.00)	88.99 (1.02)	88.86 (1.14)	88.26 (0.81)
	T (B)	1.00	1.00	1.00	1.00	1.00	1.00
	UT	0.97 (0.02)	0.99 (0.01)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.99 (0.004)
4√	T (A)	81.67 (4.53)	87.88 (2.12)	90.00 (0.00)	88.99 (1.02)	90.00 (0.00)	87.71 (1.05)
	T (B)	0.99	1.00	1.00	1.00	1.00	1.00
	UT	0.95 (0.03)	0.99 (0.01)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.99 (0.01)
ALL	T (A)	74.01 (3.84)	88.07 (1.19)	89.10 (0.91)	88.59 (0.97)	88.31 (1.43)	85.62 (0.95)
	T (B)	0.96	1.00	1.00	1.00	1.00	1.00
	UT	0.85 (0.04)	0.99 (0.01)	0.99 (0.01)	0.99 (0.01)	0.98 (0.01)	0.96 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.03, 5.98 and 15.53, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.05 and 0.14, respectively.

7.3.2. Log (10) Transformation of OR

7.3.2.1. *Success Rate*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction between % to Select x Method x Year. The results are shown in Table 7.4, and the range of SR values is shown in Figure 7.5.

Method 4L (0.70) gave the highest mean SR, while methods 1L, 2L and 3L were lower at 0.67, 0.42 and 0.64, respectively ($P < 0.05$). Method 4L was higher than all other methods but was not significantly better than methods 1L and 3L. Method 1L had a higher proportion of observations (0.31) of SRs within the range of 0.90 to 1.00, while method 2L had the least (0.05). While method 4L achieved the highest mean SR (1989 = 0.51, 1992 = 0.87) it was significantly lower ($P < 0.05$) than methods 1L and 2L for the years 1991 (0.83) and 1988 (0.60), respectively. Furthermore, method 4L gave the highest mean SR at 5 (0.62), 25 (0.68) and 35 (0.82) % to Select, while method 1L was gave the highest mean SR at 15 (0.69) and 45 (0.75) % to Select ($P < 0.05$). A % to Select of 35 gave the highest mean SR for the years 1991 (0.91) and 1992 (0.87), while 25 and 45 % to Selects were higher for 1989 (0.63) and 1988 (0.97), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were higher than UT. For UT, there were significant differences ($P < 0.05$) between % to Select x Method x Year (Appendix 5).

When compared to the results of chapter 5, the log transformation of the OR data resulted in methods 1L and 4L improving by 3 and 10%, respectively, while methods 2L and 3L decreased by 31 and 1%, respectively. Method 2L's decreased result was significant ($P < 0.05$).

Figure 7.5. Success Rate for the Four Methods for Log Transformed Ovulation Rate

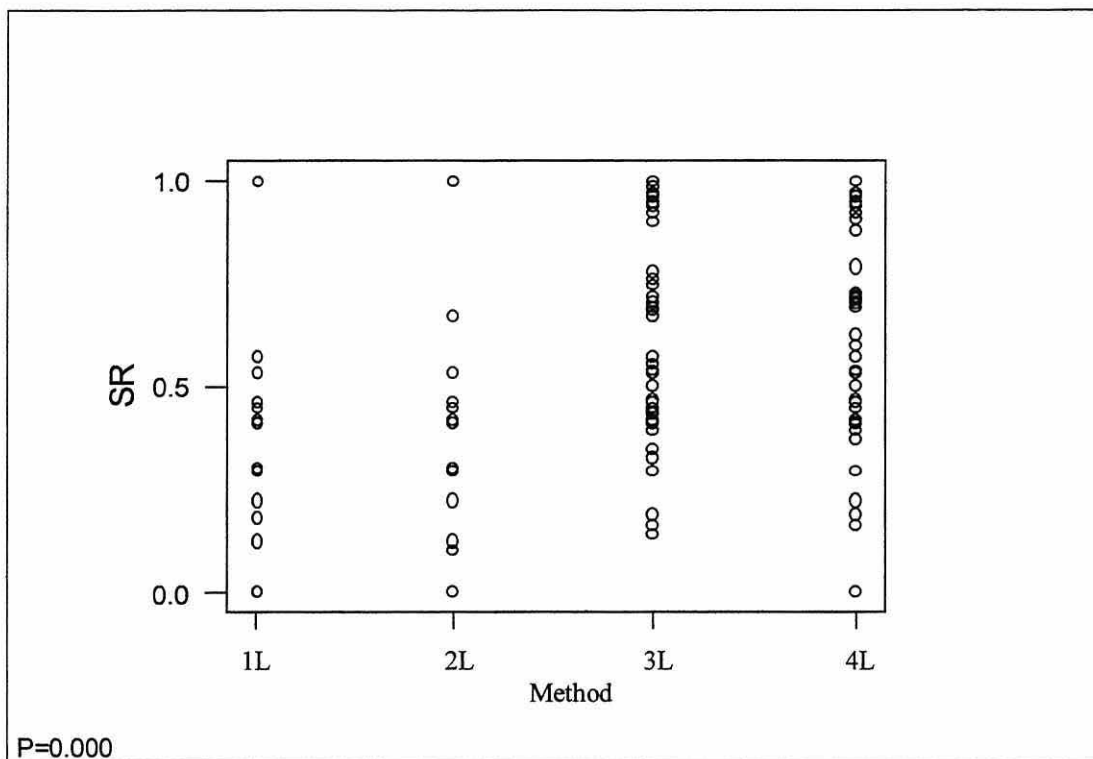


Table 7.4. Success Rate for the Four Methods for Log Transformed Ovulation Rate

% to Select	5	15	25	35	45	ALL
Method	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1L T (A)	26.36 (8.44)	43.45 (9.45)	39.66 (8.93)	50.72 (7.87)	48.61 (7.22)	41.76 (3.79)
T (B)	0.44	0.69	0.64	0.77	0.75	0.67
UT	0.35 (0.09)	0.54 (0.09)	0.51 (0.09)	0.66 (0.07)	0.65 (0.06)	0.54 (0.04)
2L T (A)	18.95 (3.88)	18.19 (1.83)	22.28 (1.44)	20.54 (2.21)	45.35 (6.67)	25.06 (2.00)
T (B)	0.32	0.31	0.38	0.35	0.71	0.42
UT	0.31 (0.06)	0.31 (0.03)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.39 (0.02)
3L T (A)	30.34 (4.91)	33.74 (5.98)	37.88 (4.28)	53.59 (6.81)	43.80 (5.73)	39.87 (2.61)
T (B)	0.50	0.55	0.61	0.80	0.69	0.64
UT	0.47 (0.06)	0.50 (0.07)	0.58 (0.05)	0.72 (0.06)	0.63 (0.05)	0.58 (0.03)
4L T (A)	38.00 (7.04)	42.11 (8.17)	42.82 (5.47)	54.77 (6.97)	43.55 (5.49)	44.25 (2.99)
T (B)	0.62	0.67	0.68	0.82	0.69	0.70
UT	0.54 (0.07)	0.56 (0.08)	0.63 (0.06)	0.73 (0.06)	0.63 (0.05)	0.62 (0.03)
ALL T (A)	28.41 (3.21)	34.37 (3.64)	35.66 (2.96)	44.90 (3.58)	45.33 (3.09)	37.73 (1.51)
T (B)	0.47	0.56	0.58	0.71	0.71	0.61
UT	0.42 (0.04)	0.48 (0.04)	0.52 (0.03)	0.61 (0.03)	0.64 (0.03)	0.53 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.86, 9.35 and 24.27, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

7.3.2.2. *Proportion of the Target Number Identified (C/TN)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of % to Select x Method x Year. The results are shown in Table 7.5, and the range of C/TN values is shown in Figure 7.6.

Method 1L (0.72) gave the highest mean C/TN, while Methods 2L, 3L and 4L were lower at 0.42, 0.65 and 0.71, respectively ($P < 0.05$). Method 1L was higher than all the other methods but was not significantly better than methods 3L and 4L. Method 1L had a higher proportion of observations (0.37) of C/TN within the range of 0.90 to 1.00, while method 2L had the least (0.05).

While method 1L achieved the highest mean C/TN (1989 = 0.51, 1991 = 0.86, 1992 = 0.91) it was significantly lower ($P < 0.05$) than method 2L for the year 1988 (0.60). Method 4L also gave a mean C/TN of 0.51 for the year 1989. Method 4L gave the highest mean C/TN at 5 (0.62), 25 (0.69) and 35 (0.84) % to Select, while method 1L gave the highest mean C/TN at 15 (0.74) and 45 (0.75) % to Select ($P < 0.05$). A % to Select of 35 gave the highest mean C/TN for the years 1991 (0.91) and 1992 (0.92), while 45 and 25 % to Selects were higher for 1988 (0.97) and 1989 (0.63), respectively ($P < 0.05$). T C/TN results were higher than UT.

When compared to the results of chapter 5, the L transformation of the OR data resulted in methods 3L and 4L increasing C/TN by 1 and 7%, respectively, while method 1L was not affected. Method 2L's decrease from 0.73 (chapter 5) to 0.42 was significant ($P < 0.05$).

Figure 7.6. C/TN for the Four Methods for Log Transformed Ovulation Rate

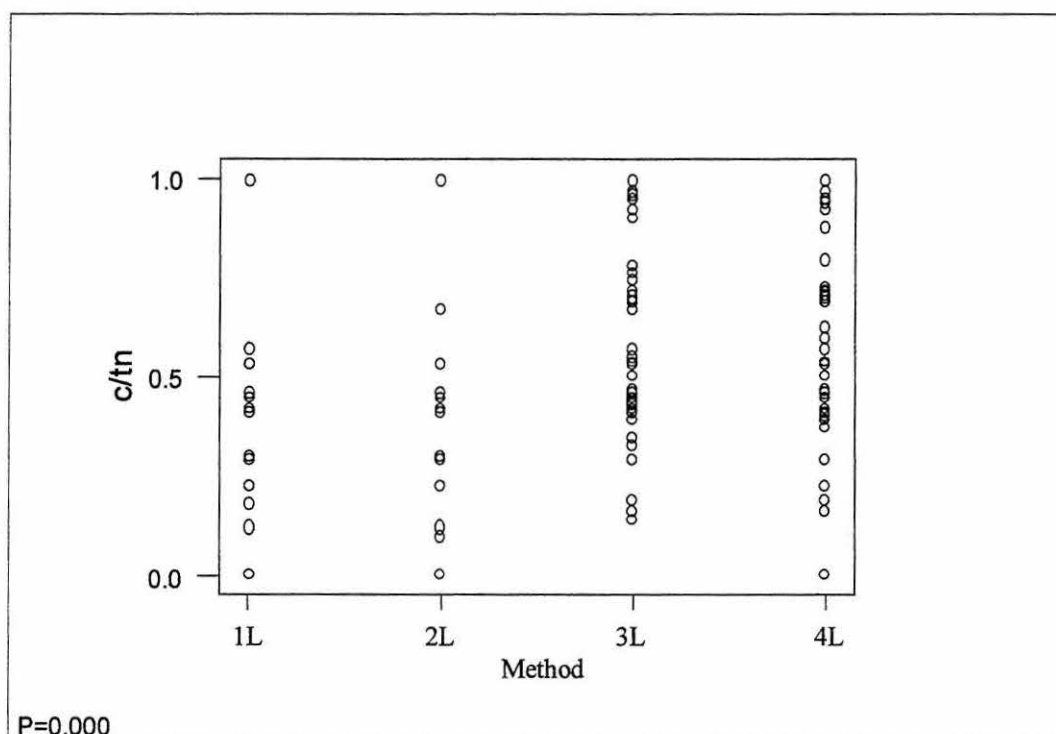


Table 7.5. C/TN for the Four Methods for Log Transformed Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1L	T (A)	35.67 (9.88)	47.52 (9.78)	43.28 (9.45)	54.34 (8.12)	48.61 (7.22)	45.88 (3.96)
	T (B)	0.58	0.74	0.68	0.81	0.75	0.72
	UT	0.44 (0.11)	0.58 (0.10)	0.54 (0.90)	0.69 (0.07)	0.65 (0.06)	0.58 (0.04)
2L	T (A)	18.95 (3.88)	18.19 (1.83)	22.28 (1.44)	20.54 (2.21)	45.35 (6.67)	25.06 (1.99)
	T (B)	0.32	0.31	0.38	0.35	0.71	0.42
	UT	0.31 (0.06)	0.31 (0.03)	0.38 (0.02)	0.35 (0.04)	0.63 (0.06)	0.39 (0.02)
3L	T (A)	30.34 (4.91)	34.99 (6.59)	37.98 (4.29)	55.32 (7.28)	43.80 (5.73)	40.49 (2.73)
	T (B)	0.50	0.57	0.61	0.82	0.69	0.65
	UT	0.47 (0.06)	0.51 (0.07)	0.59 (0.05)	0.72 (0.07)	0.64 (0.05)	0.58 (0.03)
4L	T (A)	38.00 (7.04)	43.64 (8.60)	43.83 (5.92)	56.80 (7.46)	43.55 (5.49)	45.17 (3.13)
	T (B)	0.62	0.69	0.69	0.84	0.69	0.71
	UT	0.54 (0.07)	0.57 (0.08)	0.63 (0.06)	0.73 (0.07)	0.63 (0.05)	0.62 (0.03)
ALL	T (A)	30.74 (3.21)	36.09 (3.86)	36.84 (3.13)	46.75 (3.78)	45.33 (3.09)	39.15 (1.58)
	T (B)	0.51	0.59	0.60	0.73	0.71	0.63
	UT	0.44 (0.04)	0.49 (0.04)	0.53 (0.03)	0.62 (0.04)	0.64 (0.03)	0.54 (0.02)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 8.00, 9.51 and 24.69, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.08, 0.09 and 0.24, respectively.

7.3.2.3. *Proportion of those Selected that were Correct (C/TS)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 7.6, and the range of C/TS values is shown in Figure 7.7.

Methods 2L, 3L and 4L all gave a mean C/TS of 1.00, while method 1L was lower at 0.98 ($P < 0.05$). Method 1L significantly differed to all other methods ($P < 0.05$). Method 3L had a higher proportion of observations (1.00) of C/TS within the range of 0.90 to 1.00, while method 1L had the least (0.86). All methods gave a mean C/TS of 1.00 at 15, 25, 35 and 45 % to Select, while only method 3L gave a mean C/TS of 1.00 at 5 % to Select ($P < 0.05$). Furthermore, all methods gave a mean C/TS of 1.00 for the year 1991. Methods 2L, 3L and 4L for the year 1988, methods 3L and 4L for the year 1989 and methods 2L and 3L for the year 1992 also achieved a mean C/TS of 1.00 ($P < 0.05$).

All % to Selects had a mean C/TS of 1.00 for the years 1988, 1989 and 1991, except for 5 % to Select for the years 1988 and 1989 ($P < 0.05$). The year 1992 achieved a mean C/TS of 1.00 at 25 and 45 % to Selects ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TS results were higher than UT and there were fewer instances of a mean C/TS of 1.00 (Appendix 5).

When compared to the results of chapter 5, method 1L decreased by 1%, while none of the other methods differed ($P > 0.05$).

Figure 7.7. C/TS for the Four Methods for Log Transformed Ovulation Rate

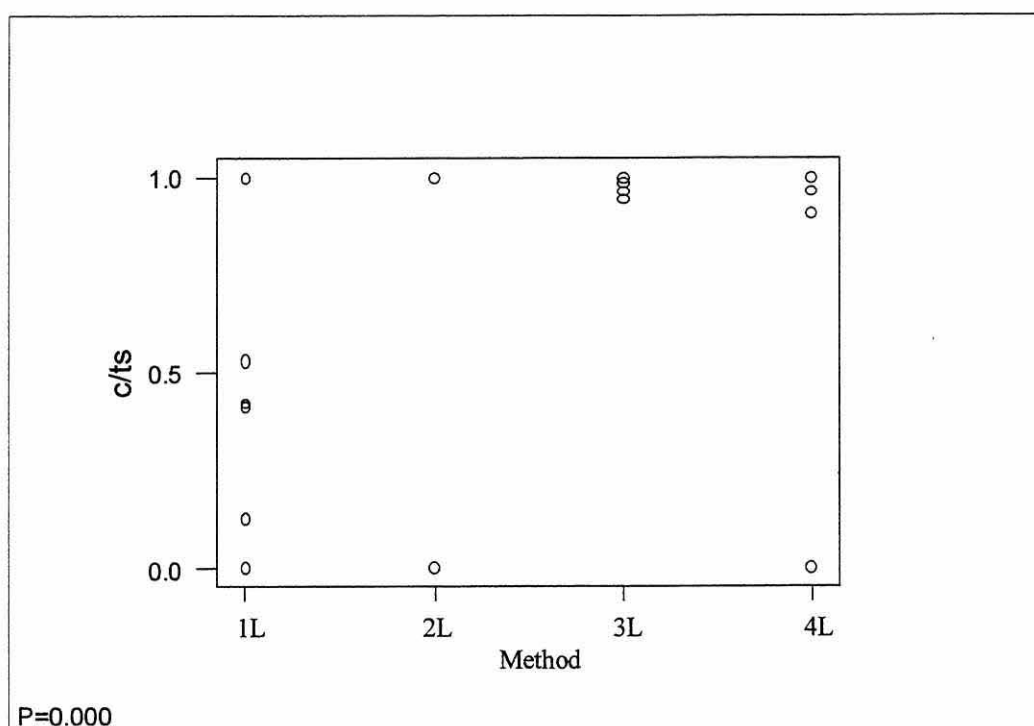


Table 7.6. C/TS for the Four Methods for Log Transformed Ovulation Rate

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1L	T (A)	46.94 (11.21)	85.93 (4.07)	86.38 (3.62)	86.38 (3.62)	90.00 (0.00)	79.13 (3.11)
	T (B)	0.73	1.00	1.00	1.00	1.00	0.98
	UT	0.53 (0.12)	0.96 (0.04)	0.97 (0.03)	0.97 (0.03)	1.00 (0.00)	0.89 (0.03)
2L	T (A)	67.50 (10.06)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	90.00 (0.00)	85.50 (2.21)
	T (B)	0.92	1.00	1.00	1.00	1.00	1.00
	UT	0.75 (0.11)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.95 (0.02)
3L	T (A)	90.00 (0.00)	88.76 (1.25)	88.99 (1.02)	88.27 (1.20)	90.00 (0.00)	89.20 (0.40)
	T (B)	1.00	1.00	1.00	1.00	1.00	1.00
	UT	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
4L	T (A)	84.38 (5.62)	88.47 (1.53)	88.99 (1.02)	87.97 (1.39)	90.00 (0.00)	87.96 (1.20)
	T (B)	0.99	1.00	1.00	1.00	1.00	1.00
	UT	0.94 (0.06)	0.99 (0.01)	1.00 (0.00)	0.99 (0.003)	1.00 (0.00)	0.98 (0.01)
ALL	T (A)	72.21 (4.46)	88.29 (1.12)	88.59 (0.97)	88.15 (1.00)	90.00 (0.00)	85.45 (1.02)
	T (B)	0.95	1.00	1.00	1.00	1.00	1.00
	UT	0.80 (0.05)	0.99 (0.01)	0.99 (0.01)	0.99 (0.01)	1.00 (0.00)	0.95 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

T (A) Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.30, 6.30 and 16.36, respectively.

UT Least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.06 and 0.17, respectively.

7.4. DISCUSSION

Transformation using $\sqrt{}$ resulted in both methods 3 $\sqrt{}$ (0.72) and 4 $\sqrt{}$ (0.72) achieving the highest SR means, with methods 1 $\sqrt{}$ and 2 $\sqrt{}$ being lower at 0.64 and 0.47, respectively ($P < 0.05$). However, transformation using L resulted in method 4L achieving the highest mean SR (0.70), followed by method 1L (0.67), with methods 2L and 3L being lower at 0.42 and 0.64, respectively. When comparing L and $\sqrt{}$ results, methods 2 $\sqrt{}$, 3 $\sqrt{}$ and 4 $\sqrt{}$ achieved higher SR results when using $\sqrt{}$, by 5, 8 and 2%, respectively, while method 1L result was higher than method 1 $\sqrt{}$ by 3%.

A review of the OR results for chapter 5 shows that the mean SR results ranged from 0.60 (method 4) to 0.73 (method 2), with methods 1 and 3 being 0.64 and 0.63, respectively. The transformation of the OR trait data resulted in a wider range of results, with method 2L being at 0.42 and methods 3 $\sqrt{}$ and 4 $\sqrt{}$ at 0.72. Compared to chapter 5 results, method 2 $\sqrt{}$ and 2L SR results significantly ($P < 0.05$) decreased in value by 26% and 31%, respectively. Methods 3 $\sqrt{}$, 3L, 4 $\sqrt{}$ and 4L increased SR by 9, 1, 12 and 10%, respectively. Method 1 $\sqrt{}$ result (0.64) was the same as method 1, while method 1L increased in SR by 3%. A comparison of methods 1, 3 and 4 for chapter 5, $\sqrt{}$ and L showed that the improvements in SR were not significant ($P > 0.05$).

7.4.1. Effects of Transformation on Method 1

When compared to chapter 5, the transformation of OR had little effect on the results of method 1. Indeed, transformation using $\sqrt{}$ did not result in any change in overall SR (0.64) while transformation of OR using L resulted in a 3% increase in SR (0.67).

The results for the different years across method 1, 1 $\sqrt{}$ and 1L show that the most variation in results was for the year 1992, where the mean SR for that year increased by 7% for L, but decreased by 4% for $\sqrt{}$. This increase in result by 7% for L was the main contributing factor that resulted in method 1L improving on method 1 by 3%. The improvement in SR for method 1L for the year 1992 resulted in the years 1988 and 1992 significantly differing in result; a finding not found for method 1. In contrast, the mean SR (0.83) for the year 1991 remained the same across methods 1,

1L and $1\sqrt{}$, and for 1988 and 1989, the results only differed by a maximum of 2%.

A review of the tables in Appendix 5 shows how method 1L for the year 1992 at 5 and 15 % to Select decreased in SR to that of method 1, but this decrease was not as much as the combined increase in SR at 25, 35 and 45 % to Select. This increase was mainly due to the results at 45 % to Select, where the SR increased by 17%. Such an increase was a result of an increased number of SR of 1 (25 in total) for method 1L when compared to method 1 (22 in total) and a 3.75% increase in the number of SR within the range of 0.76 to 1.00.

7.4.2. Effects of Transformation on Method 2

When comparing methods 2L and $2\sqrt{}$ results against those of method 2, a decrease in SR was observed, to a varying degree, across the four years ($P < 0.05$). The most notable change in result was the method 2L result for 1991, where SR decreased by 38%. The decrease in SR resulted in method 2, for the year 1991, no longer being significantly different from any other year for either $\sqrt{}$ or L. Furthermore, transformation using $\sqrt{}$ resulted in the years 1989 and 1992 no longer being significantly different for method 2. The smallest changes were for 1989 where both 2L and $2\sqrt{}$ SR decreased by 14%. The high SR result (0.73) of method 2 in chapter 5 was partly due to 35% of the SR result being 1. A review of figures 5.7, 7.2 and 7.5 do not show marked differences in the trend of results observed. However, the difference in the number of SR of 1 has contributed to the lower SR results within this chapter, with 2L and $2\sqrt{}$ having 5 and 10% of SR results of 1. This drop in SR of 1 was attributed to the years 1988, 1991 and 1992. For 2L, all of these years decreased in SR of 1 by 40%, with 1991 and 1992 not having any SR of 1, and 1988 decreasing to 20% SR of 1. The method $2\sqrt{}$ results for SR of 1 were the same as 2L for the years 1988 and 1991, but 1992 only decreased by 20%. Neither $\sqrt{}$ or L transformation of OR resulted in the number of SR of 1 increasing from 0% for the year 1989 (Table 7.7).

Table 7.7 Proportions of Method 2 Success Rate of 1.00

Year/ Method	1988	1989	1991	1992	ALL
2	0.60	0.00	0.40	0.40	0.35
2L	0.20	0.00	0.00	0.00	0.05
2√	0.20	0.00	0.00	0.20	0.10

L = Log(10), √ = Square Root, Proportion range = 0.00 to 1.00

As observed for method 2, for both methods 2L and 2√, other than the SR results of 1, there were no other instances of results within the 0.76 to 1.00 range. Furthermore, there was no difference in the proportion of SR results within the 0.51 to 0.76 range. The proportion of SR results falling within the 0.26 to 0.50 range increased by 25% and 20% for 2L and 2√, respectively, while for the range 0.00 to 0.25, the increase was lower, at 5% for both 2L and 2√.

A comparison of the SR results of chapter 5 and the two transformations over the five % to Selects clearly identifies why methods 2√ and 2L had decreased SR to that of method 2. While the mean SR results for 25, 35 and 45 % to Select were exactly the same for both 2L and 2√ as those of method 2, both 5 and 15 % to Selects decreased considerably. At 5 % to Select, L and √ transformations resulted in SR decreases of 65% and 39%, respectively, while for 15 % to Select both transformations decreased SR by 63%. A review of the data sets for both L and √ showed that the historical threshold values at 5 and 15 % to Select ranged from 1 to 20% too high, meaning that the methods selected considerably fewer records. This was due to the marked clustering of the data. The historical coefficient of variation for method 2 was 49%, while the use of L and √ resulted in contrasting coefficients of variation, ranging from 57% for L to 25% for √. However, these different values did not result in different trends for the transformed data sets. Indeed, both methods 2L and 2√ results identified how, with increased % to Select, the SR in general improved. At 5 and 15 % to Select, the proportion of OR values that were lower in value than the historical threshold was greater than at higher % to Selects. For example, at 5 and 15 % to Select, method 2L was unable to select 77% and 69%, respectively, of the OR values

due to the historical threshold value being too high. For 25, 35 and 45 % to Select, the amount that could not be selected was lower at 62%, 65% and 37%, respectively. Furthermore, the transformation of OR resulted in a higher percentage (64% for 2√ and 100% for 2L) of historical thresholds, across the % to Selects, that were higher relative to the data sets in use than that of method 2 (45%).

7.4.3. Effects of Transformation on Method 3

The transformation of OR data using L resulted in method 3L increasing in SR result by 1% when compared to method 3. Unlike √, transformation using L resulted in decreased SR at 5 and 15 % to Select and for the years 1989 and 1992. The most evident decreases in SR were at 5 % to Select (29%) and for the year 1989 (12%). The decrease in SR for the year 1989 was sufficient enough to make a significant difference between the years 1989 and 1992 for method 3L. Unlike method 3 results for OR, comparisons of years 1988 and 1992, and 1991 and 1992 for method 3L showed that these years were no longer significantly different. While these decreases were present, the improvement in SR at all other % to Selects and years was effective enough to result in an overall improvement by 1%. A review of the spreadsheet for 1989, at 5 % to Select identified that of the four data sheets, 2 of the sheets resulted in method 3L being able to select the 4 highest, of the 7, log OR, while the other two sheets selected only 1 or 2. For the data sheet where only 2 log OR were selected, of the 96 threshold values produced for method 3L, 18 of the thresholds were above all of the OR L values, 77 of the thresholds would enable the top 4, of 7, animals to be selected. Only 1 threshold value was low enough to be able to select the 3, of 7, second highest L OR. The selection was further compounded as the method was dependent on the random order of OR. In this instance, the random ordering resulted in threshold values that were too high for the particular L OR being recorded.

However, by using √, the SR increased by 9%. In part, this was due to the higher number of SRs of 1, where 3√ had 10 instances while method 3 only had 7. Furthermore, for 3√ the percentage of SRs over the different ranges was very different to those for method 3. The use of √ has resulted in 17.5% increase in the number of SR results within the range of 0.51 to 1.00, with 15% of these results being above

0.75.

A review of the $3\sqrt{}$ results showed that SR improved by between 5 to 12% across the % to Selects, and by between 3 and 19% across the years. The improvement in SR across the % to Selects and years was most evident for the years 1988 and 1991. For 1988, the SR improved by 11, 18, 13, 17.5 and 20.5% for the % to Selects 5, 15, 25, 35 and 45, respectively. For the same % to Selects, SR improved (less so than for 1988) for 1991 by 5, 11, 4, 13.5 and 6.5%, respectively. SR improved less so for the years 1989 and 1992, with a mean SR increase of 4% across the % to Selects. At 5 % to Select, the SR result was not affected for the years 1989 and 1992. Unlike the results of method 3 OR, a comparison of Method x Year showed that none of the interactions were significant.

By transforming OR using $\sqrt{}$, the coefficient of variation for the 1988 data decreased by 48 to 24% and the difference between the minimum and maximum values of the data set decreased by 6 to 1.64. For the same year, the range of threshold values that were calculated by method $3\sqrt{}$ was less than method 3. At 45 % to Select, where the result increased by 20.5%, the method $3\sqrt{}$ threshold values ranged between 51% and 63% of the maximum data set value while for method 3 the range was wider at between 42% to 76%. The wider range in threshold values for method 3 resulted in the method under selecting (i.e. $TS < TN$ (Total number selected by program < Target number of animals to be selected)) as a number of the threshold values were too high for the data set. For the year 1988 at 45 % to Select, this occurred for each of the four random data sheets, whereas for $3\sqrt{}$, under selecting only occurred in one of the data sheets and two of the remaining three data sheets obtained a SR of 1. For $3\sqrt{}$, over the 5 % to Selects, the number of records selected in the fourth data sheet was 5% higher than required.

7.4.4. Effects of Transformation on Method 4

Method 4 showed a consistent increase in mean SR when transforming using $\sqrt{}$ or L, where SR increased by 12 and 10%, respectively. Indeed, at all % to Selects, except

for 5 % to Select for 4L which decreased by 10%, all mean SRs increased within a range of 5% to 20%. Similarly, for all years, the mean SRs increased within a range of 4% to 21%, except for the year 1989 for 4L, which decreased by 4%. The most consistent changes across methods $4\sqrt{}$ and 4L were for 45 % to Select where they both increased mean SR by 13%, and for the year 1992 where the mean SR increased by 11 and 12%, respectively. For method 4, a comparison of results for Method x Year showed that there were no significant differences. However, within this chapter, the increase in methods 4L and $4\sqrt{}$ SRs for the year 1992 resulted in SR for this year being significantly better than 1988 (4L only) and 1989 ($4\sqrt{}$ and 4L).

The improvement of SR for methods $4\sqrt{}$ and 4L was a result of increased percentages of SR values within the range of 0.76 to 1.00, where increases of 20% and 14% were observed for $\sqrt{}$ and log, respectively. Furthermore, of the SR values that were within this range, 25% and 19% were in the range of 0.9 to 1.00, again, increases by 15% and 19% when compared to method 4 for $4\sqrt{}$ and 4L, respectively. The number of SR of 1 doubled for $4\sqrt{}$, from 8.75% for method 4 to 17.5%. For 4L, there was a 6.25% increase of SR of 1 to 15%. Transformation using $\sqrt{}$ may have achieved a higher SR by 2% because the coefficient of variation across the different years was similar (range of 23% to 27%) while for L, the range was much wider at 56% to 73%. Furthermore, the SR improved the most for years where the range of OR values was of a wider spectrum. For the year 1989, the (un-transformed) OR values ranged, for method 4 from 1 to 5, while for the other years, the range was greater at 1 to 7 for the years 1988 and 1992, and 1 to 10 for the year 1991. It was for these years (1988, 1991 and 1992) where the SR results improved more so. The distance between a transformed OR value and its next value decreased with increasing OR value (Figure 9.1) which in turn meant that the calculated threshold value was less likely to be much too high or low for an OR value to be selected throughout the updating procedure.

7.4.5. Chapter Conclusions

In practice, a farmer could record OR for each animal and then perform a $\sqrt{}$ or L transformation on the data using a scientific calculator. Alternatively, a farmer could

be provided with a sheet that details the corresponding transformation values. As OR is a whole number and of a small range, the sheet could contain, for example, just eleven rows for OR range of 0 – 10, with two columns: one detailing the OR count and the second detailing the transformed value. The requirement to transform the data does somewhat complicate the calculation of the starting historical values, in particular, the standard deviation, required for methods 2 and 3 (Section 7.2.1.2).

The results show that transformation of OR values using $\sqrt{}$ and L does not significantly ($P>0.05$) improve SR, and that methods $3\sqrt{}$, $4\sqrt{}$ and 4L were the best methods. Compared to methods 1, 3 and 4, methods 1L, $3\sqrt{}$, 3L, $4\sqrt{}$ and 4L had increased SR while method $1\sqrt{}$ remained the same. Only methods $2\sqrt{}$ and 2L showed a significant ($P<0.05$) change in result when compared to method 2, with the methods decreasing in SR by 26% and 31%, respectively. Methods 1 (0.64), 3 (0.63) and 4 (0.60), to a lesser extent, had similar SR values, none of which were significantly different from the other. By transforming OR using $\sqrt{}$, methods $3\sqrt{}$ and $4\sqrt{}$ improved in SR by 9% and 12%, respectively, while method $1\sqrt{}$ SR remained the same. Again, these methods did not significantly ($P>0.05$) differ from each other. By transforming using L, method 1L improved SR by 3% and this was sufficiently enough an improvement for this method to achieve a higher SR than method 3L, which only improved SR by 1%. Method 4L improved SR by 10%, resulting in method 4L achieving the highest SR for the L data. When compared to chapter 5, the methods that achieved the highest and lowest SR results reversed their order. In chapter 5, methods 2 and 4 achieved the highest and lowest SR respectively, while using $\sqrt{}$ and L, it was method 4 that achieved the highest SR while methods $2\sqrt{}$ and 2L achieved the lowest.

Methods 3 and 4, in general, are expected to achieve higher SR values as a result of the updating of the threshold values as new animals are recorded. This expectation has been evident for the traits MD and MY in chapters 5 and 6. The transformation of the data has resulted in this expectation also becoming evident for OR values that have transformed using $\sqrt{}$, and to a lesser extent, L. A review of the results shows how the OR SR values have increased to 0.72 ($3\sqrt{}$ and $4\sqrt{}$) and 0.70 (4L). However, it should be noted that the highest SR result (0.72) of this chapter is lower than the highest SR

results reported in chapter 5 for MD (0.78) and MY (0.86). If a SR of 0.72 was considered an acceptable level, and taking into account the complexity of the historical data calculations for methods $3\sqrt{}$ and $3L$, I would suggest that method $4\sqrt{}$ in the first instance, followed by $4L$, should be used for OR.

In summary, the findings of this chapter, compared to those of chapters 5 and 6 can be expressed with the following rankings:

OR: $2 > 3\sqrt{} = 4\sqrt{} > 4L > 1L > 3L = 1\sqrt{} = 1 > 3 > 4 > 3M > 2\sqrt{} > 2L > 2M$

Where: $\sqrt{}$ and L represent methods using OR data that has been transformed using square root and $\log(10)$, respectively (current chapter). M represents methods that were modified (chapter 6). All other entries relate to the results of chapter 5.

No significant differences between the adjacent methods above were observed.

CHAPTER 8 A COMPARISON OF FOUR METHODS TO SELECT NON-UNIQUELY TAGGED ANIMALS USING MUSCLE DEPTH AND MILK YIELD DATA CORRECTED FOR ENVIRONMENTAL EFFECTS

8.1. INTRODUCTION

8.1.1. Correcting for Environmental Factors

In order to aid selection of animals, there are a number of steps that can be taken. These steps include the management of the animals in a way which will make it easier to disentangle genetics and environment and adjusting records of performance for known environmental effects. Disentangling the effects of genes and environment enables selection of animals that have high genetic merit, rather than those that perform well simply because they are managed. The environmental factors that obscure true genetic merit can be divided into two types: 1. those which it is difficult to attribute to individual animals, for example, disease, and 2. those which we can identify as affecting particular animals (Simm, 1998).

It is the second type of environmental influences that attempts can be made to adjust for. Such factors include age of dam, age of ram, rearing type, lactation number and breed. While it is not possible to know the exact effect that any of these factors has on an individual animal's performance, it is possible to estimate the average effect that any of these factors has in a group of animals. Adjusting for these is generally better than doing nothing about it (Simm, 1998).

There are a number of ways of adjusting records of performance to help to deal with environmental factors, including additive correction factors, multiplicative correction factors, standardising to adjust records, regression coefficients and contemporary comparisons.

8.1.1.1. Additive Correction Factors

Additive correction factors have been used widely in the past. The advantages of this type of adjustment are that, (a) they are easy to use and (b) they make no assumption about the average genetic merit of animals in different contemporary groups. The disadvantages of additive corrections factors are that, (a) many records of performance

are needed to estimate correction factors accurately, (b) they have to be estimated from data prior to the selection of animals, (c) they may be fairly specific to a particular herd, flock or management system and (d) there is a possibility that they will over/under-correct records of performance (Simm, 1998).

8.1.1.2. Multiplicative Correction Factors

Multiplicative correction factors are similar to additive factors but the records of performance are adjusted by multiplying by the correction factors rather than adding the correction factors. For example, if triplets were 4% lighter than twins, all weights for triplets would be multiplied by 1.04 to bring them to the level expected for twins. Most of the advantages and disadvantages of multiplicative correction factors are similar to those for additive correction factors. However, multiplicative correction factors are more appropriate when the scale of the correction depends on the mean level of performance in the herd or flock. When correction factors are going to be used across herds or flocks which have very different levels of performance, multiplicative correction factors may be more appropriate than additive adjustments (Simm, 1998).

8.1.1.3. Standardising to Adjust Records (Contemporary Comparison)

This method of adjustment was used widely by the Meat and Livestock Commission in beef and sheep performance recording in Britain until recently, and is still used in dairy cattle and beef evaluations in several countries. This method involves assigning records from animals born in a specified time period to a contemporary group. Assigning records is based on the factors to be adjusted for. Within each of these groups, each record is expressed as a deviation from the mean of the groups, in standard deviation units. For example, within a flock, lambs born in one season could be assigned to four groups: single reared from two-year-old dams, single reared from older dams, multiple reared from two-year-old dams and multiple reared from older dams. The mean and standard deviation of the trait concerned are then calculated separately for each of the four groups and the performance record of each animal is expressed as a deviation from the mean of its own group and then divided by the

standard deviation of that group. This gives records expressed in standard deviation units rather than the units in which the trait was measured. These standardised measurements (contemporary comparisons) can be compared directly across contemporary groups within a flock or herd.

Advantageously, this method of adjustment does not require prior information on the effects of the different factors, e.g., the effect of being born as a single, and it reduces possible bias from preferential treatment of some animals. However, standardising records in each contemporary group assumes that the different groups are of equal genetic merit. Furthermore, the results for a whole group can be greatly influenced by an animal in that group with extremely high or low performance and corrections may be unreliable when groups are small. Compared to additive and multiplicative correction factors, standardising is likely to over-correct and remove some genetic differences (Simm, 1998).

8.1.1.4. Regression Coefficients

Where the environmental factors are not categorical, or where there are a large number of categories, regression can be used to calculate adjusted trait values, taking into account the relationship between the trait and the factor (Steel and Torrie, 1981).

Typically, Adjusted $Y = Y - b(x - \bar{x})$

Where Adjusted Y = Adjusted trait measurement

Y = Original trait measurement

b = Regression coefficient (Y vs. X)

x = Factor level (e.g. age of animal)

\bar{x} = Mean across all factor levels (e.g. mean age)

\bar{x} may be replaced by any factor level to which the trait is to be adjusted (e.g. adjusting the weight of animals to a defined standard age).

8.1.1.5. Best Linear Unbiased Prediction (BLUP)

The modern approach to correcting for factors is to use BLUP. BLUP is a statistical technique which disentangles genetics from management and feeding, and produces an accurate prediction of breeding values. It achieves this by estimating environmental effects and predicting breeding values simultaneously. BLUP can be applied under different sets of assumptions (models) which differ in sophistication. The most common BLUP models are: (a) sire models, (b) sire-maternal grandsire models and (c) individual animal models. The name of the model indicates the animals for which breeding values are predicted, and the relationships used to predict them. BLUP evaluations can be performed for one trait or several traits at a time (Simm, 1998). Refer to section 2.3.1. of the literature review for further details.

8.1.2. Environmental Factors Affecting Muscle Depth

A number of studies have reported how rearing type, dam age and ram age affect muscle depth (MD). Bishop (1993), Gilmour *et al* (1994) and Saatci (1998) all found a significant effect of rearing type on MD, with single born lambs being heavier and having deeper MD than twins, and Ap Dewi *et al* (2002) reported generally high (0.20 – 0.23) litter effects. Furthermore, Gilmour *et al* (1994), Fogarty *et al* (1994), and Saatci (1998) all reported significant effects of age of dam on MD, with lambs from older dams having greater MD than lambs from younger dams. However, Ap Dewi *et al* (2002) reported a generally low (0.02 – 0.04) permanent environmental effect of dam. The effect of ram age on MD was also reported by Fogarty *et al* (1994) and Saatci (1998) who found that the older the animal, the greater the MD. However, Saatci (1998) noted that this result could have been related to lamb weight, for when weight was included as a covariate, age did not have an effect on MD.

8.1.3. Environmental Factors Affecting Milk Yield

Two documented factors affecting milk yield (MY) are lactation number and breed. Ray *et al* (1992) found lower MY in lactation one when compared to lactation four or five. Similarly, Marti and Funk (1994) observed that cows in lactation five produced some 2000kg more milk than cows in lactation one. In a study using Jersey and

Holstein cows, Gonzalez and Boschini (1996) found a significant effect of lactation number in both breeds, with Jersey cows having highest and lowest MYs at the first and sixth calvings, while for Holstein cows, for the fourth and second calvings. Similar results were reported by Özcelik and Arpacik (2000) who also found a significant effect of lactation number for Holstein cows, and the best MY being obtained in the fourth lactation. Pirzada (2001) found low yields in lactations 1 and 2, an increase from lactation 3 to 5, and a decline thereafter.

Gonzalez and Boschini (1996) also identified an effect of breed on MY, with Holstein cows having 30% greater MY/lactation than Jersey cows. This agrees with the findings by Hoekstra *et al* (1994) who observed a significant breed effect of Holstein-Friesians over Dutch Friesians by some 500 kg MY. Furthermore, Hirooka and Bhuiyan (1995) observed significant breed effects for MY across Zebu, Holstein x Zebu, Holstein x (Holstein x Zebu) and Holstein cows, with Zebu and Holstein having the lowest and highest MY, respectively. In contrast, Singh and Yadav (1999) found no significant effect of breed on monthly MY when comparing various crossbreeds of Haryana, Jersey, Swiss Brown and Danish Red.

8.1.4. Aims of Current Research

Chapter 5 examined four methods that used trait data that had not been corrected for environmental factors. Sections 8.1.2 and 8.1.3 highlight the importance of environmental factors on MD and MY, and, therefore, it is important to consider correcting records for such effects. The purpose of this chapter is to examine alternative selection methods that incorporate knowledge of environmental factors, with an aim to demonstrate how environmental factors could be taken into account when applying simplified on-farm selection procedures.

8.2. MATERIALS AND METHODS

The four methods, as defined in sections 3.2 and 5.1, were evaluated over a range of % to Selects (5, 15, 25, 35 and 45 % to Select). Refer to section 3.3 for a more detailed description of % to Select. All materials and methods were the same as those

detailed in chapter 3 and section 5.2. of chapter 5, with the exception of only using example data sets of MD and MY (section 3.1.) and applying correction factors to these data sets as detailed in sections 8.2.1. and 8.2.2. MD and MY were transformed using correction factors and each of the four methods described in sections 3.2 and 5.1 were then used to select from the transformed data. The four methods have been denoted as 1E, 2E, 3E and 4E to distinguish them as using data transformed by environmental correction factors. The methods were applied using the model described in Section 3.6. and the results analysed as described in Section 3.8.

8.2.2. Application of Correction Factors

8.2.2.1. Muscle Depth

Correction factors for Ram Age, Rearing Type and Dam Age were applied to the MD data. MD correction factors for environmental effects, for Welsh Mountain sheep, were obtained from Saatci (1998). The correction factors were applied to the data sets in a step-by-step process. For MD, there were three steps to enable the three correction factors to be applied. To achieve this, the following formulae were used:

Step 1: Correction for Ram Age

$$AMD_1 = MD - (\text{coefficient} \times (\text{Actual Age} - \text{Target Age}))$$

Where:

AMD₁ was the MD adjusted for ram age,

MD was the original MD value,

coefficient was a regression coefficient of 0.031 mm per day of age (Saatci, 1998),

Actual Age was the age of the animal whose MD value is being corrected,

Target Age was the mean of ages (393 days) from Saatci (1998).

Step 2: Correction for Rearing Type

$$AMD_2 = AMD_1 + (RT_i - 25.63)$$

Where:

AMD₂ was the MD adjusted for both ram age and rearing type,

AMD_1 was the MD value corrected for ram age,

RT_i was the mean weight of rearing type i . Mean weights were:

i	Group	Mean Weight
1	Singles	25.84
2	Twins	25.27

(Saatci, 1998)

25.63 was the data set mean (Saatci, 1998).

Step 3: Correction for Dam Age

$$AMD_3 = AMD_2 + (AG_i - 25.63)$$

Where:

AMD_3 was the MD that has been adjusted for ram age, rearing type and dam age,

AMD_2 was the MD corrected for both ram age and rearing type,

AG_i was the mean MD for age group I , where age of the dam was in years. Mean weights were:

<u>Dam Age (Years)</u>	<u>Mean</u>
2	25.18
3	25.36
4	25.71
5+	25.91

25.63 was the data set mean (Saatci, 1998).

8.2.2.2. Milk Yield

Correction factors for Breed and Lactation Number were applied to the MY data.

MY correction factors for environmental effects were obtained from Pirzada (2001).

The correction factors were applied to the data sets in a step-by-step process. For MY, there were two steps to enable the two correction factors to be applied. To achieve this, the following formulae were used:

Step 1: Correction for Breed

$$AMY_1 = MY + BCi$$

Where:

AMY₁ was the MY adjusted for breed,

MY was the original MY value,

BCi was the correction factor coefficient for breed, in litres (Pirzada, 2001).

The correction factor coefficients were:

<u>i</u>	<u>Coefficient</u>
1	38.305
2	-38.305

(Note: these coefficients represent the difference between the breed mean and the overall mean)

Step 2: Correction for Lactation Number

The following equation was used to adjust AMY, for lactation number, standardizing the MY to the fourth lactation.

$$AMY_2 = AMY_1 - LCi$$

Where:

AMY₂ was the MY adjusted for both breed and lactation number,

AMY₁ was the MY value corrected for breed,

LCi was the correction factor coefficient for lactation (Pirzada, 2001).

The lactation means (in litres) were:

<u>Lactation Number</u>	<u>Mean MY</u>
1	-1378.62
2	-408.12
3	-88.78
4	0
5	-67.62
6+	-261.42

(Note: these coefficients represent the difference between the lactation 4 MY and MY

in other lactations)

8.2.3. Computing Strategies

8.2.3.1. Muscle Depth

Within sheet 1 (Section 3.6), the original MD data was present in Column H. Three columns (I, J and K) were inserted to calculate AMD_1 , AMD_2 and AMD_3 , respectively. Sheets 2 to 6 (Section 3.6) were populated with the adjusted MD (AMD_3) data.

Correction factors and constants (as defined in Section 8.2.1.1) were entered into spare cells in sheet 1 (Appendix 1) and referenced for the correction of the MD values.

8.2.3.2. Milk Yield

Within sheet 1 (Section 3.6), the original MY data was present in Column H. Two columns (I and J) were inserted to calculate AMY_1 and AMY_2 , respectively. Sheets 2 to 6 (Section 3.6) were populated with the adjusted MY (AMY_2) data.

Correction factors and constants (as defined in Section 8.2.1.2) were entered into spare cells in sheet 1 (Appendix 1) and referenced for the correction of the MY values.

8.2.4. Data Set for Comparison of Methods Across Chapter 5 and Current Chapter

For the purposes of comparing the methods in chapter 5 with the current chapter the data sets for statistical analysis contained all results for the current chapter and the MD and MY results of chapter 5. All statistical models for the comparison of methods are detailed in section 3.8 of chapter 3.

8.3. RESULTS

The success rate (SR), proportion of the target number identified by the program (C/TN) and proportion of those selected that were correct (C/TS) were tested for normal distribution using the Anderson-Darling test (section 3.7). None of the variables had a normal distribution ($P < 0.05$) (Appendix 4). Therefore, descriptive results are shown for transformed (T) data. The data was transformed using arcsine (section 3.7). Any marked differences between un-transformed (UT) and T data are detailed in the results section. Both UT and T data are displayed within the tables but the graphs display the T results only. Further tabulated results are presented in Appendix 5.

All results are rounded up to 2 decimal places. This can result in slight discrepancies in the T data (see Section 5.3).

8.3.1. Muscle Depth

8.3.1.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed. The results are shown in Table 8.1, and the range of SR values is shown in Figure 8.1.

Methods 3E (0.78) and 4E (0.78) gave the highest mean SR, while methods 1E and 2E SR were lower at 0.65 and 0.63, respectively ($P < 0.05$). Neither methods 1E and 2E, nor 3E and 4E differed significantly from each other ($P > 0.05$). Method 2E had a higher proportion (0.20) of SR within the range of 0.90 to 1.00, while method 3E had the least (0.14).

Overall, method 3E gave the highest SR for the years 1992 (0.85) and 1993 (0.73) while method 2E was significantly higher for the years 1991 (0.84) and 1994 (0.88). Method 3E gave the highest SR for all % to Selects (25 = 0.79, 35 = 0.80, 45 = 0.84), except for 5% (method 4E = 0.82) and 15% (method 2E = 0.79). Furthermore, a % to Select of 25 gave the highest SR for the year 1994 (0.84), while % to Selects of 15 and 45 gave the highest SR for the years 1991 (15 = 0.85), 1992 (45 = 0.79) and 1993 (45 = 0.66), ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were higher than UT. For UT, method 3E achieved the highest mean SR at 15 % to Select, and a % to Select of 25 gave the highest mean SR for the year 1991 ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the correction for environmental effects for MD resulted in methods 1E, 2E and 3E improving SR by 2, 1 and 3%, respectively. Method 4E was not affected by the correction for environmental effects. A comparison of the methods showed that none of these within method improvements were significant ($P > 0.05$).

Figure 8.1. Success Rate for the Four Methods for Muscle Depth

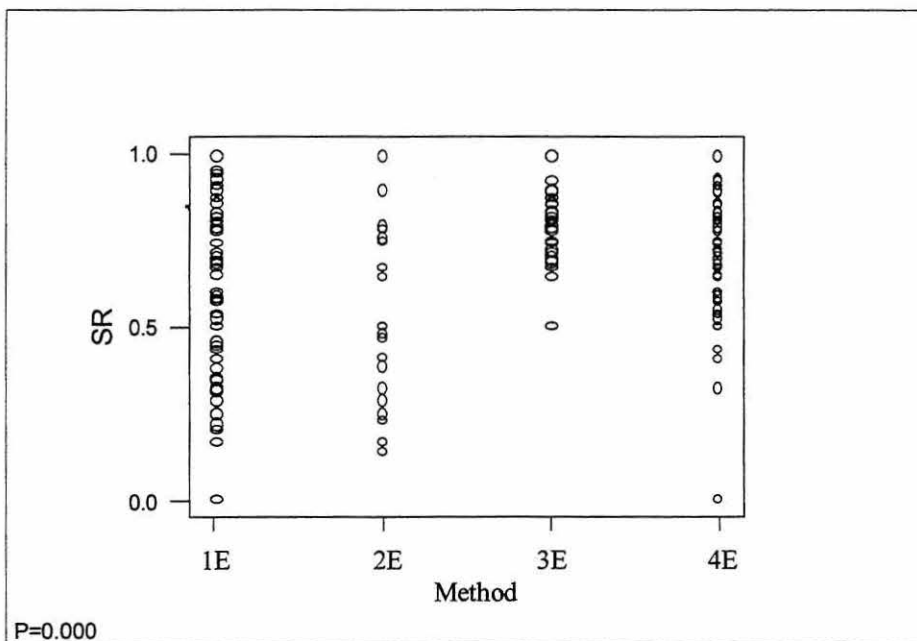


Table 8.1. Success Rate for the Four Methods for Muscle Depth

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	36.84 (8.31)	31.23 (2.67)	40.70 (3.41)	43.46 (3.59)	49.06 (4.19)	40.26 (2.22)
	T (B)	0.60	0.52	0.65	0.69	0.75	0.65
	UT	0.49 (0.09)	0.51 (0.04)	0.63 (0.04)	0.67 (0.04)	0.73 (0.05)	0.61 (0.03)
2E	T (A)	22.48 (3.67)	51.94 (9.83)	47.68 (7.95)	34.78 (3.11)	39.31 (2.83)	39.24 (2.93)
	T (B)	0.38	0.79	0.74	0.57	0.63	0.63
	UT	0.37 (0.06)	0.62 (0.10)	0.63 (0.08)	0.56 (0.04)	0.62 (0.04)	0.56 (0.03)
3E	T (A)	45.02 (5.74)	49.80 (3.36)	52.57 (1.91)	52.93 (1.98)	57.41 (3.53)	51.55 (1.63)
	T (B)	0.71	0.76	0.79	0.80	0.84	0.78
	UT	0.65 (0.05)	0.74 (0.03)	0.79 (0.02)	0.79 (0.02)	0.82 (0.02)	0.76 (0.01)
4E	T (A)	54.81 (8.34)	49.48 (4.64)	48.62 (2.38)	52.26 (2.36)	50.91 (2.25)	51.22 (2.03)
	T (B)	0.82	0.76	0.75	0.79	0.78	0.78
	UT	0.69 (0.08)	0.72 (0.04)	0.74 (0.03)	0.78 (0.02)	0.77 (0.02)	0.74 (0.02)
ALL	T (A)	39.79 (3.64)	45.61 (3.04)	47.39 (2.30)	45.86 (1.67)	49.17 (1.80)	45.57 (1.17)
	T (B)	0.64	0.71	0.74	0.72	0.76	0.71
	UT	0.55 (0.04)	0.65 (0.03)	0.70 (0.02)	0.70 (0.02)	0.73 (0.02)	0.67 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.97, 7.10 and 18.42, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.06, 0.07 and 0.19, respectively.

8.3.1.2. Proportion of the Target Number Identified by the Program (C/TN)

Significant effects ($P < 0.05$) of Method and Year were observed. Significant effects ($P < 0.05$) of all possible interactions were observed, with the exception of the interactions of % to Select x Method, and % to Select x Method x Year. The results are shown in Table 8.2, and the range of C/TN values is shown in Figure 8.2.

Method 2E (0.99) gave the highest mean C/TN, while methods 1E, 3E and 4E were lower at 0.90, 0.88 and 0.87, respectively ($P < 0.05$). Neither methods 1E and 3E, 1E and 4E, nor 3E and 4E differed significantly from each other ($P > 0.05$). Method 2E had a higher proportion (0.85) of C/TN within the range of 0.90 to 1.00, while method 4E had the least (0.40).

Overall, method 2E (1992 and 1993 = 1.00 and 1994 = 0.98) gave the highest C/TN but it was significantly lower ($P < 0.05$) than method 1E (0.99) for the year 1991. Furthermore, a % to Select of 5 gave the highest SR for the years 1991 (1.00), 1992 (0.99) and 1993 (0.97), while a % to Select of 15 gave the highest SR for the year

1994 (15 = 0.92) ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were higher than UT. For UT, a % to Select of 45 achieved the highest mean C/TN for the year 1992 ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the correction for environmental effects for MD resulted in methods 1E, 2E, 3E and 4E improving C/TN by 5, 4, 7 and 8%, respectively. A comparison of the methods showed that none of these within method improvements were significant ($P > 0.05$).

Figure 8.2. C/TN for the Four Methods for Muscle Depth

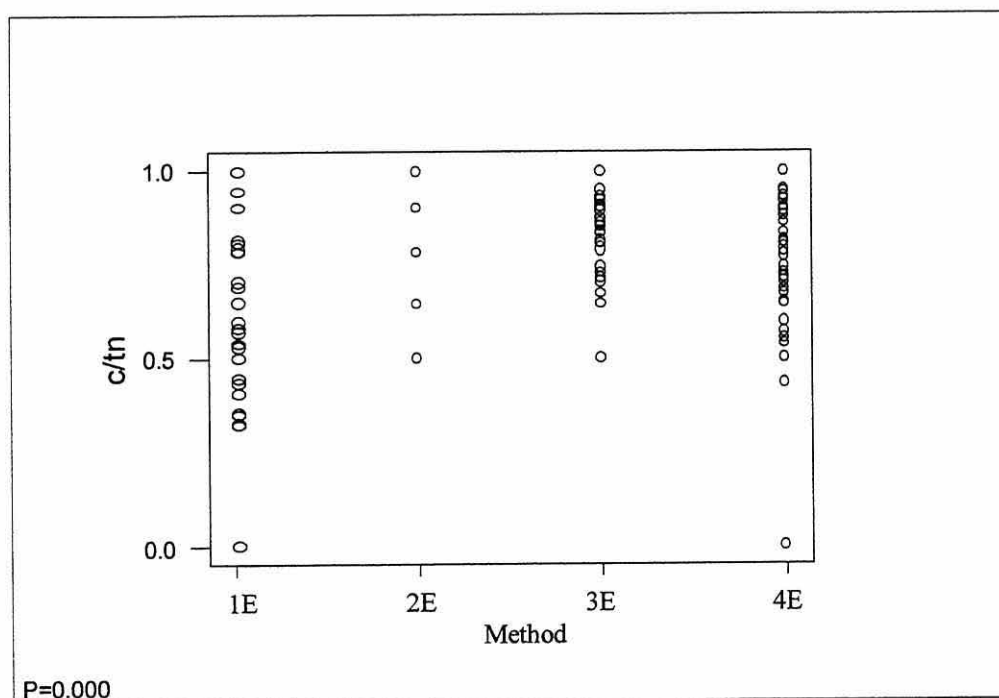


Table 8.2. C/TN for the Four Methods for Muscle Depth

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	73.13 (7.73)	62.05 (8.26)	61.88 (7.05)	62.55 (7.28)	63.64 (6.72)	64.65 (3.27)
	T (B)	0.96	0.88	0.88	0.89	0.90	0.90
	UT	0.84 (0.07)	0.75 (0.07)	0.79 (0.06)	0.78 (0.06)	0.81 (0.06)	0.79 (0.03)
2E	T (A)	75.00 (6.71)	90.00 (0.00)	83.54 (2.89)	77.45 (5.61)	80.32 (4.33)	81.26 (2.07)
	T (B)	0.97	1.00	0.99	0.98	0.99	0.99
	UT	0.87 (0.06)	1.00 (0.00)	0.97 (0.01)	0.91 (0.04)	0.94 (0.02)	0.94 (0.01)
3E	T (A)	67.50 (7.50)	64.27 (5.49)	59.00 (2.81)	57.97 (3.04)	62.45 (4.03)	62.24 (2.17)
	T (B)	0.92	0.90	0.86	0.85	0.89	0.88
	UT	0.81 (0.06)	0.84 (0.04)	0.84 (0.02)	0.83 (0.02)	0.85 (0.03)	0.83 (0.02)
4E	T (A)	73.13 (7.73)	62.26 (5.94)	56.03 (4.21)	55.71 (3.40)	54.26 (3.60)	60.28 (2.41)
	T (B)	0.96	0.88	0.83	0.83	0.81	0.87
	UT	0.84 (0.05)	0.81 (0.04)	0.79 (0.03)	0.80 (0.03)	0.79 (0.03)	0.81 (0.02)
ALL	T (A)	72.19 (3.64)	69.65 (3.19)	65.11 (2.62)	63.42 (2.72)	65.17 (2.64)	67.11 (1.34)
	T (B)	0.95	0.94	0.91	0.89	0.91	0.92
	UT	0.84 (0.03)	0.85 (0.03)	0.85 (0.02)	0.83 (0.02)	0.85 (0.02)	0.84 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.70, 9.16 and 23.77, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.07, 0.08 and 0.20, respectively.

8.3.1.3. Proportion of those Selected that were Correct (C/TS)

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method and % to Select x Method x Year. The results are shown in Table 8.3, and the range of C/TS values is shown in Figure 8.3.

Methods 3E (0.97) and 4E (0.97) gave the highest mean C/TS while methods 1E and 2E were lower at 0.90 and 0.74, respectively ($P < 0.05$). Overall, method 3E gave the highest C/TS, but it was significantly lower ($P < 0.05$) than method 4E for the years 1992 (0.98), 1993 (0.98) and 1994 (0.99), and method 2E for the year 1991 (0.99). All methods differed significantly ($P < 0.05$) from each other, except for methods 3E and 4E. Method 4E had a higher proportion (0.76) of C/TS within the range of 0.90 to 1.00 while method 2E had the least (0.35).

When compared to the results of chapter 5, the correction for environmental effects for MD resulted in methods 2E, 3E and 4E decreasing C/TS by 5, 2 and 3%,

respectively. Method 1E was not affected by the correction for environmental effects. A comparison of the methods showed that method 4E's decrease from 1.00 to 0.97 was significant ($P < 0.05$).

Figure 8.3. C/TS for the Four Methods for Muscle Depth

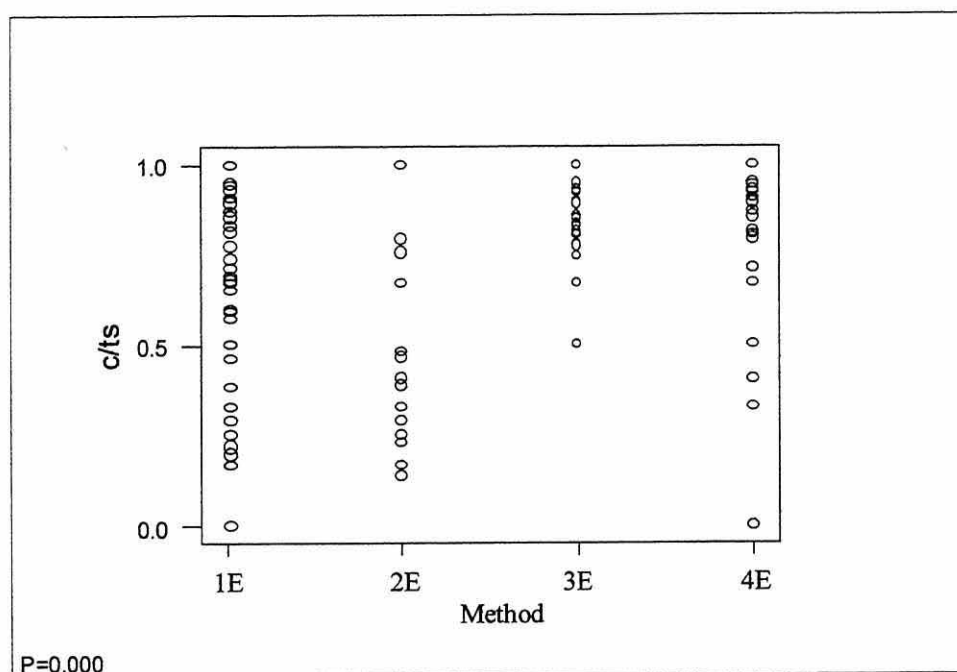


Table 8.3. C/TS for the Four Methods for Muscle Depth

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	48.09 (9.76)	59.19 (7.33)	68.82 (6.43)	70.92 (5.45)	75.43 (4.86)	64.49 (3.23)
	T (B)	0.74	0.86	0.93	0.94	0.97	0.90
	UT	0.58 (0.10)	0.76 (0.06)	0.85 (0.05)	0.88 (0.04)	0.92 (0.03)	0.80 (0.03)
2E	T (A)	37.48 (8.58)	51.94 (9.83)	54.14 (9.26)	47.34 (7.04)	49.05 (6.50)	47.99 (3.69)
	T (B)	0.61	0.79	0.81	0.73	0.75	0.74
	UT	0.49 (0.09)	0.62 (0.10)	0.66 (0.09)	0.65 (0.07)	0.68 (0.06)	0.62 (0.04)
3E	T (A)	67.52 (6.65)	72.84 (5.14)	77.82 (4.14)	78.85 (3.35)	80.15 (3.38)	75.44 (2.11)
	T (B)	0.92	0.95	0.98	0.98	0.98	0.97
	UT	0.83 (0.05)	0.90 (0.03)	0.94 (0.02)	0.96 (0.01)	0.96 (0.01)	0.92 (0.01)
4E	T (A)	66.06 (8.30)	73.99 (5.44)	77.82 (4.14)	83.48 (2.96)	83.43 (2.56)	76.96 (2.35)
	T (B)	0.91	0.96	0.98	0.99	0.99	0.97
	UT	0.79 (0.08)	0.90 (0.03)	0.94 (0.02)	0.97 (0.01)	0.98 (0.01)	0.91 (0.02)
ALL	T (A)	54.79 (4.39)	64.49 (3.69)	69.65 (3.33)	72.01 (3.00)	72.01 (2.81)	66.22 (1.59)
	T (B)	0.82	0.90	0.94	0.95	0.95	0.91
	UT	0.67 (0.04)	0.79 (0.03)	0.85 (0.03)	0.86 (0.02)	0.88 (0.02)	0.81 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across years.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 7.54, 8.96 and 23.27, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.06, 0.07 and 0.19, respectively.

8.3.2. Milk Yield

8.3.2.1. Success Rate

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of % to Select x Method x Farm. The results are shown in Table 8.4, and the range of SR values is shown in Figure 8.4.

Method 4E (0.87) gave the highest mean SR, while methods 1E, 2E and 3E SR were lower at 0.77, 0.43 and 0.81, respectively ($P < 0.05$). All methods differed significantly from each other, except for 1E and 3E ($P > 0.05$). Method 4E had a higher proportion (0.46) of SR within the range of 0.90 to 1.00, while method 2E had none (0.00). A % to Select of 45 gave the highest SR for the farms B (0.84), C (0.82) and D (0.87) while a % to Select of 35 gave the highest SR for the farm A (0.85) ($P < 0.05$).

Marked differences between UT and T data were seen. T SR results were higher than UT. For UT, all methods differed significantly from each other ($P < 0.05$) (Appendix 5).

When compared to the results of chapter 5, the correction for environmental effects for MY resulted in methods 1E, 2E and 3E decreasing SR by 1, 17 and 1%, respectively. Method 4E improved SR by 1%. A comparison of the methods showed that method 2E's decrease from 0.60 to 0.43 was significant ($P < 0.05$).

Figure 8.4. Success Rate for the Four Methods for Milk Yield

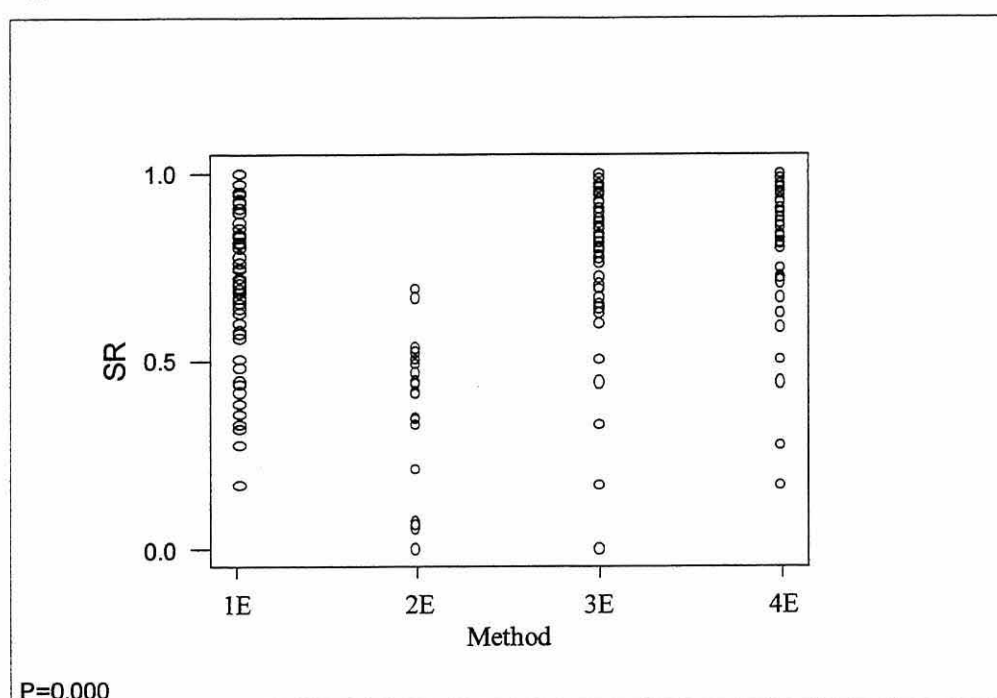


Table 8.4. Success Rate for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	32.42 (3.81)	49.62 (4.26)	54.24 (3.98)	56.43 (4.03)	59.63 (4.11)	50.47 (2.06)
	T (B)	0.54	0.76	0.81	0.83	0.86	0.77
	UT	0.52 (0.05)	0.73 (0.04)	0.78 (0.04)	0.80 (0.04)	0.83 (0.03)	0.73 (0.02)
2E	T (A)	16.74 (3.01)	22.91 (3.57)	24.26 (3.49)	29.99 (2.28)	33.92 (1.51)	25.56 (1.42)
	T (B)	0.29	0.39	0.41	0.50	0.56	0.43
	UT	0.28 (0.05)	0.38 (0.06)	0.40 (0.05)	0.49 (0.03)	0.55 (0.02)	0.42 (0.02)
3E	T (A)	28.75 (3.59)	55.71 (3.61)	57.79 (1.63)	63.13 (3.20)	65.78 (2.07)	54.23 (1.96)
	T (B)	0.48	0.83	0.85	0.89	0.91	0.81
	UT	0.47 (0.05)	0.80 (0.03)	0.84 (0.02)	0.87 (0.02)	0.90 (0.01)	0.78 (0.02)
4E	T (A)	38.66 (3.45)	66.10 (4.08)	65.61 (2.39)	65.27 (2.65)	66.37 (1.72)	60.40 (1.78)
	T (B)	0.62	0.91	0.91	0.91	0.92	0.87
	UT	0.61 (0.05)	0.88 (0.03)	0.90 (0.02)	0.89 (0.02)	0.91 (0.01)	0.84 (0.02)
ALL	T (A)	29.14 (1.97)	48.58 (2.76)	50.47 (2.46)	53.71 (2.33)	56.43 (2.09)	47.67 (1.17)
	T (B)	0.49	0.75	0.77	0.81	0.83	0.74
	UT	0.47 (0.03)	0.70 (0.03)	0.73 (0.03)	0.76 (0.02)	0.80 (0.02)	0.69 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 4.49, 5.34 and 13.87, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.06 and 0.15, respectively.

8.3.2.2. *Proportion of the Target Number Identified by the Program (C/TN)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interactions of % to Select x Method and % to Select x Method x Farm. The results are shown in Table 8.5, and the range of C/TN values is shown in Figure 8.5.

Methods 2E (0.94) and 4E (0.94) gave the highest mean C/TN, while methods 1E and 3E were lower at 0.92 and 0.89, respectively ($P < 0.05$). Methods 2E and 3E, and 3E and 4E differed significantly from each other ($P < 0.05$). Method 2E had a higher proportion (0.75) of C/TN within the range of 0.90 to 1.00, while method 3E had the least (0.51).

Overall, method 2E (farms A, B and C = 1.00) gave the highest C/TN but it was significantly lower ($P < 0.05$) than method 4E (0.92) for the farm D. Furthermore, a % to Select of 15 gave the highest C/TN for the farms B (0.98) and C (0.99), while % to Selects of 35 and 45 gave the highest C/TN for the farms A (0.97) and D (0.92), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TN results were higher than UT, and method 4E (0.89) achieved the highest mean C/TN, while method 2E (0.80) achieved the least (Appendix 5).

When compared to the results of chapter 5, the correction for environmental effects for MY resulted in methods 1E, 2E and 4E improving C/TN by 8, 1 and 3%, respectively. Method 3E was not affected by the correction for environmental effects. A comparison of the methods showed that method 1E's increase from 0.84 to 0.92 was significant ($P < 0.05$).

Figure 8.5. C/TN for the Four Methods for Milk Yield

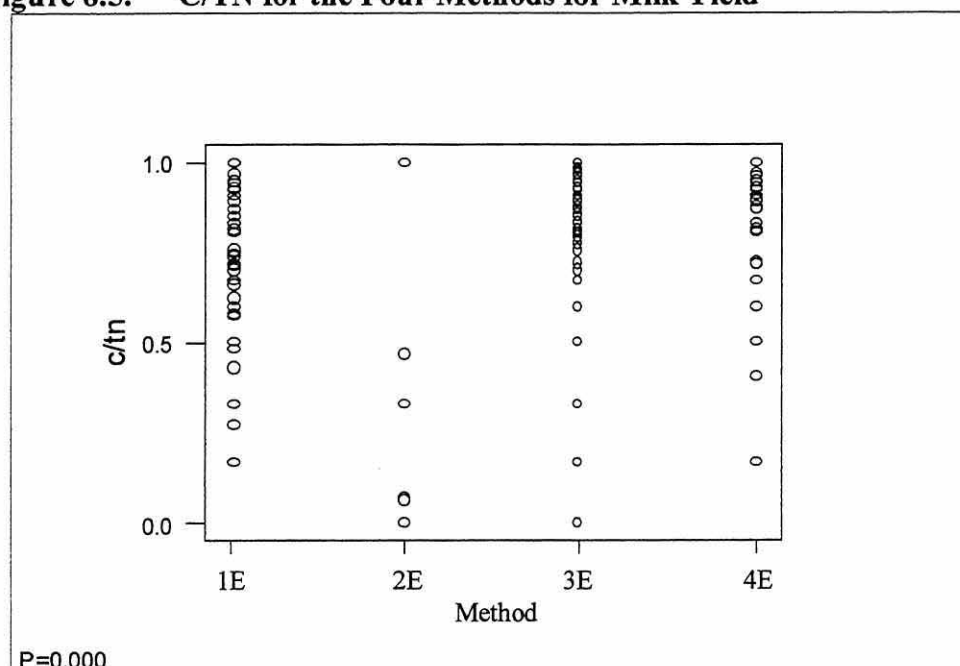


Table 8.5. C/TN for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	60.02 (7.43)	71.15 (5.67)	69.65 (5.74)	67.47 (5.36)	67.32 (5.24)	67.12 (2.62)
	T (B)	0.87	0.95	0.94	0.92	0.92	0.92
	UT	0.76 (0.07)	0.88 (0.05)	0.87 (0.04)	0.87 (0.04)	0.87 (0.04)	0.85 (0.02)
2E	T (A)	67.50 (10.06)	68.36 (9.68)	68.50 (9.61)	72.24 (7.94)	74.51 (6.93)	70.22 (3.90)
	T (B)	0.92	0.93	0.93	0.95	0.96	0.94
	UT	0.75 (0.11)	0.76 (0.10)	0.77 (0.10)	0.83 (0.07)	0.87 (0.06)	0.80 (0.04)
3E	T (A)	43.33 (7.84)	65.19 (4.10)	67.44 (3.80)	67.37 (3.73)	70.14 (3.04)	62.70 (2.37)
	T (B)	0.69	0.91	0.92	0.92	0.94	0.89
	UT	0.58 (0.08)	0.87 (0.03)	0.89 (0.02)	0.89 (0.03)	0.92 (0.02)	0.83 (0.02)
4E	T (A)	58.24 (6.97)	78.47 (3.52)	71.41 (3.35)	70.00 (3.53)	69.32 (2.89)	69.49 (2.02)
	T (B)	0.85	0.98	0.95	0.94	0.94	0.94
	UT	0.76 (0.06)	0.95 (0.02)	0.92 (0.02)	0.91 (0.02)	0.92 (0.01)	0.89 (0.02)
ALL	T (A)	57.27 (4.13)	70.79 (3.10)	69.25 (3.00)	69.27 (2.66)	70.32 (2.38)	67.38 (1.41)
	T (B)	0.84	0.94	0.93	0.93	0.94	0.92
	UT	0.71 (0.04)	0.87 (0.03)	0.86 (0.03)	0.88 (0.02)	0.89 (0.02)	0.84 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 6.60, 7.84 and 20.36, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.05, 0.06 and 0.17, respectively.

8.3.2.3. *Proportion of those Selected that were Correct (C/TS)*

Significant effects ($P < 0.05$) of Method, % to Select and Year and their interactions were observed, with the exception of the interaction of % to Select x Method. The results are shown in Table 8.6, and the range of C/TS values is shown in Figure 8.6.

Method 4E (0.98) gave the highest mean C/TS while methods 1E, 2E and 3E were lower at 0.96, 0.65 and 0.97, respectively ($P < 0.05$). Overall, method 4E (farms A and D = 0.99) gave the highest C/TS, but it was significantly lower ($P < 0.05$) than methods 1E and 3E for the farms C (0.92) and B (1.00), respectively. Neither methods 1E and 3E, nor 3E and 4E differed significantly ($P > 0.05$) from each other. Method 4E had a higher proportion (0.79) of C/TS within the range of 0.90 to 1.00 while method 2E had the least (0.20). Furthermore, a % to Select of 45 gave the highest C/TS for the farms B (0.96) and C (0.96), while % to Selects of 15 and 45 gave the highest C/TS for the farms D (0.99) and A (0.95), respectively ($P < 0.05$).

Marked differences between UT and T data were seen. T C/TS results were higher than UT. For UT, significant differences ($P < 0.05$) both within and between Method, % to Select and Year were seen. Method 4E gave the highest C/TS for farm C (0.89). Furthermore, a % to Select of 45 gave the highest C/TS for all farms (Appendix 5).

When compared to the results of chapter 5, the correction for environmental effects for MY resulted in methods 1E, 2E, 3E and 4E decreasing C/TS by 4, 14, 1 and 1%, respectively. A comparison of the methods showed that the decrease in C/TS for methods 1E and 2E was significant ($P < 0.05$).

Figure 8.6. C/TS for the Four Methods for Milk Yield

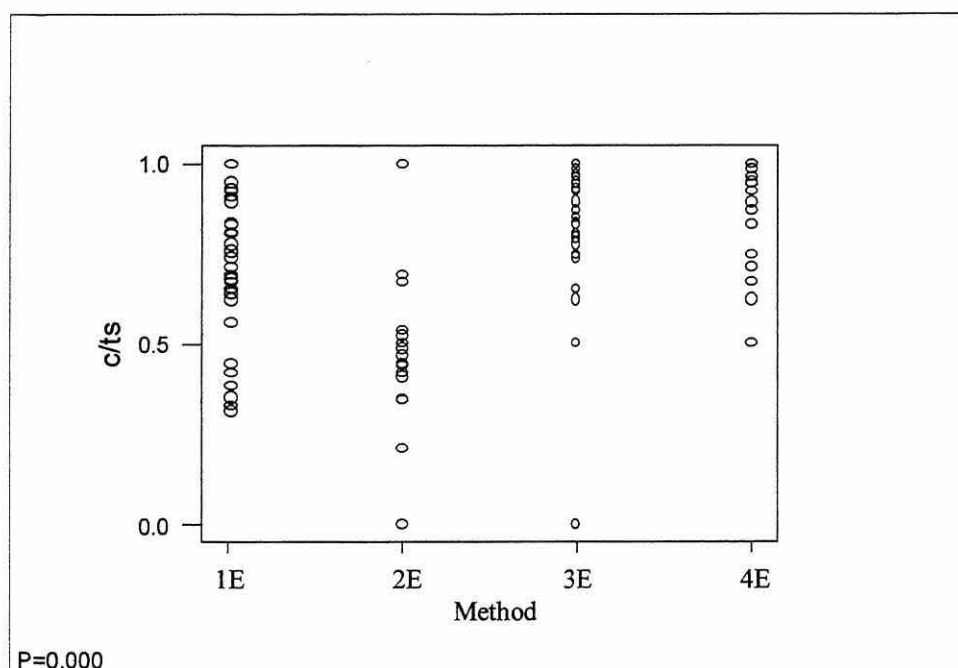


Table 8.6. C/TS for the Four Methods for Milk Yield

% to Select		5	15	25	35	45	ALL
Method		Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
1E	T (A)	62.40 (8.35)	68.47 (6.33)	74.59 (4.97)	77.70 (4.34)	82.31 (3.56)	73.10 (2.63)
	T (B)	0.89	0.93	0.96	0.98	0.99	0.96
	UT	0.75 (0.08)	0.85 (0.04)	0.91 (0.03)	0.94 (0.02)	0.96 (0.02)	0.88 (0.02)
2E	T (A)	16.74 (3.01)	44.55 (7.09)	45.75 (6.83)	47.75 (6.49)	49.41 (6.17)	40.84 (2.99)
	T (B)	0.29	0.70	0.72	0.74	0.76	0.65
	UT	0.28 (0.05)	0.61 (0.06)	0.63 (0.06)	0.66 (0.05)	0.69 (0.05)	0.58 (0.03)
3E	T (A)	64.90 (7.21)	76.33 (4.78)	77.05 (3.55)	80.98 (2.45)	82.23 (1.84)	76.30 (2.04)
	T (B)	0.91	0.97	0.97	0.99	0.99	0.97
	UT	0.81 (0.07)	0.92 (0.03)	0.95 (0.02)	0.97 (0.01)	0.98 (0.004)	0.93 (0.02)
4E	T (A)	64.42 (6.03)	76.65 (4.68)	82.84 (2.82)	84.44 (2.56)	87.13 (1.57)	79.10 (1.92)
	T (B)	0.90	0.97	0.99	0.99	1.00	0.98
	UT	0.83 (0.04)	0.93 (0.03)	0.97 (0.01)	0.98 (0.01)	0.99 (0.004)	0.94 (0.01)
ALL	T (A)	52.11 (4.07)	66.50 (3.28)	70.06 (2.96)	72.72 (2.79)	75.27 (2.64)	67.33 (1.49)
	T (B)	0.79	0.92	0.94	0.95	0.97	0.92
	UT	0.67 (0.04)	0.83 (0.03)	0.87 (0.02)	0.89 (0.02)	0.91 (0.02)	0.83 (0.01)

se = Standard Error, UT = Untransformed Results, T (A) = Transformed Data in Arc-Sine format, T (B) = Transformed Data Back-Transformed to a Proportion. Results are averaged across farms.

For T (A), the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 5.79, 6.89 and 17.88, respectively.

For UT, the least significant differences for comparison on methods, % to Select and the interaction between method and % to Select were 0.04, 0.05 and 0.13, respectively.

8.4. DISCUSSION

When compared to the results for methods 1 to 4, the modifications to the four methods to take into account environmental effects that affect MD and MY did not result in any significant ($P>0.05$) improvement in SR. Indeed, of the four methods across the two traits, the only significant finding was that for MY, where method 2E decreased SR by 17%.

8.4.1. Effects of Environmental Correction Factors - Method 1E

The results for MD showed that method 1E altered little from method 1 as a result of the environmental correction factors applied for ram age, dam age and rearing. The method increased in mean SR by 2%, with the number of SR results of 0.9 to 1.00 decreasing by 4%. A review of figures 5.1 and 8.1 shows how the application of environmental correction factors has led to a more varied range of SR results, with SR results above 0.75 being notably present. The 2% SR improvement was mainly due to the improved SR at 5 % to Select, where method 1E improved SR by 13%. This increase brought the SR result at 5 % to Select more in line with the SR results at other % to Selects. For methods 1 to 4, the range in SR across the % to Selects was from 0.47 – 0.78, while for methods 1E to 4E, the range was less at 0.52 – 0.75. Similarly, method 1E across the four years resulted in a less varied set of results, with a range of 0.52 – 0.72. Two of the years increased SR while the other two decreased, with the decreases almost cancelling out the increases obtained. The most notable year effects were the 17% increase and 10% decrease for the years 1991 and 1992, respectively. This was due to the increases in the proportion of the target number that were identified by the program (C/TN) being counter-acted by the decreases in the proportion of those selected that were correct (C/TS).

While MD SR increased by 2%, MY SR decreased by 1%. While the overall decrease for SR was observed, the number of SR within the range of 0.90 to 1.00 increased by 4%. A review of figures 5.4 and 8.4 shows how the application of environmental correction factors has led to a more varied range of SR results, with there being more SR results below 0.5 as a result of the environmental correction factor application. Unlike MD, the range of SR results across the % to Selects was greater for methods

1E to 4E (0.54 – 0.86) than for methods 1 to 4 (0.66 – 0.82), while the converse was true for the SR results across the different farms. Both the proportion of the target number that were identified by the program (C/TN) and the proportion of those selected that were correct (C/TS) behaved in the same fashion as that identified for MD above. A comparison of the C/TN and C/TS results shows that the differences in results, for methods 1 and 1E, were significant ($P<0.05$).

8.4.2. Effects of Environmental Correction Factors - Method 2E

For MD, compared to method 2, method 2E SR increased by 1%, with the number of SR within the range of 0.90 to 1.00 decreasing by 1%. A comparison of the results of methods 2 and 2E showed that this increase in SR by 1% was not significant ($P>0.05$). The increase in SR was a result of an increase in SR for the year 1994, at 25 % to Select, where an increase of 9% was observed. However, because there were nearly as many instances of SR decreasing over the other % to Selects and years, the notable increase mentioned above was counter-acted. The proportion of the target number that were identified by the program (C/TN) was very high (Figure 8.2) for method 2E (0.99), and indeed, was considerably higher than for methods 1E (0.90), 3E (0.88) and 4E (0.87). At 15 % to Select, and for the years 1992 and 1993, C/TN for method 2E was 1.00. However, because the proportion of those selected that were correct (C/TS) was much lower for method 2E (0.74) compared to methods 1E (0.90), 3E (0.97) and 4E (0.97), method 2E ranked last of all the methods (Figure 8.3). A review of figures 5.1 and 8.1 shows how the range of SR results between 0.00 to 1.00 was more varied in the current chapter.

Unlike MD, the SR result for MY showed a negative effect, with a decrease in SR by 17%. A comparison of the results of methods 2 and 2E showed that this decrease in SR was significant ($P<0.05$). The number of SR within the range of 0.90 to 1.00 decreased from 5% for method 2 to 0% for method 2E. A review of figures 5.4 and 8.4 shows how the range of SR values for method 2E was less than for method 2; with no SR values greater than 0.69 as a result of the environmental correct factor application.

A review of MY C/TN and C/TS for method 2E shows that the method decreased SR as a result of poor C/TS results. C/TN was not affected by the correction for environmental factors. Figures 5.5 and 8.5 confirm this. However, across the % to Selects, C/TS decreased in value by a range of 10 - 19%, and for the farm C, by 28%. A review of the program for farm C shows that across the % to Selects, the historical threshold was 13% to 23% lower than the true threshold value. When the method was run over the % to Selects, it was clear to see that the low historical threshold value enabled the method to over select, thus causing poor results for C/TS. A comparison of C/TS for methods 2 and 2E shows that the change in result was significant ($P < 0.05$). The poor SR (0.19) result for farm D for method 2 did not change as a result of the environmental correction factor application in method 2E.

8.4.3. Effects of Environmental Correction Factors - Method 3E

Overall, MD SR increased by 3% from 0.75 for method 3 to 0.78 for method 3E, but the proportion of SR within the range of 0.90 to 1.00 decreased by 10%. A comparison of the results for methods 3 and 3E shows that this increase in SR for MD was not significant ($P > 0.05$). A review of figures 5.1 and 8.1 shows that the application of environmental correction factors resulted in all method 3E SR values being 0.50 or above, as opposed to a wider range of SR values observed for method 3.

The main reason for SR increasing by 3% for MD was the improved result at 35 % to Select, and for the year 1994. The 17% and 20% increases in SR that these two respectively show are negated by the 5 % to Select and the years 1991 and 1993 results. The improvements in SR are a result of the improved C/TN results. At all % to Selects and for all the years, C/TN increased in value, by up to 20%. However, the decrease in C/TS at all % to Selects and for all the years, except 1994, meant that overall, the SR only improved by 3%. These conflicting results were due to the method 3E threshold values being low enough in places for the method to over-select records. However, none of the C/TN and C/TS changes between methods 3 and 3E were significant ($P > 0.05$).

For MY, the application of environmental correction factors resulted in method 3E SR

decreasing by 1% when compared to method 3. A comparison of the results for methods 3 and 3E shows that this increase in SR for MY was not significant ($P>0.05$). A review of figures 5.1 to 5.3 and 8.1 to 8.3 shows that there was no real effect as a result of the environmental correction factor application. While the overall SR decreased, the proportion of SR within the range of 0.90 to 1.00 increased by 9% from 37% to 46%. Of all the methods, this proportion of SR results within the noted range is by far the highest; method 2 did not have any SR within this range. SR decreased as a result of decreased C/TS. C/TN did not alter in value.

8.4.4. Effects of Environmental Correction Factors - Method 4E

The results of MD method 4E show that the overall SR value was unaltered as a result of correcting for environmental effects. A comparison of the results for methods 4 and 4E indeed show no significant effect ($P>0.05$) for SR or C/TN. However, the decrease by 3% of C/TS was significant ($P<0.05$). A review of figures 5.1, 5.2, 8.1 and 8.2 shows that there were fewer SR or C/TN values within the range of 0.00 to 0.50. For method 4, the % of SR and C/TN within 0.00 to 0.50 was 23% and 22%, respectively, while for method 4E, only 10% and 6% were within the range. This shows that while the overall SR did not change, the range of SR values lessened enough for only 10% of the SR results falling below a SR of 0.50. A clear difference in results can be seen for C/TS when reviewing figures 5.3 and 8.3. The correction for environmental factors has resulted in a much more varied set of C/TS values; with a 15% decrease in SR values of 1.00.

For MY, the overall SR increased by 1% for method 4E when compared to method 4. Any differences between SR, C/TN and C/TS of methods 4 and 4E were not significant ($P>0.05$). A review of figures 5.4 to 5.6 and 8.4 to 8.6 clearly shows how the correction for environmental factors has removed any SRs of 0.00. The increase in SR was achieved due to the increase in C/TN, which was high enough to counteract the decrease in C/TS.

8.4.5. Chapter Conclusions

The results indicate that adjusting records of performance for known environmental effects does not alter the data enough to cause the methods to significantly improve in their SR. This result was not unexpected considering that the actual data set is used, for methods 1E, 3E and 4E, in order to calculate the method thresholds. However, although SR did not alter significantly, it does not mean that different animals were not selected. More, it shows how these methods are not detrimentally affected by corrected MD or MY data. That method 2E SR decreased by 17%, when compared to method 2, for MY ($P < 0.05$) would suggest that the correction for environmental effects meant that the data set changed significantly enough to be further away from the historical threshold value that was used. Therefore, it would not be appropriate to use method 2E in practice.

The objective of this chapter was to demonstrate how environmental factors could be corrected for in on-farm selection procedures. The results for methods 1E, 3E and 4E show that it is possible to correct for environmental factors without significant effects on SR, but the additional workload (to identify environmental factors) may not be justified if SR is not substantially improved.

The results of this chapter show that method 4E followed by method 3E for MY and either methods 3E or 4E for MD would be the most appropriate methods to use. Refer to chapter 9 for discussion on the practical application of correcting for environmental effects.

In summary, the findings of this chapter, compared to those of chapter 5 can be expressed with the following rankings:

MD: $4E = 4 = 3E > 3 > 1E > 1 = 2E > 2$

MY: $4E > 4 > 3 > 3E > 1 > 1E > 2 > * 2E$

Where: E represents methods using data corrected for environmental effects (current chapter). All other entries relate to the results of chapter 5.

* indicates a significant difference between the methods either side of its entry

CHAPTER 9 GENERAL DISCUSSION

The objectives of this study were to examine four methods for the selection of animals for future breeding, in flocks/herds where animals are not uniquely tagged. Animals were selected when their recorded trait value was on or above a threshold value calculated by the method. Each of the methods obtained their threshold values, over the % to Selects, in different ways (section 3.2). Modifications to the methods based on characteristics of the data or background information on the animals were also examined where appropriate (chapters 6 to 8), with the success rate (SR) of the modified methods compared to the SR of the methods in their original format (chapter 5). The four methods were evaluated using example data for three contrasting traits, namely Muscle Depth (MD), Milk Yield (MY) and Ovulation Rate (OR).

9.1. COMPARISON OF METHODS AND FACTORS AFFECTING SUCCESS RATE

9.1.1. Comparison of Method Performance

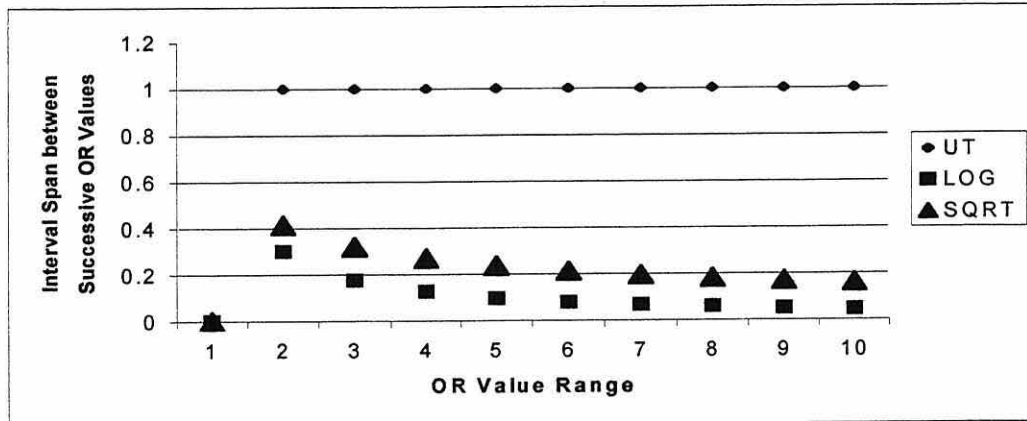
The SRs of the methods for each of the chapters are shown in Table 9.1. With the exception of OR, the SR results for the methods were within the expected ranking, with method 4 achieving the best SR, followed by method 3. Both of these methods updated the threshold value as each record was entered. The highest SRs were achieved for methods 3, 4, 3E and 4E applied to MY. The lowest SR was achieved for method 2M for OR trait data.

Overall, the SR was highest for MY, followed by MD and then OR. The modifications made to the methods (chapter 6) or to trait data (chapters 7 and 8) did result in some significant differences ($P < 0.05$) between the results of chapter 5 and the respective chapter. However, all but one of these significant differences was for where SR had decreased (Table 9.1).

To eradicate the possibility of extreme historical data being used for methods 2 and 3, the methods were modified. As opposed to using historical data, the methods used the minimum and maximum trait values of the data set in use in order to calculate the mean, standard deviation and hence the threshold values (chapter 6). Modification showed a variety of results. For MY, the modifications resulted in the SR values for both methods 2M and 3M improving on methods 2 and 3, respectively, particularly method 2M which had an increased SR by 12%. The modification was less successful for MD, with method 2M increasing on method 2 by only 1% and method 3M decreasing in SR value. Modification resulted in a worsening of SR for both of these methods for OR, particularly method 2M which significantly decreased by 49% when compared to method 2 ($P < 0.05$).

Log (L) and square root ($\sqrt{}$) transformations on the original raw OR data were performed in an attempt to improve the SR, since the underlying theory assumes the data to be normally distributed. Acknowledging that the raw OR data did not conform to a normal distribution, the transformation of the data, using L and $\sqrt{}$ (chapter 7) was performed. $\sqrt{}$ was suitable as the data was in the form of small, whole numbered counts (Parker, 1973) and L was used as the data graphically illustrated itself as a parabolic shape (Appendix 7) (Dowdy and Wearden, 1983). The SR results for methods $1\sqrt{}$, 1L, $3\sqrt{}$, 3L, $4\sqrt{}$ and 4L were favourable, though not significant ($P > 0.05$), in that they identified that the transformation of the data that was not normally distributed did not have a significantly negative effect on SR. While not significant ($P > 0.05$), the transformations resulted in the SR for methods $2\sqrt{}$ and 2L being 26% and 31% lower, respectively, than method 2. Using either $\sqrt{}$ and L resulted in the interval between a transformed OR value and its next value decreasing with increasing OR value (Figure 9.1). This meant that the calculated threshold value was less likely to be much too high or low for an OR value to be selected throughout the updating process.

Figure 9.1. A Comparison of the Interval Span between Successive OR (sorted in ascending order) Values For Untransformed, Logged and Square Rooted OR



The first value for each of the legends is 0, as the value has no previous value to compare itself to. UT = Untransformed (Chapter 5), Log = Logged OR, SQRT = Square Rooted OR (Chapter 7)

Correcting for environmental effects is a recognised procedure (Bourdon, 1997). Conceptually, it is sensible to correct for known environmental effects, and correcting for such effects within the methods demonstrated that it was possible to do so in practice. Correction factors obtained from Saatci (1998) and Pirzada (2001) were used to adjust the trait data (chapter 8). Correcting the data did not negatively impact the SR for MD or MY, but for both traits, none of the increases in SR when compared to chapter 5 were significant. The largest increase observed was for method 3E for MD. The decrease in SR by 17% for method 2E, when compared to method 2, MY was significant ($P < 0.05$).

Table 9.1. Summary of Success Rate by Trait, Method and Chapter

Trait/ Method		Chapter				
		5	6	7 ($\sqrt{\cdot}$)	7 (log)	8
MD	1	0.63				0.65
	2	0.62	0.63			0.63
	3	0.75	0.68			0.78
	4	0.78				0.78
MY	1	0.78				0.77
	2	0.60	0.72 *			0.43 *
	3	0.82	0.85			0.81
	4	0.86				0.87
OR	1	0.64		0.64	0.67	
	2	0.73	0.24 *	0.47 *	0.42 *	
	3	0.63	0.59	0.72	0.64	
	4	0.60		0.72	0.70	

MD = Muscle Depth, MY = Milk Yield, OR = Ovulation Rate $\sqrt{\cdot}$ = Square Root Transformation
 * indicates a significant difference in result between the asterisked value and that for chapter 5.

9.1.2. Factors Affecting Method Performance

9.1.2.1. Example Data Set Characteristics - Normal Distribution

When large data sets are displayed in the form of frequency histograms, they often approximate a bell-shaped (normal) distribution (Lynch and Walsh, 1998). Both MY and MD conformed to the normal distribution, but OR did not (Section 7.1. and Figure 7.1.). OR, as a trait, has a tendency towards a skewed distribution (Dowdy and Wearden, 1983; Simm, 1998), as illustrated by Figure 7.1.

If a data set is normally distributed, then it is more likely that a sub-set drawn at random from the population is normally distributed if the data set is big (Lynch and Walsh, 1998). For a trait like OR, it is still likely to be non-normal even if the data set is very big, e.g. if OR was measured in 10,000 sheep, it is likely that there would be many with OR counts of 1 to 3, and relatively few with OR counts greater than 5. Of the three traits, MY had the highest average SR values for methods 1, 1M, 1E, 3, 3M, 3E, 4, 4M

and 4E (Table 9.1), within a range of 0.77 to 0.87. Methods 1 and 1E results for MY were comparable to methods 3, 3E, 4 and 4E results for MD (Table 9.1). Both MD and OR highest SRs were considerably lower at 0.78 and 0.73, respectively. The high SR results for MY could be attributed to the greater extent to which the data was normally distributed.

9.1.2.2. Example Data Set Characteristics-Effects of Year/Farm

There was only one instance where the effect of year/farm was not significant for SR ($P>0.05$), and that was for MY in chapter 6. The most notable difference in SR, for all of the traits, across the years/farms within any individual chapter were for method 2. In some cases (e.g. MD 1991 and 1994, chapter 5 and 8; OR 1988, 1991 and 1992, chapters 5 and 7) the data set threshold values over the % to Selects were similar to the historical threshold values at the same % to Selects. The variation in the data across the years/farms was sufficient enough for the actual data set threshold values (e.g. MD 1992 and 1993, chapters 5 and 8; OR 1989, chapter 5 and 7) to differ vastly from the historical threshold values. The mean SR results for the years 1992 and 1993 were lower than for the years 1991 and 1994, for chapters 5, 6 and 8.

Of the three traits, OR showed the greatest differences across the years. For OR, there was a marked difference between the true and historical data set threshold values for the years 1989 (chapter 5 and 7), and 1988, 1989 and 1991 (chapter 6), for all % to Selects. The lowest SR obtained was 0.11, for method 2M, for the year 1991. Here, the historical threshold value was 50% lower than the true data set threshold value, at 45 % to Select. Interestingly, as the % to Select increased, the difference between the historical and true data set thresholds increased, too. This was because the true threshold value decreased through increasing % to Select, as did the historical threshold, but, the historical threshold decreased more quickly. The findings for MD were similar, with marked differences between the true and historical data set threshold values for the years 1991 and 1993, for all % to Selects. For the year 1993 and at 45 % to Select, the historical threshold value was 13% lower than the true data set threshold value. These observations for OR and MD were, but to a lesser extent, essentially the same for the

farms for MY.

The refinement of methods 2 and 3 to obtain 2M and 3M, respectively, by using the minimum and maximum trait values of the data set (Clegg, 1988) in order to calculate the historical thresholds (over the % to Selects) did result in the differences between the different years/farms being less so. As noted above, the effect of farm was not significant ($P>0.05$) for chapter 6 MY. The low method 2M SR results for OR are discussed in chapter 6, sections 6.4.1 and 6.4.2.

A method's good success when using historical data is reliant on the historical data being of a similar mean and standard deviation to that of the records being measured. The above discussion notes how method 2's SR was affected due to the large differences found between the historical data and the data set in question. When the minimum and maximum values were used for the calculation of method 2M's threshold, threshold values that were too high were obtained in the case of OR because of the range and frequency of the data (Figure 7.1).

9.1.3. Overall Summary

Overall, across the different traits, methods 4, 4√, 4L and 4E had the highest SR. Table 9.1 shows that for MY and OR, method 4 improved by correction for environmental effects (MY) (Simm, 1998) or transformation of non-normal data (OR) (Parker, 1973; Dowdy and Wearden, 1983). However, the correction for environmental effects for MY only resulted in an increase in SR by 1%, and for MD, the SR result was unaltered. Such correction greatly increases workload since farmers would have to devise some way of recording environmental factors (Simm, 1998), some of which may be difficult without animal ID e.g. age. Method 4 could be set as the standard with the possibility of adjusting for environmental factors if information on environmental factors is available, and if the effects of the environmental factors are likely to be significant, e.g. where there is a group consisting of two breeds or a mixture of ages.

Method 1, 1√, 1L and 1E results were affected, in part, by the sampling threshold value obtained from the 10% sample for each data set. Sampling was based on a random sampling regime (Snedecor and Cochran, 1967; Senter, 1969; Downie and Heath, 1974), but the fact that it is a random sample does not alleviate the fact that the sample may have too many high or low values. The method did not benefit from the threshold value being updated.

A level of caution should be applied to skewed data such as that shown by the OR data in this research project. While the SR results did improve with transformation of original OR data, this data did not achieve a normal distribution.

The application of the techniques depends on the complexity of the recording process and the number of animals. For example, laparoscopy is likely to be used in small groups and is time consuming. Furthermore, individual identity for each animal in small groups is unlikely to be a major restriction. In contrast, with weighing of large numbers of non-uniquely tagged lambs, the techniques would be very appropriate. Table 9.2 lists both the advantages and disadvantages for each of the methods.

Compared to fully recorded schemes presently in operation (e.g. Sheepbreeder) (Simm, 1998), simplified recording like the methods of this research would allow for low-cost recording, no need for tagging/pedigree recording and the techniques used would allow farmers to be introduced to technologies (e.g. MD ultrasonic scanning, OR evaluation using laparoscopy equipment). However, the disadvantages include that these methods are not as accurate as BLUP/EBVs (Simm, 1998; Van Arendonk *et al*, 1994), and may mislead farmers (i.e., why should they record pedigrees if a computer gives them an answer without pedigree recording?). The adoption of these methods in a commercial environment is discussed in section 9.2.

Table 9.2 The Advantages and Disadvantages of the Methods

METHOD	ADVANTAGES	DISADVANTAGES
1	<ul style="list-style-type: none"> • Can give good estimate of threshold. • Would not be affected by the order in which animals are recorded, since the threshold is the same from start to finish. 	<ul style="list-style-type: none"> • Sampling is time-consuming and may not be practical for traits such as OR. • The random sample for the sampling may not necessarily be a true reflection of the entire herd/flock, resulting in a sample threshold value that is too high or low.
2	<ul style="list-style-type: none"> • A quick method. • Does not need complex on-farm computing 	<ul style="list-style-type: none"> • Reliant on historical data availability (not applicable to 2M). • Threshold may be unreliable if the historical data greatly differs from the actual data being recorded (not applicable to 2M). • For method 2M, the minimum and maximum values may be very extreme resulting in an unrealistic mean and standard deviation.
3 and 4	<ul style="list-style-type: none"> • Likely to be more reliable than methods 1 and 2 due to the threshold value updating as each animal is measured. • Will eventually reach a very good estimate of threshold. 	<ul style="list-style-type: none"> • Ideally these methods need a computer. A scientific calculator would be possible, but: the process would be slow, the user would require a certain level of expertise, and it would be easy to lose stored values. A robust portable PC/hand held device would be preferable. • Reliability depends on the order of the animals. A lot of high results being recorded first would lead to errors. • Method 3 is reliant on historical data availability.

Method numbers 1, 2, 3 and 4 also relate to methods ending in M, $\sqrt{}$, L and E

9.2. DEVELOPMENT AND APPLICATION

9.2.1. Uptake of Simplified Recording in a Commercial Environment

Hill farming and rangeland production systems operate in areas with marginal land that is not generally suitable for crop, or in some instances, dairy production. In addition to constraints on agricultural production, such areas are associated with other issues including low farmers' incomes, rural depopulation and even environment/landscape protection (Ap Dewi, 1999).

Anderson (2001) noted that the uptake of genetic improvement schemes in hill areas of the UK had been limited through a lack of knowledge of the available technology and the potential benefits. There are approximately 700 flocks recording under Sheepbreeder (Signet, 2001). This includes Terminal Sire breeds (e.g. Suffolk, Texel, Charollais), Crossing Breeds (e.g. Blue Faced Leicester, Border Leicester), Maternal Breeds (e.g. Lley, Dorset) and Hill Breeds (e.g. Blackface, Cheviots, Beulah, Welsh Mountain). The hill breeds tend to be recorded under one of the three "strategies" - Welsh Sheep Strategy, Highlands and Islands Sheep Strategy and Northern Uplands Sheep Strategy. Recording under such a scheme means the breeder pays a heavily subsidised fee, or no fee, direct to Signet. Due to the problems breeders have in recording and tagging large numbers when lambing in hill situations, most hill breeders only record a nucleus flock set up on each farm and so the "whole" sheep flock is rarely recorded. There are approximately 265 flocks recording hill breeds in the UK and the average recorded flock size is approximately 120 ewes. The actual whole flock size on farm would be much larger.

These strategies are geared around formal recording schemes requiring tagged animals. Such schemes may increase the divide between those who record and those who do not. There currently isn't an intermediate stepping stone. The methods of this research are not deemed to be an alternative to formal schemes. However, they could be used in situations where there is no formal recording (e.g. range cattle) and low-cost input is imperative. They could be offered as part of a programme for farmers who don't record, to encourage them to join formal schemes or to allow them to record part of a herd/flock and apply simplified recording in another part (e.g. large sheep flocks). Another possibility is to use the techniques as the basis for introducing farmers to a new technology (e.g. ultrasonic scanning) (Pagot, 1992; Simm, 1998).

In terms of application of the methods for the traits in the current research, there would be minimal extra effort required. For both MD and OR, whether for ultrasonic scanning (MD) or performing a laparoscopy (OR), the animal would have been captured anyway. Upon obtaining each individual MD, for example, it would be possible to colour code

those animals to be selected. The methods can equally be applied to, for example, weights in range managed cattle or MY in test-day records of cattle milk production.

In practice, any correction for environmental effect could be programmed into the computer system (Simm, 1998), so all the farmer would need to do is enter the species/breed and trait for which environmental correction is required. Similarly, where a computer is not available, sheets with threshold values could be produced, with appropriate thresholds for different categories of animals.

In order to adopt methodologies, such as those researched here, there are different ways in which a farmer could be supported for example: A. Advice – this is an effective mechanism where the farmer agrees that extension is required in the existing market and the farmer is confident that the extension tool will benefit the farm and provide a solution to the specific problem (Van Den Ban and Hawkins, 1988). B. Increasing a farmer's knowledge - the farmer may lack the knowledge of what schemes are available or may lack the knowledge and insight to recognise their problems, to think of a possible solution, or to select the most appropriate solution to achieve their goals (Anderson, 2001; Van Den Ban and Hawkins, 1998).

Knowledge can be increased by providing the farmers with a background to why these methods are being promoted. These methods: are low-cost and quick alternatives to large group breeding schemes/cooperatives; they benefit those farmers where animals are not uniquely identifiable through a tag; they are suitable for situations where there is no formal recording at present; they could enable small-holdings and lower income farms to begin selecting their top performing animals; they could act as an introduction to new technology and where offered as part of a programme for farmers who don't currently record, the benefit of selection would encourage them to join formal schemes. Prior to and during uptake of the methods, advice would be provided as how to use the methods, with possible training sessions for individual farmers or regions as a whole being provided.

9.2.2. Future Investigations of Methods

To date, these methods have been examined over three traits from data sets supplied by academic/livestock departments. These methods now require further testing. This should include:

- The testing of the methods over a wider range of traits and species, for example: goats, camels, beef cattle, pig meat, sheep wool, buffalo milk/meat.
- The methods should be tested in the field with a wide range of traits. Field trials are required as practical hindrances may have been overlooked and these would need to be tackled. For example, there may be instances where it is not possible to use a calculator/PC. In such cases, an alternative would need to be used. One such example could be the use of detailed sheets with step-by-step instructions. These sheets would include % to Select, sample size and sample size threshold value. Methods 3 and 4, would need some 'electronic method'. The need to test the adoption of the concepts in the commercial environment, taking into account any cost, practical and technical (computing) implications involved. Only in time would it be possible to see whether the use of such methods help in the adoption of full-scale breeding schemes by farmers.

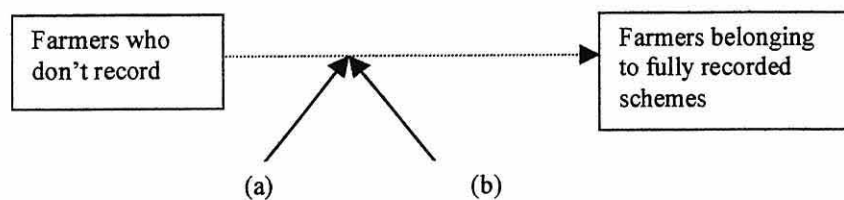
9.3. GENERAL CONCLUSIONS

- The results demonstrate that consistently good SR (>0.78 for MD and MY) can be obtained using methods 4 and 4E. Method 4 could be used as the standard with the possibility of adjusting for environmental factors if information on environmental factors is available. For a low-tech method, methods 1 or 2 could be used if the sampling/historical values are reliable.
- The results further demonstrate that correcting for environmental effects did not significantly affect the results for methods 4E, 3E and 1E.
- The results show that the methods are inappropriate for some traits (i.e. OR). OR data can be skewed with most of the data values in the lower region of the scale (Figure 7.1). When a threshold value is obtained using values from the upper

range, it results in a threshold that is too high for the majority of the OR data. This results in low SR rates of the methods.

- The methods have a built in flexibility. As such, a farmer is able to specify what percentage of the top best performing animals are to be selected.
- The methods benefit large herds/flocks.
- The methods could be applied as one of two concepts:

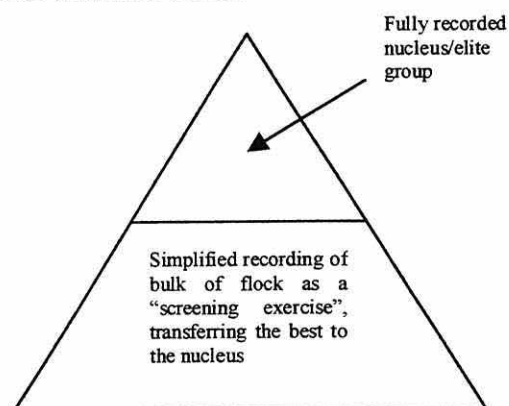
○ Acting as a Continuum



The methods could be an intermediate stage with options:

- (a) No environmental correction
- (b) With environmental correction

○ In One Herd or Flock



- The two above noted concepts could be applied to hill farming in the UK and rangeland production systems throughout the world, including developing countries.
- The methods offer a stepping stone for knowledge. Farmers would realise the benefits of recording their herd/flock data, would obtain knowledge from

participating in such a scheme and could then become involved in fully recorded breeding schemes.

- Participation in such a scheme would have low-cost implications. This would be particularly the case for farmers who use the sheet scheme as opposed to computing technology.

REFERENCES

- Acciaoli, A., Franci, O., Pugliese, C., Parisi, G. and Lucifero, M. (2000) Variation and repeatability of a.m. and p.m. records for milk yield and composition in Massese ewes. *Zootecnica e Nutrizione Animale*, **26**: 253 – 262
- Abdel-Aziz, M (1994) Evaluation of some environmental factors affecting weaning weight of Rahmany and Barki lambs. *Alexandria Journal of Agricultural Research*, **39**: 149 - 166
- Akhtar, S., Gardner, I.A., Hird, D.W. and Holmes, J.C. (1988) Computer simulation to compare three sampling plans for health and production. *Preventive Veterinary Medicine*, **6**: 171 - 181
- Anderson, J (2001) Sheep Strategies. www.mlc.org.uk
- Anderson, S.M., Mao, I.L. and Gill, J.L. (1989) Effect of frequency and spacing of sampling on accuracy and precision of estimating total lactation milk yield and characteristics of the lactation curve. *Journal of Dairy Science*, **72**: 2387-2394
- Ap Dewi, I. (1999) Sheep production systems: problems and opportunities. Sheep Production in the North Aegian Sea – Problems and Opportunities Conference. Kalloni, Lesbos, Greece, 103 - 111
- Ap Dewi, I., Owen, J. B., El-Sheikh, A., Axford, R. F. E. and Beigi-Nassiri, M. (1996) Variation in ovulation rate and litter size of Cambridge sheep. *Animal Science*, **62**: 489 - 495
- Ap Dewi, I., Owen, J.B. and Williams, G.L.I. (1990) An analysis of ultrasonic fat and muscle measurements in hill ewe and ram lambs. In: *New Developments in Sheep Production*. Occasional Publication No. 14 British Society of Animal Production 1990 (Ed. C.F.R. Slade and T.L.J. Lawrence) pp 176 – 181.
- Ap Dewi, I., Saatci, M. and Ulutas, Z. (2002) Genetic parameters of weights, ultrasonic muscle and fat depths, maternal effects and reproductive traits in Welsh Mountain sheep. *Animal Science*, **74**: 399 - 408
- Ashmawy, A.A. (1990) Selection subindices for improvement of milk, fat or protein yield in Holstein-Friesian cows. *Egyptian Journal of Animal Production*, **27**: 185 - 194
- Avadesian, G. A. (1996) Some factors influencing part and total milk yields in Iraqi buffaloes. *Agricultural Sciences*, **23**: 89 – 93
- Barillet, F. (1985) Genetic improvement of milk composition in ewes. The example of the Lacaune breed. PhD Thesis, Paris-Grignon.

- Bayley, N.D., Liss, R.M. and Stallard, J.E. (1952) A comparison of bimonthly and quarterly testing with monthly testing for estimating dairy cattle production. *Journal of Dairy Science*, **35**: 350
- Behnke, R. H., Jr. (1985) Measuring the benefits of subsistence versus commercial livestock production in Africa. *Agricultural Systems*, **16**: 109 – 135
- Bishop, S. C. (1993) Selection for predicted carcass lean content in Scottish Blackface sheep. *Animal Production*, **56**: 379 - 386
- Bishop, S.C., Conington, J., Waterhouse, A. and Simm, G. (1996) Genotype x environment interactions for early growth and ultrasonic measurements in hill sheep. *Animal Science*, **62**: 271 - 277
- Bolgiano, D. C., Van Vleck, L. D. and Everett, R. W. (1979) Fluctuations in sire evaluations. *Journal of Dairy Science*, **62**: 760 - 767
- Bourdon, R.M. (1997) Understanding Animal Breeding. Publ. Prentice Hall.
- Bradford, G. E., Quirke, J. F. and Famula, T. R. (1986) Fertility, embryo survival and litter size in lines of Targhee sheep selected for weaning weight or litter size. *Journal of Animal Science*, **62**: 895 – 904
- Brash, L.D., Fogarty, N.M. and Gilmour, A.R. (1994) Reproductive performance and genetic parameters for Australian Dorset sheep. *Australian Journal of Agricultural Research*, **45**, 427 – 441
- Brash, L. D., Fogarty, N. M., Gilmour, A. R. and Luff, A. F. (1992) Genetic parameters for liveweight and ultrasonic fat depth in Australian meat and dual-purpose sheep breeds. *Australian Journal of Agricultural Research*, **43**: 831 - 841
- Bunge, R., Thomas, D. L. and Nash, T. G. (1993) Performance of hair breeds and prolific wool breeds of sheep in southern Illinois: lamb production of F1 ewe lambs. *Journal of Animal Science*, **71**: 2012 - 2017
- Cameron, N. D. (1992) Correlated responses in slaughter and carcass traits of crossbred progeny to selection for carcass lean content in sheep. *Animal Production*, **54**: 379 - 388
- Cameron, N. D. and Bracken, J. (1992) Selection for carcass lean content in a terminal sire breed of sheep. *Animal Production*, **54**: 367 - 377
- Carrick, M. J., Oldham, C. M. and Lindsay, D. R. (1976) The repeatability of ovulation rate in Merino ewes. *Proceedings of the Australian Society of Animal Production*, **11**: 125 – 128
- Casu, S. and Labussiere, J. (1972) Premiers résultats concernant la suppression d'une ou plusieurs traits par semaine chez le brebis sarde. *Annals Zootech.* **21**: 223 - 232

- Clegg, F. (1988) Simple Statistics. A Course Book for the Social Science. . Publ. Cambridge University Press.
- Cobby, J. M. and LeDu, Y. L. P. (1978) On fitting curves to lactation data. *Animal Production*, **26**: 127 - 133
- Cobuci, J.A., Euclides, R.F., Verneque, R. da., Teodoro, R.L., Lopes, P. de S and Almeida e Silva, M. de (2000) Lactation curve in Guzera breed. *Revista Brasileira de Zootecnia*, **29**: 1332 - 1339
- Congleton, W.R. Jr. and Everett, R.W. (1980) Error and bias in using the incomplete gamma function to describe lactation curves. *Journal of Dairy Science*, **63**: 101 - 108
- Conington, J., Bishop, S.C., Waterhouse, A and Simm, G. (1995) A genetic analysis of early growth and ultrasonic measurements in hill sheep. *Animal Science*, **61**: 85 - 93
- Conington, J., Bishop, S.C., Waterhouse, A and Simm, G. (1998) A comparison of growth and carcass traits in Scottish Blackface lambs sired by genetically lean or fat rams. *Animal Science*, **67**: 299 - 309
- Cooper, J.B. and Hargrove, G.L. (1982) Age and month of calving adjustments of Holstein protein, milk, and fat lactation yields. *Journal of Dairy Science*, **65**: 1673 - 1678
- Croston, D., Kempster, A.J., Guy, D.R. and Jones, D.W. (1987) Carcass composition of crossbred lambs by ten sire breeds compared at the same carcass subcutaneous fat proportion. *Animal Production*, **44**: 99-106
- Davis, G.H., Montgomery, G.W. and Kelly, R.W. (1982) Estimates of the repeatability of ovulation rate in Booroola cross ewes. 2nd World Congress on Genetics Applied to Livestock Production, 4-8 October. 8. Symposia (2), 674 - 679
- DEFRA (2001) www.defra.gov.uk
- Dimitrov, I. (1978) Selection characters of Ile-de-France sheep in Bulgaria. 1. Ewe fertility, growth and meat production of lambs. *Zhivotnov"dni-Nauki*, **51**: 58-67
- Dommerholt, J. (1975) Correction of cows' milk yield for differences in age, season and stage of lactation. *Agricultural Research Reports*, 844
- Dowdy, S. and Wearden, S. (1983) Statistics for Research. Publ. John Wiley & Sons
- Downie, N.M. and Heath, R.W. (1974) Basic statistical methods, 4th Edition. Publ. Harper and Row.

- Fadel, I., Owen, J. B., Kassem, R. and Whitaker, C. J. (1989) Aspects of the lactation curve in the Awassi ewe under semi-arid conditions and the development of simplified milk recording. *Research and Development in Agriculture*, **6**: 169 - 176
- Fahmy, M.H. (1989) Repeatability of ovulation rate, number of lambs born and ova loss in sheep with different ovulation rates. *Canadian Journal of Animal Science*, **69**: 307 - 314
- Falconer, D.S. (1989) Introduction to Quantitative Genetics, 3rd Edition. Published by Longman Scientific and Technical
- Falconer, D.S. and Mackay, T.F.C. (1996) Introduction to Quantitative Genetics, 4th Edition. Published by Langman
- Famula, T. R. and Van Vleck, L. D. (1981) Sire evaluation by only extended partial milk and fat records. *Journal of Dairy Science*, **64**: 484 - 490
- Ferreira, G.B. and Fernandes, H.D. (2000) Genetic parameters for productive traits in Holstein cows in Goias State, Brazil. *Revista Brasileira de Zootecnia*, **29**: 421 - 426
- Flamant, J. C. and Barillet, F. (1982) Adaptation of the principles of selection for milk production to milking ewes: a review. *Livestock Production Science*, **9**: 549 - 559
- Flamant, J.C. and Boyazoglu, J.C. (1978) Le contrôle laitier ovin en France, ses modalités et son organization: dossier réalisé par F.Barillet de l'Union Nationale des Livres Généalogiques. *Acad. Agric. France*, 1481 - 1484
- Flamant, J.C. and Poutous, M. (1970) Aspects quantitatifs de la production laitière des brebis 7. Précision d'un contrôle laitier alterné (AT) et d'un contrôle laitier d'alternance quelconque corrigé pour les écarts moyens entre les performances due soir et du matin. *Ann. Génét. Sél. Anim.*, **3**: 65 - 73
- Fogarty, N. M., Brash, L. D. and Gilmour, A. R. (1994) Genetic parameters for reproduction and lamb production and their components and liveweight, fat depth and wool production in Hyfer sheep. *Australian Journal of Agricultural Research*, **45**: 443 - 457
- Fogarty, N.M. and Gilmour, A.R. (1998) Effect of season on lambing performance of selection and control flock ewes tested in an 8-monthly lambing system. *Wool Technology and Sheep Breeding*, **46**: 286 - 290
- Freitas, A.R. de, Manzano, A. and Esteves, S.N. (1999) Sample size involving multiple traits: an application to digestibility in cattle. *Pesquisa Agropecuaria Brasileira*, **34**: 1999 - 2005
- Gabiña, D. (1995) Genetic improvement of mutton sheep. *Cahiers Options Méditerranéennes*, **6**: 87-99

- Gabiña, D., Urarte, E. and Arranz, J. (1986) Simplified methods for milk recording. Application to sheep breeds in the Basque country. *Investigación Agraria, Producción y Sanidad Animales*, **1**: 159 - 170
- Gilmour, A.R., Luff, A.F., Fogarty, N.M. and Banks, R. (1994) Genetic parameters for ultrasound fat depth and eye muscle measurements in live Poll Dorset sheep. *Australian Journal of Agricultural Research*, **45**: 1281 - 1291
- Gonzalez, V.N. and Boschini, F.C. (1996) Milk production in Holstein and Jersey herds in the Central Valley of Costa Rica. *Nutricion Animal Tropical*, **3**: 43 - 59
- Grossman, M. and Koops, W. J. (1988) Multiphasic analysis of lactation curves in dairy cattle. *Journal of Dairy Science*, **71**: 1598 - 1608
- Haciislamolu, B. and Evrim, M. (1995) Phenotypic and genetic parameters of production traits in Ramliç sheep. 2. The effects of some environmental factors on production traits. *Türk Veterinerlik ve Hayvancilik Dergisi*, **19**: 23 - 33
- Haines, M. (1987) Hill farming developments. *Farm Management*, **6**: 203 - 212
- Hanrahan, J. P. (1987) Genetic variation in ovulation rate in sheep. *New Techniques in Sheep Production*. 37 - 46
- Hanrahan, J. P. and Owen, J. B. (1985) Ovulation rate in Cambridge ewes. *Animal production*. Report from Dunsinea, Moorepark and Western Research Centres. Research report, 70-71
- Herring, W. O., Miller, D. C., Bertrand, J. K. and Benyshek, L. L. (1994) Evaluation of machine, technician, and interpreter effects on ultrasonic measures of backfat and longissimus muscle area in beef cattle. *Journal of Animal Science*, **72**: 2216 - 2226
- Hill, A.G. (1985) *Population, Health and Nutrition in the Sahel*. Publ. KPI Ltd.
- Hill, W.G. (1998) Foreward note in *Genetic Improvement of Cattle and Sheep* by G. Simm. Publ. Farming Press.
- Hirooka, H. and Bhuiyan, A.K.F.H. (1995) Additive and heterosis effects on milk yield and birth weight from crossbreeding experiments between Holstein and the local breed in Bangladesh. *Asian Australasian Journal of Animal Sciences*, **8**: 295 - 300
- Hoekstra, J., Van Der Lugt, A.W., Van Der Wef, J.H.J. and Ouweltjes, W. (1994) Genetic and phenotypic parameters for milk production and fertility traits in upgraded dairy cattle. *Livestock Production Science*, **40**, 225 - 232
- Hoel, P.G. (1976) *Elementary Statistics*, 4th Edition. Publ. Wiley

- Holechek, J. L., Pieper, R. D. and Herbel, C. H. (1995) Range management: principles and practices. *Range Management: Principles and Practices*, 2nd Edition
- Houghton, P. L. and Turlington, L. M. (1992) Application of ultrasound for feeding and finishing animals: a review. *Journal of Animal Science*, **70**: 930 – 941
- Jahnke, H. E. (1982) Livestock production systems and livestock development in tropical Africa. *Livestock Production Systems and Livestock Development in Tropical Africa*.
- Jamrozik, J., Schaeffer, L.R., Burnside, E.B. and Sullivan, B.P. (1991) Threshold models applied to Holstein conformation traits. *Journal of Dairy Science*, **74**: 3196-3201
- Jarkin, I. and Tuncel, E. (1972) Genetische parameter für milch und andere leistungen und die genetischen verbesserungsmöglichkeiten beim invesishaf. *Z. Tierz. Zuechtungsbiol*, **89**, 199 - 216
- Jenkins, T.G., Leymaster, K.A. and MacNeil, M.D. (1995) Development and evaluation of a regression equation of prediction for fat-free soft tissue in heterogenous populations of cattle. *Journal of Animal Science*, **73**: 3627 – 3632
- Jenkins, T.G., Leymaster, K.A. and Turlington, L.M. (1988) Estimation of fat-free soft tissue in lamb carcasses by use of carcass and resistive impedance measurements. *Journal of Animal Science*, **66**: 2174
- Jury, K. E., Johnson, D. L. and Clarke, J. N. (1979) Adjustment factors for lamb weaning weight. I. Estimates from commercial flocks. *New Zealand Journal of Agricultural Research*, **22**: 385 - 389
- Kempster, A.J., Croston, D., Guy, D.R. and Jones, D.W. (1987) Growth and carcass characteristics of crossbred lambs by ten sire breed, compared at the same estimated carcass subcutaneous fat proportion. *Animal Production*, **44**: 83 - 98
- Kempster, A. J., Cuthbertson, A. and Harrington, G. (1982) Carcase evaluation in livestock breeding, production and marketing. In: *Carcase Evaluation in Livestock Breeding, Production and Marketing*.
- Kennedy, B.W., Sola, G. and Moxley, J.E. (1978) Correction factors for first, second and last test day milk yields. *Canadian Journal of Animal Science*, **58**: 419-426
- Keown, J.F. and Everett, R.W. (1985) Age-month adjustment factors for milk, fat, and protein yields in Holstein cattle. *Journal of Dairy Science*, **68**: 2664 - 2669

- Khan, M.S. and Shook, G.E. (1996) Effects of age on milk yield: time trends and method of adjustment. *Journal of Dairy Science*, **79**: 1057 - 1064
- Khanna, A.S. and Balaine, D.S. (1989) Simulating lactation milk yield from interval recording in crossbred (temperate x Zebu) dairy cattle. *Tropical Agriculture*, **66**: 365 - 368
- Kominakis, A., Rogdakis, E. and Koutsotolis, K. (1998). Genetic parameters for milk yield and litter size in Boutsico dairy sheep. *Canadian Journal of Animal Science*, **78**, 525 – 532
- Kurowska, Z. and Danell, Ö. (1992) The influence of region, production level and flock size on lamb weight adjustments in the Swedish Sheep Recording Scheme. *Acta Agriculturae Scandinavica. Section A, Animal Science*, **42**: 91 – 98
- Lamberson, W. R. and Thomas, D. L. (1982) Effects of season and breed of sire on incidence of estrus and ovulation rate in sheep. *Journal of Animal Science*, **54**: 533 - 539
- Lee, G.J. and Atkins, K.D. (1994) Improving the reproductive performance of the current flock. *Wool Technology and Sheep Breeding*, **42**: 338 – 342
- Lewis, R. and Shelton, M. (1986) The use of production records as a method for improving the reproductive performance of sheep. 3rd World Congress on Genetics Applied to Livestock Production, Lincoln, Nebraska, USA, July 16-22, IX. Breeding Programs for Dairy and Beef Cattle, Water Buffalo, Sheep, and Goats, 665 - 670
- Leymaster, K. A., Mersmann, H. J. and Jenkins, T. G. (1985) Prediction of the chemical composition of sheep by use of ultrasound. *Journal of Animal Science*, **61**: 165 – 172
- Lindstrom, U.B. (1976) Milk recording in developing countries. *World Animal Review*, **19**: 34 - 42
- Lynch, M. and Walsh, B. (1998) Genetics and Analysis of Quantitative Traits. Publ. Sinauer Associates, Inc.
- McDaniel, B.T. (1969) Accuracy of sampling procedure for estimating lactation yields: A review. *Journal of Dairy Science*, **52**: 1742 - 1761
- McEwan, J.C., Dodds, K.G., Davis, G.H., Fennessy, P.F. and Hishon, M. (1991) Heritability of ultrasonic fat and muscle depths in sheep and their correlations with production traits. *Proceedings of the Australian Association of Animal Breeding and Genetics*, **9**: 276 - 279
- MAFF (now DEFRA) (2000) www.defra.gov.uk

- Mao, I.L., Burnside, E.B., Wilton, J.W. and Freeman, M.G. (1974) Age-month adjustment of Canadian dairy production records. *Canadian Journal of Animal Science*, **54**: 533 - 541
- Marcq, F., Detilleux, J. and Leroy, P. L. (1999) Growth performance of Texel lambs in Belgium: estimation of non-genetic and genetic factors. *Annales de Médecine Vétérinaire*, **143**: 125 - 130
- María, G. and Gabiña, D. (1992) Simplification of milk recording scheme in Latxa milking sheep. *Livestock Production Science*, **31**: 313 - 320
- Marti, C. F. and Funk, D. A. (1994) Relationship between production and days open at different levels of herd production. *Journal of Dairy Science*, **77**: 1682 - 1690
- Mavrogenis, A.P. (1996) Estimates of environmental and genetic parameters influencing milk and growth traits of Awassi sheep in Cyprus. *Small Ruminant Research*, **20**: 141 - 146
- Mead, R., Curnow, R.N. and Hasted, A.M. (1993) Statistical Methods in Agriculture and Experimental Biology. Chapman & Hall.
- Meyer, K., Graser, H.U. and Hammond, K. (1989) Estimates of genetic parameters for first lactation test day production of Australian black and white cows. *Livestock Production Science*, **21**: 177-199
- Mitchell, A.L., Wong, P.C., Elsasser, T.H. and Schmidt, W.F. (1991) Application of NMR spectroscopy and imaging for body composition analysis as related to sequential measurement of energy deposition. In: *Energy Metabolism of Farm Animals*, Ed. By C.Wenk and M. Boessinger, Zurich, Switzerland.
- MLC (1989) www.mlc.org.uk
- Morales, F., Blake, R.W., Stanton, T.L. and Hahn, M.V. (1989) Effects of age, parity, season of calving, and sire on milk yield of Carora cows in Venezuela. *Journal of Dairy Science*, **72**: 2161 - 2169
- Morant, S. V. and Gnanasakthy, A. (1989) A new approach to the mathematical formulation of lactation curves. *Animal Production*, **49**: 151 - 162
- Morley, F.H.W. (1990) The profitability of ewe selection. *Proceedings of the Australian Society of Animal Production*, **18**: 312 - 315
- Morris, J. (1991) Extension Alternatives in Tropical Africa. Publ. Overseas Development Institute.
- Morris, T.R. (1999) Experimental Design and Analysis in Animal Sciences. CAB International.

- Murdia, C.K. and Tripathi, V.N. (1991) Effectiveness of different selection indices for genetic advancement in Jersey cattle. *Indian Journal of Dairy Science*, **44**: 162 - 166
- National Assembly of Wales (2000). Welsh Agricultural Statistics Publication
- Nelsen, T. C. and Kress, D. D. (1981) Additive and multiplicative correction factors for sex and age of dam in beef cattle weaning weight. *Journal of Animal Science*, **53**: 1217 – 1224
- Newman, S.A. N., Wickham, G. A., Rae, A. L. and Anderson, R. D. (1983) Weaning weight adjustments for selecting lambs born to year-old ewes. *New Zealand Journal of Agricultural Research*, **26**: 427 – 431
- Nichols, M.E., Dolezal, H.G., Fitch, G.Q., Phillips, W.A. and Gardner, T.L. (1992) Evaluation of real-time ultrasound for predicting carcass traits of feedlot lambs. *Animal Science Research Report, Agricultural Experiment Station, Oklahoma State University*, **MP-136**, 43 - 47
- Noether, G.E. (1976) Introduction to statistics: a nonparametric approach, 2nd Edition. Publ. London Houghton Mifflin
- Norman, H.D., Meinert, T.R., Schutz, M.M. and Wright, J.R. (1995) Age and seasonal effects on Holstein yield for four regions of the United States over time. *Journal of Dairy Science*, **78**: 1855 - 1861
- Notter, D.R. and Copenhaver, J.S. (1980) Performance of Finnish Landrace crossbred ewes under accelerated lambing. I. Fertility, prolificacy and ewe productivity. *Journal of Animal Science*, **51**: 1033 - 1042
- Oakley, P. and Garforth, C. (1985) Guide to Extension Training. Publ. Food & Agriculture Organisation of the United Nations.
- Olesen, I. and Husabø, J.O. (1994) Effect of using ultrasonic muscle depth and fat depth on the accuracy of predicted phenotype and genetic values of carcass traits on live ram lambs. *Acta Agriculturae Scandinavica, Section A, Animal Science*, **44**: 65 - 72
- Ott, L. and Mendenhall, W. (1985) Understanding Statistics. 4th Edition. Publ. Duxbury Press.
- Owen, J.B., Brown, K. and Flint, R. (1980) Selection for prolificacy in sheep in relation to meat production characters. *Paper, 31st Annual Meeting, European Association for Animal Production*, No. **G1.9**
- Özcelik, M. and Arpacik, R. (2000) The effect of lactation number on milk production and reproduction in Holstein cows. *Türk Veterinerlik ve Hayvancilik Dergisi*, **24**: 39 – 44
- Pagot, J. (1992) Animal Production in the Tropics. Publ. Macmillan

- Pander, B.L. and Hill, W.G. (1993) Genetic evaluation of lactation yield from test day records on incomplete lactation. *Livestock Production Science*, **37**: 23-36
- Pander, B.L., Hill, W.G. and Thompson, R. (1992) Genetic parameters of test day records of British Holstein-Friesian heifers. *Animal Production*, **55**: 11 - 21
- Parker, R.E. (1973) Introductory Statistics for Biology. The Institute of Biology's Studies in Biology no. 43. Publ. Edward Arnold (Publishers) Ltd.
- Peart, G.R. (1979) Sociological, economic, business and genetic aspects of sheep group breeding schemes. In: *Sheep Breeding 2nd Edition*. (ed. G.L. Tomes, D.E. Robertson and R.J. Lightfoot; revised by W. Haresign). Publ. Butterworths.
- Pirzada, R.H. (2001) Genetic analysis of production, fertility and health traits of dairy cows. Thesis (Ph.D.), University of Wales, Bangor.
- Pollott, G. E. (2000) A biological approach to lactation curve analysis for milk yield. *Journal of Dairy Science*, **83**: 2448 - 2458
- Pollott, G.E. and Gootwine, E. (2000) Appropriate mathematical models for describing the complete lactation of dairy sheep. *Animal Science*, **71**: 197-207
- Pritchard, T.C. and Ap Dewi, I. (2003) Timing of ultrasonic scanning for Welsh Mountain Rams. *Proceedings of the British Society of Animal Science 2003*. p143
- Pryce, J. E., Veerkamp, R. F., Thompson, R., Hill, W. G. and Simm, G. (1997) Genetic aspects of common health disorders and measures of fertility in Holstein Friesian dairy cattle. *Animal Science*, **65**: 353 – 360
- Ptak, E., Horst, H.S. and Schaeffer, L.R. (1993) Interaction of age and month of calving with year of calving for production traits of Ontario Holsteins. *Journal of Dairy Science*, **76**: 3792
- Purchas, R. W. and Beach, A. D. (1981) Between-operator repeatability of fat depth measurements made on live sheep and lambs with an ultrasonic probe. *New Zealand Journal of Experimental Agriculture*, **9**: 213 – 220
- Purser, A.F. (1965) Repeatability and heritability of fertility in hill sheep. *Animal Production*, **7**, 75 - 82
- Radomska, M.J., Klewiec, J. and Martyniuk, E. (1985) The preliminary results of selection for prolificacy in Polish Merino sheep. *Genetics of Reproduction in Sheep*, 111 – 112.
- Ray, D. E., Halbach, T. J. and Armstrong, D. V. (1992) Season and lactation number effects on milk production and reproduction of dairy cattle in Arizona. *Journal of Dairy Science*, **75**: 2976 – 2983

- Ricordeau, G., Poivey, J. P., Lajous, D. and Eychenne, F. (1986) Genetic aspects of ovulation rate and embryo mortality in Romanov ewes. 3rd World Congress on Genetics applied to Livestock Production, Lincoln, Nebraska, USA, July 16-22, XI. Genetics of reproduction, lactation, growth, adaptation, disease, and parasite resistance, 90-95
- Robinson, D.L., McDonald, C.A., Hammond, K. and Turner, J.W. (1992) Live animal measurement of carcass traits by ultrasound assessment and accuracy on sonographers. *Journal of Animal Science*, **70**: 1667 - 1676
- Rodriguez-Iglesias, R.M, Miquel, M.C., Vulich, S.A. and Murtagh, J.J. (1992) Heritability of ovulation rate and litter size at birth in Corriedale ewes. *Revista Argentina de Produccion Animal*, **12**: 169 – 175
- Rogdakis, E., Bizelis, I., Kominakis, A., Papavasiliou, D., Maliappis, M. and Georgantopoulou, F. (1994) Ultrasonic fat and muscle depth measurements in pigs: repeatability and implementation of the selection process. *Epithers Zotehniks Epistms*, **19**: 5-19
- Rogers, G.W. and McDaniel, B.T. (1989) The usefulness of selection for yield and functional type traits. *Journal of Dairy Science*, **72**: 187 - 193
- Russel, A.J.F. (1983) Meeting the feed requirements of the hill ewe. *Sheep Production*, Chapter 12. Ed. Haresign, W. Publ. Butterworths.
- Saatci, M. (1998) Genetic parameters of production traits in Welsh mountain sheep. Thesis (Ph.D.), University of Wales Bangor.
- Sandford, S. (1983) Management of pastoral development in the Third World. *Management of Pastoral Development in the Third World*.
- Sargent, F.D., Butcher, K.R. and Legates, J.E. (1967) Environmental influences on milk constituents. *Journal of Dairy Science*, **50**: 177 - 184
- Schoenian, S. G. and Burfening, P. J. (1990) Ovulation rate, lambing rate, litter size and embryo survival of Rambouillet sheep selected for high and low reproductive rate. *Journal of Animal Science*, **68**: 2263 - 2270
- Scott, R.F. and Roberts, E.M. (1976) Effect of flock and sample size on the effectiveness of sheep selection. *Proceedings of the Australian Society of Animal Production*, **11**: 21 - 23
- Secchiari, P., Panella, F., Martorana, F. and Morbidini, L. (1992) Massese sheep: heritability and repeatability of milk yield. *Zootecnica e Nutrizione Animale*, **18**: 21 – 25
- Senter, R. J., (1969) Analysis of data; introductory statistics for the behavioural sciences. Publ. Foresman

- Serrano, M., Ugarte, E., Jurado, J.J., Perez-Guzman, M.D. and Legarra, A. (2001) Test day models and genetic parameters in Latxa and Manchega dairy ewes. *Livestock Production Science*, **67**: 253 - 264
- Shook, G.E, Johnson, L.P. and Dickinson, F.N. (1980) Factors for improving accuracy of estimates of test-interval yield. *DHI Lett*, **56(4)**. USDA, Beltsville, MD
- Signet (2001) Personal Communication
- Simm, G. (1992) Selection for lean meat production in sheep. *Progress in Sheep and Goat Research*, 193 - 215
- Simm, G. (1998) Genetic Improvement of Cattle and Sheep. Publ. Farming Press
- Simm, G. and Dingwall, W.S. (1989) Selection indices for lean meat production in sheep. *Livestock Production Science*, **21**: 223 - 233
- Simm, G., Lewis, R. M., Grundy, B. and Dingwall, W. S. (2002) Responses to selection for lean growth in sheep. *Animal Science*, **74**: 39 - 50
- Simm, G., Young, M. J. and Beatson, P. R. (1987) An economic selection index for lean meat production in New Zealand sheep. *Animal Production*, **45**: 465 - 475
- Singh, D. and Yadav, A.S. (1999) Studies on genetic and non-genetic factors causing fluctuations in progressive milk records of crossbred cattle. *Indian Journal of Dairy Science*, **52**: 31 - 35
- Slosarz, P., Stanis, M. and Gut, A. (2001) Application of real-time (B-mode) ultrasonography for assessing the longissimus dorsi intramuscular fat content in live lambs. *Animal Science Papers and Reports*, **19**: 51 - 56
- Smith, J.F. (1989) Principles of reproduction. In: *Sheep Production. Volume 1. Breeding and Reproduction* (Ed. G.A.Wickham and M.F. McDonald), 211 - 237. New Zealand Institute of Agricultural Science.
- Snedecor, G.W. and Cochran, W.G. (1967) Statistical methods, 6th Edition. Publ. Ames, Iowa State University Press [1967]
- Sormunen-Cristian, R., Ketoja, E. and Hepola, H. (1997) Sufficiency of the energy and protein standards for lactation of adult multiparous Finnish Landrace ewes. *Small Ruminant Research*, **26**: 223 - 237
- Speedy, A.W. (1980) Sheep Production Science into Practice. Publ. Longman.
- Steel, R.G.D. and Torrie, J.H. (1981) Principles and Procedures of Statistics: A Biometrical Approach, 2nd Edition. Publ. McGraw-Hill International.

- Stouffer, J.R. and Westervelt, R.G. (1997) A review of ultrasonic applications in animal science. *Journal of Clinical Ultrasound*, **45**: 124 - 127
- Suzuki, M. and Van Vleck, L.D. (1994) Heritability and repeatability for milk production traits of Japanese Holsteins from an animal model. *Journal of Dairy Science*, **77**, 583 - 588
- Swalve, H.H. (2000) Theoretical basis and computational methods for different test-day genetic evaluation methods. *Journal of Dairy Science*, **83**: 1115 - 1124
- Tekerli, M., Akinci, Z., Dogan, I. and Akcan, A. (2000) Factors affecting the shape of lactation curves of Holstein cows from the Balikesir province of Turkey. *Journal of Dairy Science*, **83**: 1381 – 1386
- Timashev, I.Z., Gerasimenko, G.E. and Sergeeva, L.G. (1982) The effectiveness of selecting fine-wooled sheep for prolificacy. *Razvedenie Ovets I Koz, Sherstovedenie*, 15 - 19
- Tosh, J.J. and Kemp, R.A. (1994) Estimation of variance components for lamb weights in three sheep populations. *Journal of Animal Science*, **72**: 1184-1190
- Tuncel, E. (1977) Possibilities of utilization of part lactation records for selection and progeny testing in Awassi sheep. *Tropical Agriculture*, **54**: 15 - 19
- Van Arendonk, J.A.M., Tier, B. and Kinghorn, B.P. (1994) Use of multiple genetic markers in prediction of breeding values. *Genetics*, **137**: 319-329
- Van Den Ban, A.W. and Hawkins, H.S. (1988) Agricultural Extension. Publ. Longman Scientific & Technical
- Van Den Ban, A.W. and Hawkins, H.S. (1998) Agricultural Extension. Publ. Longman Scientific & Technical
- Van Tassell, V.P., Quass, R.L. and Everett, R.W. (1992) Parameter estimates of 305-day ME records and 305-day test-day residual records. *Journal of Dairy Science*, **75**: Supplement 1, 251.
- Van Vleck, L.D. and Henderson, C.R. (1961) Utilising both part and complete daughter records in sire evaluation. *Journal of Dairy Science*, **44**: 2068
- Venus, C.A. and Cain, P.J. (1997) The effect of likely future changes in hill farming support on farm incomes. *Farm Management*, **9**, 440 - 452
- Verneque R da S., Martinez, M.L., Teodoro, R.L. and da S Verneque, R. (2000) Cow and sire genetic evaluation from Gyr breed based on partial records of milk production. *Revista Brasileira da Zootecnia*, **29**: 1060 – 1066

- Visser, P.M. and Thompson, R. (1992) Comparisons between genetic variances estimated from different types of relatives in dairy cattle. *Animal Production*, **55**: 315 - 320
- Willis, M.B. (1998) Dalton's Introduction to Practical Animal Breeding, 4th Edition. Publ. Blackwell Science.
- Wilmink, J.B.M. (1987) Adjustment of lactation yield for age at calving in relation to level of production. *Livestock Production Science*, **16**: 321 - 334
- Wilson, D.E. (1992) Application of ultrasound for genetic improvement. *Journal of Animal Science*, **70**: 973 - 983
- Wood, P.D.P. (1967) Algebraic model of the lactation curve in cattle. *Nature*, **216**, 164 - 165
- Yazdi, M. H., Eftekhari-Shahroudi, F., Hejazi, M. and Liljedahl, L. E. (1998) Environmental effects on growth traits and fleece weights in Baluchi sheep. *Journal of Animal Breeding and Genetics*, **115**: 455 - 465
- Young, M.J., Deaker, J.M. and Logan, C.M. (1992) Factors affecting repeatability of tissue depth determination by real-time ultrasound in sheep. *Proceedings of the New Zealand Society of Animal Production*, **52**: 37-39
- Zerabruk, M. (1995) The application of BLUP and REML to estimate breeding value and variance components of ovulation rate in Cambridge sheep. M.Sc. Dissertation, University of Wales, Bangor.

APPENDIX 1
EXAMPLE OF THE DATA ENTRY SHEET (SHEET 1) OF EXCEL SPREADSHEET
PROGRAMS

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	M1991 Master Copy												
2	Ram	Year	Rearing	Dam_Age	Ram_Age	Weight	Fat	Muscle	M Mean	M St. Dev.	z (%)	1st x %	Threshold Value
3	90051	91	1	6	389	49	3.3	24	24.435897	2.198023895	0.4861	5	28.05132363
4	90053	91	2	3	389	48	2.3	23				15	26.71400167
5	90076	91	1	2	388	53	3.3	24		Lowest 1st %	5	25	25.91844338
6	90085	91	1	3	388	53	4	23		Step size	10	35	25.28284236
7	90090	91	2	4	388	52	1	22				45	24.71210435
8	90151	91	1	3	387	52	2.7	25				55	24.15969052
9	90152	91	1	3	385	48	3.3	24				65	23.58895251
10	90180	91	2	4	383	48	3	24				75	22.9533515
11	90204	91	1	6	378	47	3.3	27				85	22.15779321
12	90217	91	1	3	370	51	2	24		Sample Size	4		
13	90268	91	2	4	395	48	3	23				% to Select	25
14	90269	91	2	5	393	49	3	29				Threshold	25.91844338
15	90270	91	2	3	395	49	4.3	26				this threshold is the best you could achieve since it is based on the whole data	
16	90271	91	1	3	396	53	5.3	23					
17	90272	91	2	3	399	48	2.3	19					
18	90273	91	1	3	393	48	2	24					
19	90274	91	1	5	396	47	3.3	27				Method 2	Historical Data
20	90276	91	2	3	399	51	3.3	23				mean	24.43
21	90277	91	2	4	393	48	3	29				st dev	2.313
22	90278	91	2	4	403	48	1.7	24				M2 threshold	25.99009622
23	90279	91	1	3	399	48	3.7	25				(and M3 starting value)	
24	90280	91	2	3	399	47	2.7	22					
25	90281	91	1	3	394	48	2	24					
26	90282	91	1	2	394	51	2.3	25					
27	90283	91	2	5	392	53	2.7	24					
28	90284	91	2	4	399	51	2.3	23					
29	90285	91	1	3	393	48	2.3	27					
30	90286	91	1	3	393	51	3.3	24					
31	90287	91	1	5	392	55	3.3	25					
32	90288	91	1	5	399	60	3	28					
33	90289	91	1	5	393	47	1.3	22					
34	90290	91	1	2	398	52	2	21					
35	90291	91	2	5	399	48	2	23					
36	90292	91	1	4	394	52	2.3	27					
37	90293	91	1	4	394	52	4.7	25					
38	90294	91	1	6	394	56	3	29					
39	90295	91	1	2	396	48	2	25					
40	90041	91	1	2	389	54	3.3	24					
41	90021	91	1	3	390	51	1.7	23					

APPENDIX 1
EXAMPLE OF THE RANDOM SEQUENCE DATA SETS OF EXCEL SPREADSHEET
PROGRAMS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		M91R1				%	25		SAMPLE SIZE		4	Random sequence to get	Average	26.25	Method 1 Threshold
2		Ram	Year	Rearing	Dam_Age	Ram_Age	Weight	Fat	Muscle	RAND	methods 1 and 4 started	St. Dev.	2.217355783	27.74558511	
3	1	90041	91	1	2	389	54	3.3	24	3.394253373	233.2353679	25	1	25	FALSE
4	2	90090	91	2	4	388	52	1	22	4.552781041	250.0220175	27	2	27	FALSE
5	3	90076	91	1	2	388	53	3.3	24	4.709976317	340.8833627	29	3	29	FALSE
6	4	90279	91	1	3	399	48	3.7	25	6.220974183	451.6525237	24	4	24	FALSE
7	5	90291	91	2	5	399	48	2	23	10.82315374	701.4950408	25	5		FALSE
8	6	90286	91	1	3	393	51	3.3	24	16.13644317	833.2182677	29	6		FALSE
9	7	90268	91	2	4	395	48	3	23	17.22283576	1257.121278	24	7		FALSE
10	8	90294	91	1	6	394	56	3	29	23.05046178	1328.234836	24	8		
11	9	90180	91	2	4	383	48	3	24	27.95559553	1437.277803	24	9		FALSE
12	10	90217	91	1	3	370	51	2	24	34.67063071	1683.898379	23	10		FALSE
13	11	90053	91	2	3	389	48	2.3	23	35.86709263	2241.691571	24	11		FALSE
14	12	90285	91	1	3	393	48	2.3	27	41.6832138	2475.524867	27	12		FALSE
15	13	90293	91	1	4	394	52	4.7	25	41.89687617	2822.907714	22	13		FALSE
16	14	90288	91	1	5	399	60	3	28	42.76605198	2845.204634	29	14		
17	15	90273	91	1	3	393	48	2	24	46.4631738	2859.389957	24	15		FALSE
18	16	90276	91	2	3	399	51	3.3	23	48.186129	3287.554111	23	16		FALSE
19	17	90204	91	1	6	378	47	3.3	27	51.12870796	3443.415578	25	17		FALSE
20	18	90289	91	1	5	393	47	1.3	22	52.83594313	3472.443509	24	18		FALSE
21	19	90269	91	2	5	393	49	3	29	57.90383738	3578.032906	22	19		
22	20	90280	91	2	3	399	47	2.7	22	60.06757866	3868.894536	25	20		FALSE
23	21	90283	91	2	5	392	53	2.7	24	60.21408813	3888.183094	27	21		FALSE
24	22	90277	91	2	4	393	48	3	29	62.25741342	4160.871484	27	22		
25	23	90021	91	1	3	390	51	1.7	23	70.58016009	4470.800545	23	23		FALSE
26	24	90284	91	2	4	399	51	2.3	23	75.03408745	4492.376434	24	24		FALSE
27	25	90278	91	2	4	403	48	1.7	24	78.00161632	5366.35798	23	25		FALSE
28	26	90295	91	1	2	396	48	2	25	80.02551597	5567.442707	24	26		FALSE
29	27	90270	91	2	3	395	49	4.3	26	80.96609568	5647.722587	26	27		FALSE
30	28	90051	91	1	6	389	49	3.3	24	84.57836631	5865.651986	23	28		FALSE
31	29	90151	91	1	3	387	52	2.7	25	87.88544045	5990.427707	24	29		FALSE
32	30	90281	91	1	3	394	48	2	24	88.74546682	6007.052546	25	30		FALSE
33	31	90152	91	1	3	385	48	3.3	24	93.98777031	6098.963495	21	31		FALSE
34	32	90292	91	1	4	394	52	2.3	27	105.559315	6519.335927	22	32		FALSE
35	33	90290	91	1	2	398	52	2	21	107.2175163	6601.575214	23	33		FALSE
36	34	90271	91	1	3	396	53	5.3	23	109.1551771	6614.883783	25	34		FALSE
37	35	90085	91	1	3	388	53	4	23	109.3896828	6618.705068	28	35		FALSE
38	36	90287	91	1	5	392	55	3.3	25	109.5855965	6675.964733	23	36		FALSE
39	37	90272	91	2	3	399	48	2.3	19	113.7906692	6736.257556	24	37		FALSE
40	38	90282	91	1	2	394	51	2.3	25	114.1806742	6904.450157	23	38		FALSE
41	39	90274	91	1	5	396	47	3.3	27	122.01886	7842.164819	19	39		FALSE
42															

P	Q	R	S	T	U	V	W	X	Y
1 CORRECT SELECTION	Method 1	Method 2	Method 2	Method 3	Method 3	Method 3	Method 4	Method 4	Method 4
2 Sheet 6 Selected	Correctly Selected	Selected	Correctly Selected	Threshold	Selected	Correctly Selected	Threshold	Selected	Correctly Selected
3	FALSE	FALSE	FALSE	25.77509622	FALSE	FALSE	27.26226027	FALSE	FALSE
4	FALSE	FALSE	FALSE	24.63261435	FALSE	FALSE	26.84161335	FALSE	FALSE
5	FALSE	FALSE	FALSE	24.58164985	FALSE	FALSE	26.55766878	FALSE	FALSE
6	1	FALSE	FALSE	24.87699132	1	1	26.44212106	FALSE	FALSE
7		FALSE	FALSE	24.63921382	FALSE	FALSE	26.19972832	FALSE	FALSE
8		FALSE	FALSE	24.59568002	FALSE	FALSE	26.05085302	FALSE	FALSE
9		FALSE	FALSE	24.44971782	FALSE	FALSE	25.87280074	FALSE	FALSE
10	1	1	1	25.71517525	1	1	26.45092728	1	1
11		FALSE	FALSE	25.60463167	FALSE	FALSE	26.32507181	FALSE	FALSE
12		FALSE	FALSE	25.51169719	FALSE	FALSE	26.21477633	FALSE	FALSE
13		FALSE	FALSE	25.3707931	FALSE	FALSE	26.07842389	FALSE	FALSE
14	1	FALSE	1	25.65789361	1	1	26.23200446	1	1
15	1	FALSE	FALSE	25.65806833	FALSE	FALSE	26.19830091	FALSE	FALSE
16	1	1	1	26.00633736	1	1	26.42612662	1	1
17		FALSE	FALSE	25.92415364	FALSE	FALSE	26.34192579	FALSE	FALSE
18		FALSE	FALSE	25.81423079	FALSE	FALSE	26.23877446	FALSE	FALSE
19	1	FALSE	1	25.97445424	1	1	26.34248891	1	1
20		FALSE	FALSE	25.86109772	FALSE	FALSE	26.23967061	FALSE	FALSE
21	1	1	1	26.21374704	1	1	26.50820631	1	1
22		FALSE	FALSE	26.10106924	FALSE	FALSE	26.40679252	FALSE	FALSE
23		FALSE	FALSE	26.04016679	FALSE	FALSE	26.34417905	FALSE	FALSE
24	1	1	1	26.32794531	1	1	26.57316835	1	1
25		FALSE	FALSE	26.2394002	FALSE	FALSE	26.49023724	FALSE	FALSE
26		FALSE	FALSE	26.15630985	FALSE	FALSE	26.41171795	FALSE	FALSE
27		FALSE	FALSE	26.10366361	FALSE	FALSE	26.35791897	FALSE	FALSE
28	1	FALSE	FALSE	26.0902152	FALSE	FALSE	26.33719947	FALSE	FALSE
29	1	FALSE	1	26.12281435	FALSE	FALSE	26.35629636	FALSE	FALSE
30		FALSE	FALSE	26.07605446	FALSE	FALSE	26.30861107	FALSE	FALSE
31	1	FALSE	FALSE	26.06372899	FALSE	FALSE	26.29039251	FALSE	FALSE
32		FALSE	FALSE	26.02119502	FALSE	FALSE	26.24681004	FALSE	FALSE
33		FALSE	FALSE	25.98090712	FALSE	FALSE	26.20533373	FALSE	FALSE
34	1	FALSE	1	26.06054097	1	1	26.26812894	1	1
35		FALSE	FALSE	25.99669985	FALSE	FALSE	26.20865639	FALSE	FALSE
36		FALSE	FALSE	25.94208853	FALSE	FALSE	26.15551326	FALSE	FALSE
37		FALSE	FALSE	25.8898264	FALSE	FALSE	26.10443265	FALSE	FALSE
38	1	FALSE	FALSE	25.88520749	FALSE	FALSE	26.09465854	FALSE	FALSE
39		FALSE	FALSE	25.84836718	FALSE	FALSE	26.06052736	FALSE	FALSE
40	1	FALSE	FALSE	25.84677707	FALSE	FALSE	26.05363415	FALSE	FALSE
41	1	FALSE	1	25.9202347	1	1	26.11385927	1	1
42									

**EXAMPLE OF THE RANDOM SEQUENCE DATA SETS OF EXCEL SPREADSHEET
PROGRAMS cont.**

	P	Q	R	S	T	U	V	W	X	Y
43		Method 1	Method 2	Method 3	Method 4					
44	Correct No. Selected (TN)	15	15	15	15					
45	Method Selected (TS)	4	9	9	8					
46	Method Correctly Sel. (C)	4	9	9	8					
47										
48	SUCCESS RATE	0.266666667	0.6	0.6	0.533333333					
49	c/tn	0.266666667	0.6	0.6	0.533333333					
50	c/ts	1	1	1	1					

APPENDIX 1
EXAMPLE OF THE TRAIT SORTED DATASHEET OF EXCEL SPREADSHEET
PROGRAMS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Column titles must be in row 2 and data begins at row 3. Set up for trait in column I											25	Number of Animals	39			
2		Ram	Year	Rearing	Dam Age	Ram Age	Weight	Fat	Muscle				Minimum No. to Select	10	note: rounded to nearest integer		
3	1	90294	91	1	6	394	56	3	29	Top 'x' %		1	Actual No. Selected	15			
4	2	90277	91	2	4	393	48	3	29			1					
5	3	90269	91	2	5	393	49	3	29			1					
6	4	90288	91	1	5	399	60	3	28			1					
7	5	90292	91	1	4	394	52	2.3	27			1					
8	6	90285	91	1	3	393	48	2.3	27			1					
9	7	90274	91	1	5	396	47	3.3	27			1					
10	8	90204	91	1	6	378	47	3.3	27			1					
11	9	90270	91	2	3	395	49	4.3	26			1					
12	10	90295	91	1	2	396	48	2	25			1					
13	11	90293	91	1	4	394	52	4.7	25			1					
14	12	90287	91	1	5	392	55	3.3	25			1					
15	13	90282	91	1	2	394	51	2.3	25			1					
16	14	90279	91	1	3	399	48	3.7	25			1					
17	15	90151	91	1	3	387	52	2.7	25			1					
18	16	90286	91	1	3	393	51	3.3	24								
19	17	90283	91	2	5	392	53	2.7	24								
20	18	90281	91	1	3	394	48	2	24								
21	19	90278	91	2	4	403	48	1.7	24								
22	20	90273	91	1	3	393	48	2	24								
23	21	90217	91	1	3	370	51	2	24								
24	22	90180	91	2	4	383	48	3	24								
25	23	90152	91	1	3	385	48	3.3	24								
26	24	90076	91	1	2	388	53	3.3	24								
27	25	90051	91	1	6	389	49	3.3	24								
28	26	90041	91	1	2	389	54	3.3	24								
29	27	90291	91	2	5	399	48	2	23								
30	28	90284	91	2	4	399	51	2.3	23								
31	29	90276	91	2	3	399	51	3.3	23								
32	30	90271	91	1	3	396	53	5.3	23								
33	31	90268	91	2	4	395	48	3	23								
34	32	90085	91	1	3	388	53	4	23								
35	33	90053	91	2	3	389	48	2.3	23								
36	34	90021	91	1	3	390	51	1.7	23								
37	35	90289	91	1	5	393	47	1.3	22								
38	36	90280	91	2	3	399	47	2.7	22								
39	37	90090	91	2	4	388	52	1	22								
40	38	90290	91	1	2	398	52	2	21								
41	39	90272	91	2	3	399	48	2.3	19								

APPENDIX 1
EXAMPLES OF THE DATA ENTRY SHEET (SHEET 1) OF EXCEL SPREADSHEET
PROGRAMS ONCE REFINED (CHAPTER 6) OR NON-NORMAL DATA TRANSFORMED
(CHAPTER 7)

	A	B	C	D	E	F
1	REFINEMENT FOR CHAPTER 6					
2				Method 2	Historical Data	
3				mean		24
4				st dev		1.666666667
5				M2 threshold		26.74142167
6				(and M3 starting		
7				value)		
8						
9	min	19		Refining starting values.		
10	max	29		Here, mean = (max+min)/2		
11				Here St.Dev. = (max-min)/6		
12						
13	REFINEMENT FOR CHAPTER 7: SQUARE ROOT					
14				Method 2	Historical Data	
15				mean		1.603
16				st dev		0.408321357
17				M2 threshold		1.654310263
18				(and M3 starting		
19				value)		
20						
21				Achieved Mean by sqrt'ing the original historical mean value		
22				Achieved St. Dev. using process below:		
23				Historical mean =		2.57
24				Historical st dev. =		1.266
25				1 Mean - sd		1.304
26				Mean + sd		3.836
27						
28				2 SQRT O24 =		1.141928194
29				SQRT O25 =		1.958570908
30						
31				3 St. Dev		0.408321357
32						
33	REFINEMENT FOR CHAPTER 7: LOG					
34				Method 2	Historical Data	
35				mean		0.409933123
36				st dev		0.234300504
37				M2 threshold		0.652769868
38				(and M3 starting		
39				value)		
40						
41				Achieved Mean by log10'ing the original historical mean value		
42				Achieved St. Dev. using process below:		
43				historical mean =		2.57
44				historical st dev =		1.266
45				1 Mean - sd		1.304
46				Mean + sd		3.836
47						
48				2 Log10 O24 =		0.115277591
49				Log10 O25 =		0.583878598
50						
51				3 St. Dev		0.234300504
52						

APPENDIX 1
EXAMPLES OF THE DATA ENTRY SHEET (SHEET 1) OF EXCEL SPREADSHEET
PROGRAMS ONCE CORRECTED FOR ENVIRONMENTAL EFFECTS (CHAPTER 8)

1	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	M1991 Master Copy													
2	Ram	Year	Rearing	Dam_Age	Ram_Age	Weight	Fat	Muscle	Correct for Ram Age	Correct for Rearing (+ Ram Age)	Correct for Dam Age (+ Ram Age + Rearing)	M Mean	M St. Dev.	z (%)
3	90051	91	1	6	389	49	3.3	24	24.124	23.91	23.63	24.53	2.083268689	0.4861
4	90053	91	2	3	389	48	2.3	23	23.124	23.48	23.75			
5	90076	91	1	2	388	53	3.3	24	24.155	23.95	24.40		Lowest 1st %	5
6	90085	91	1	3	388	53	4	23	23.155	22.95	23.22		Step size	10
7	90090	91	2	4	388	52	1	22	22.155	22.52	22.44			
8	90151	91	1	3	387	52	2.7	25	25.186	24.98	25.25			
9	90152	91	1	3	385	48	3.3	24	24.248	24.04	24.31			
10	90180	91	2	4	383	48	3	24	24.31	24.67	24.59			
11	90204	91	1	6	378	47	3.3	27	27.465	27.26	26.98			
12	90217	91	1	3	370	51	2	24	24.713	24.50	24.77		Sample Size	4
13	90268	91	2	4	395	48	3	23	22.938	23.30	23.22			
14	90269	91	2	5	393	49	3	29	29	29.36	29.08			
15	90270	91	2	3	395	49	4.3	26	25.938	26.30	26.57			
16	90271	91	1	3	396	53	5.3	23	22.907	22.70	22.97			
17	90272	91	2	3	399	48	2.3	19	18.814	19.17	19.44			
18	90273	91	1	3	393	48	2	24	24	23.79	24.06			
19	90274	91	1	5	396	47	3.3	27	26.907	26.70	26.42			
20	90276	91	2	3	399	51	3.3	23	22.814	23.17	23.44			
21	90277	91	2	4	393	48	3	29	29	29.36	29.28			
22	90278	91	2	4	403	48	1.7	24	23.69	24.05	23.97			
23	90279	91	1	3	399	48	3.7	25	24.814	24.60	24.87			
24	90280	91	2	3	399	47	2.7	22	21.814	22.17	22.44			
25	90281	91	1	3	394	48	2	24	23.969	23.76	24.03			
26	90282	91	1	2	394	51	2.3	25	24.969	24.76	25.21			
27	90283	91	2	5	392	53	2.7	24	24.031	24.39	24.11			
28	90284	91	2	4	399	51	2.3	23	22.814	23.17	23.09			
29	90285	91	1	3	393	48	2.3	27	27	26.79	27.06			
30	90286	91	1	3	393	51	3.3	24	24	23.79	24.06			
31	90287	91	1	5	392	55	3.3	25	25.031	24.82	24.54			
32	90288	91	1	5	399	60	3	28	27.814	27.60	27.32			
33	90289	91	1	5	393	47	1.3	22	22	21.79	21.51			
34	90290	91	1	2	398	52	2	21	20.845	20.64	21.09			
35	90291	91	2	5	399	48	2	23	22.814	23.17	22.89			
36	90292	91	1	4	394	52	2.3	27	26.969	26.76	26.68			
37	90293	91	1	4	394	52	4.7	25	24.969	24.76	24.68			
38	90294	91	1	6	394	56	3	29	28.969	28.76	28.48			
39	90295	91	1	2	396	48	2	25	24.907	24.70	25.15			
40	90041	91	1	2	389	54	3.3	24	24.124	23.91	24.36			
41	90021	91	1	3	390	51	1.7	23	23.093	22.88	23.15			

	O	P	Q	R	S	T	U	V	W	X
1										
2	1st x %	Threshold Value		Environmental Factors						
3	5	27.95254255		Rearing Type				e.g.		
4	15	26.68503996		Mean	25.63	Diff	To use	Correction Factors =		
5	25	25.93101645		Single	25.84	0.21	0.21	Single	Actual MD - 0.21	
6	35	25.32859912		Twin	25.27	-0.36	0.36	Twin	Actual MD + 0.36	
7	45	24.78765841								
8	55	24.26408518								
9	65	23.72314447								
10	75	23.12072713								
11	85	22.36670363		Dam Age (Years)		Diff	To use			
12				2	25.18	-0.45	0.45			
13	% to test	45		3	25.36	-0.27	0.27			
14	Threshold	24.78765841		4	25.71	0.08	0.08			
15	this threshold is the best you could achieve			5+	25.91	0.28	0.28			
16	since it is based on the whole data									
17										
18										
19	Method 2	Historical Data								
20	mean	24.43		Age of animal	mm per day of age					
21	st dev	2.313		Coefficient =	0.031					
22	M2 threshold	24.72065499		Mean of Ages	393					
23	(and M3 starting									
24	value)									
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										

APPENDIX 2

Minitab Macros for General Linear Models and Tables of Proportions or Means

General Linear Model Analysis

GLM 'SR'=C1|C2|C6;

MEANS C1|C2|C6.

- Where 'SR' was replaced by C/TN and C/TS when required, and C1 = % to Select, C2 = Method and C6 = Year/Farm

Table of Proportions of Results on or between 0.9 and 1.0 for each Method:

MTB>Table 'Method';

SUBC>Prop 0.9 1.0 Cx.

- See Δ below

Table of Mean SR, C/TN or C/TS Results across the Methods and % to Selects

MTB>Table 'Method' '% to Select';

SUBC>Means Cx.

- See Δ below

Table of Mean SR, C/TN or C/TS across the Methods and Years

MTB>Table 'Method' 'Year';

SUBC>Means Cx.

- See Δ below

Table of Mean SR, C/TN or C/TS across the % to Selects and Years

MTB>Table '% to Select' 'Year';

SUBC>Means Cx.

- See Δ below

Δ : Cx related to the column containing the results being reviewed. Therefore, it was replaced, in turn, with the column number for the following SR, C/TN, C/TS, ASINSR, ASINC/TN or ASINC/TS.

APPENDIX 3
CHAPTER 4 SAMPLE SIZE EVALUATIONS USING PROCEDURE A

	A	B	C	D	E	F
	Trait Sub Sets	Trait Means	Trait Standard Deviations	Number of Records in Data Set	Average of Trait Means, Standard Deviations and Record Counts	
1						
2	MD91	24.4	2.20	39	MD Mean	
3	MD92	27.4	2.02	38	26.0	
4	MD93	27.7	2.18	44	MD St. Dev.	
5	MD94	24.6	1.71	43	2.03	
6	MYA	7548.6	1104.63	100	MD Average of Records	
7	MYB	7014.3	1251.64	118	41	
8	MYC	7893.5	1379.06	101		
9	MYD	5907.3	975.45	113		
10	OR88	2.8	1.34	70	MY Mean	
11	OR89	2.2	1.01	96	7090.9	
12	OR91	2.7	1.48	90	MY St. Dev.	
13	OR92	2.4	1.37	61	1177.69	
14					MY Average of Records	
15					108	
16						
17					OR Mean	
18					2.5	
19					OR St. Dev.	
20					1.30	
21					OR Average of Records	
22					79	
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
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39						
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41						
42						
43						
44						
45						
46						
47						
48						
49						
50						
51						
52						
53	MD=Muscle Depth, MY = Milk Yield, OR = Ovulation Rate, St. Dev = Standard Deviation					
54	L is how close to true mean that can be accepted					

CHAPTER 4 SAMPLE SIZE EVALUATIONS USING PROCEDURE A cont.

	G	H	I	J	K	L	M	N	O
1	% of trait	L as a % of Trait MD	L as a % of Trait MY	L as a % of Trait OR		Number of Animals to be Sampled MD	Number of Animals to be Sampled MY	Number of Animals to be Sampled OR	
2	(L)	26.00	7090.93	2.52		N/A	N/A	N/A	
3	1	0.26	70.91	0.03		233.2444839	1059.670633	10268.25309	
4	2	0.52	141.82	0.05		58.31112097	264.9176583	2567.063272	
5	3	0.78	212.73	0.08		25.91605376	117.7411814	1140.91701	
6	4	1.04	283.64	0.10		14.57778024	66.22941456	641.7658181	
7	5	1.30	354.55	0.13		9.329779355	42.38682532	410.7301236	
8	6	1.56	425.46	0.15		6.479013441	29.43529536	285.2292525	
9	7	1.82	496.36	0.18		4.760091508	21.62593129	209.5561855	
10	8	2.08	567.27	0.20		3.64444506	16.55735364	160.4414545	
11	9	2.34	638.18	0.23		2.879561529	13.08235349	126.7685567	
12	10	2.60	709.09	0.25		2.332444839	10.59670633	102.6825309	
13	11	2.86	780.00	0.28		1.927640363	8.757608537	84.86159578	
14	12	3.12	850.91	0.30		1.61975336	7.35882384	71.30731312	
15	13	3.38	921.82	0.33		1.380144875	6.270240432	60.75889402	
16	14	3.64	992.73	0.35		1.190022877	5.406482822	52.38904638	
17	15	3.90	1063.64	0.38		1.036642151	4.709647258	45.6366804	
18	16	4.16	1134.55	0.40		<1	4.13933841	40.11036363	
19	17	4.42	1205.46	0.43		<1	3.666680391	35.53028751	
20	18	4.68	1276.37	0.45		<1	3.270588374	31.69213917	
21	19	4.94	1347.28	0.48		<1	2.935375715	28.44391438	
22	20	5.20	1418.19	0.50		<1	2.649176583	25.67063272	
23	21	5.46	1489.09	0.53		<1	2.402881254	23.28402061	
24	22	5.72	1560.00	0.55		<1	2.189402134	21.21539895	
25	23	5.98	1630.91	0.58		<1	2.003158096	19.41068637	
26	24	6.24	1701.82	0.60		<1	1.83970596	17.82682828	
27	25	6.50	1772.73	0.63		<1	1.695473013	16.42920494	
28	26	6.76	1843.64	0.65		<1	1.567560108	15.18972351	
29	27	7.02	1914.55	0.68		<1	1.453594833	14.08539519	
30	28	7.28	1985.46	0.70		<1	1.351620705	13.09726159	
31	29	7.54	2056.37	0.73		<1	1.260012643	12.20957561	
32	30	7.80	2127.28	0.75		<1	1.177411814	11.4091701	
33	31	8.06	2198.19	0.78		<1	1.102674956	10.68496679	
34	32	8.32	2269.10	0.80		<1	1.034834603	10.02759091	
35	33	8.58	2340.01	0.83		<1	<1	9.429066198	
36	34	8.84	2410.91	0.86		<1	<1	8.882571877	
37	35	9.10	2481.82	0.88		<1	<1	8.38224742	
38	36	9.36	2552.73	0.91		<1	<1	7.923034792	
39	37	9.62	2623.64	0.93		<1	<1	7.500550102	
40	38	9.88	2694.55	0.96		<1	<1	7.110978594	
41	39	10.14	2765.46	0.98		<1	<1	6.750988225	
42	40	10.40	2836.37	1.01		<1	<1	6.417658181	
43	41	10.66	2907.28	1.03		<1	<1	6.108419447	
44	42	10.92	2978.19	1.06		<1	<1	5.821005153	
45	43	11.18	3049.10	1.08		<1	<1	5.553408918	
46	44	11.44	3120.01	1.11		<1	<1	5.303849737	
47	45	11.70	3190.92	1.13		<1	<1	5.070742267	
48	46	11.96	3261.83	1.16		<1	<1	4.852671593	
49	47	12.22	3332.73	1.18		<1	<1	4.648371702	
50	48	12.48	3403.64	1.21		<1	<1	4.45670707	
51	49	12.74	3474.55	1.23		<1	<1	4.276656847	
52	50	13.00	3545.46	1.26		<1	<1	4.107301236	
53	MD=Muscle Depth, MY = Milk Yield, OR = Ovulation Rate								
54	L is how close to true mean that can be accepted								

CHAPTER 4 SAMPLE SIZE EVALUATIONS USING PROCEDURE A cont.

	P	Q	R	S
1	% of trait	Sample Size (%), using the mean number of records for MD	Sample Size (%), using the mean number of records for MY	Sample Size (%), using the mean number of records for OR
2	(L)	N/A	N/A	N/A
3	1	568.888985	981.1765121	12956.78623
4	2	142.2222463	245.294128	3239.196558
5	3	63.20988723	109.0196125	1439.642915
6	4	35.55556157	61.323532	809.7991396
7	5	22.7555594	39.24706048	518.2714493
8	6	15.80247181	27.25490311	359.9107287
9	7	11.60997929	20.02401045	264.4242088
10	8	8.88890391	15.330883	202.4497849
11	9	7.023320803	12.11329027	159.9603239
12	10	5.68888985	9.811765121	129.5678623
13	11	4.70156186	8.108896794	107.080878
14	12	3.950617952	6.813725778	89.97768218
15	13	3.366207012	5.805778178	76.66737416
16	14	2.902494822	5.006002613	66.10605221
17	15	2.528395489	4.360784498	57.58571659
18	16	<1	3.83272075	50.61244622
19	17	<1	3.395074436	44.83317036
20	18	<1	3.028322568	39.99008097
21	19	<1	2.717940477	35.89137461
22	20	<1	2.45294128	32.39196558
23	21	<1	2.22489005	29.38046765
24	22	<1	2.027224198	26.77021949
25	23	<1	1.854776015	24.49297965
26	24	<1	1.703431445	22.49442054
27	25	<1	1.569882419	20.73085797
28	26	<1	1.451444544	19.16684354
29	27	<1	1.345921141	17.77336932
30	28	<1	1.251500653	16.52651305
31	29	<1	1.166678373	15.40640456
32	30	<1	1.090196125	14.39642915
33	31	<1	1.02099533	13.48260794
34	32	<1	<1	12.65311156
35	33	<1	<1	11.89787533
36	34	<1	<1	11.20829259
37	35	<1	<1	10.57696835
38	36	<1	<1	9.997520242
39	37	<1	<1	9.464416533
40	38	<1	<1	8.972843652
41	39	<1	<1	8.518597129
42	40	<1	<1	8.097991396
43	41	<1	<1	7.707784791
44	42	<1	<1	7.345116912
45	43	<1	<1	7.007456048
46	44	<1	<1	6.692554873
47	45	<1	<1	6.398412955
48	46	<1	<1	6.123244912
49	47	<1	<1	5.865453252
50	48	<1	<1	5.623605136
51	49	<1	<1	5.396412425
52	50	<1	<1	5.182714493
53	MD=Muscle Depth, MY = Milk Yield, OR = Ovulation Rate			
54	L is how close to true mean that can be accepted			

APPENDIX 3
CHAPTER 4 SAMPLE SIZE EVALUATIONS USING PROCEDURE B

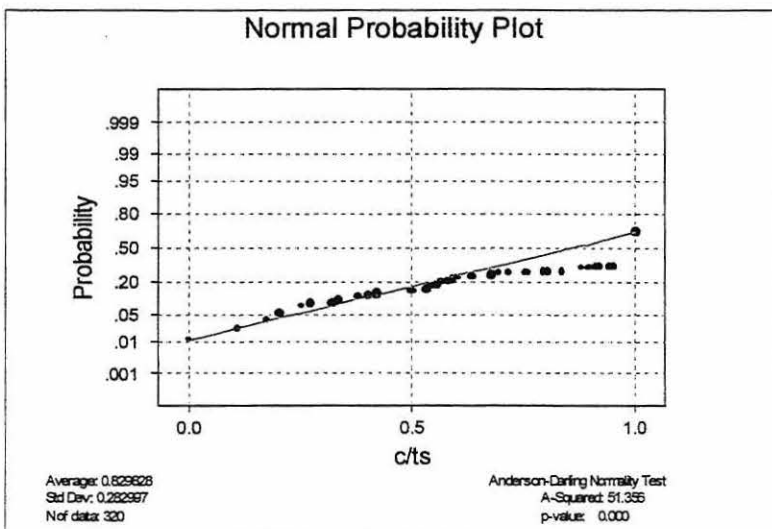
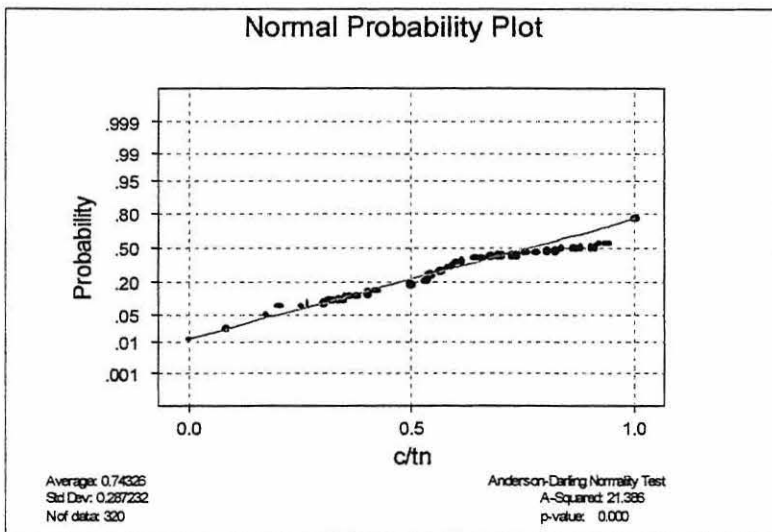
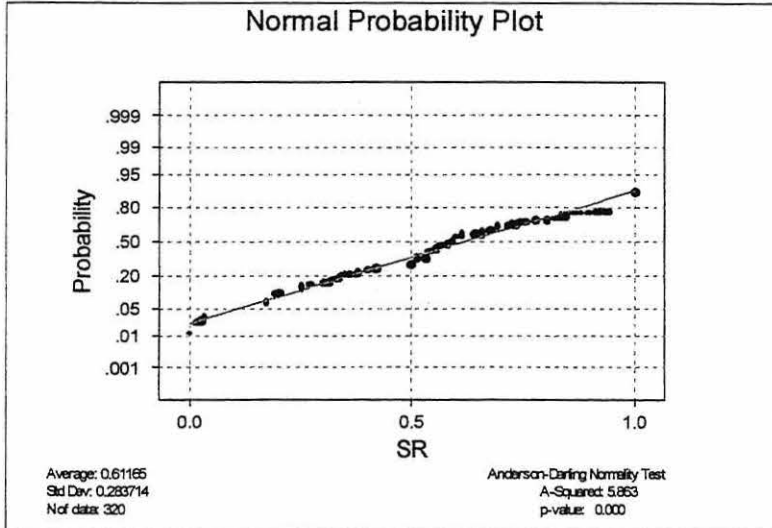
	A	B	C	D	E	F	G	H
1	Sample	MD						
2	Size (%)	1991	1992	1993	1994	Count	% of P<0.05	
3	5	0	0	0	0	0	0	
4	6	0	0	0	0	0	0	
5	7	0	1	0	0	1	2.5	
6	8	0	1	0	0	1	2.5	
7	9	1	1	0	0	2	5	
8	10	1	1	0	0	2	5	
9	11	1	1	0	1	3	7.5	
10	12	1	1	0	1	3	7.5	
11	13	1	1	0	1	3	7.5	
12	14	1	1	0	1	3	7.5	
13	15	1	1	1	1	4	10	
14	16	1	1	1	0	3	7.5	
15	17	0	1	1	0	2	5	
16	18	0	0	1	1	2	5	
17	19	0	0	1	1	2	5	
18	20	1	0	1	0	2	5	
19	21	1	0	1	0	2	5	
20	22	0	0	0	0	0	0	
21	23	0	0	0	0	0	0	
22	24	0	0	0	0	0	0	
23	25	1	1	0	0	2	5	
24	26	1	1	0	0	2	5	
25	27	0	1	0	0	1	2.5	
26	28	0	0	0	0	0	0	
27	29	0	0	0	0	0	0	
28	30	0	0	0	0	0	0	
29	31	0	2	0	0	2	5	
30	32	0	2	0	0	2	5	
31	33	0	1	0	0	1	2.5	
32	34	0	1	0	1	2	5	
33	35	0	1	0	1	2	5	
34	36	0	0	0	1	1	2.5	
35	37	0	0	0	0	0	0	
36	38	0	0	0	0	0	0	
37	39	0	0	0	1	1	2.5	
38	40	0	0	1	1	2	5	
39	41	0	1	1	0	2	5	
40	42	0	1	1	0	2	5	
41	43	1	1	0	0	2	5	
42	44	1	0	0	0	1	2.5	
43	45	1	0	0	0	1	2.5	
44	46	1	0	0	0	1	2.5	
45	47	1	0	0	0	1	2.5	
46	48	0	0	0	0	0	0	
47	49	0	0	0	0	0	0	
48	50	0	0	0	0	0	0	
49								
50	MD = Muscle Depth, MY = Milk Yield, OR = Ovulation Rate							

CHAPTER 4 SAMPLE SIZE EVALUATIONS USING PROCEDURE B cont.

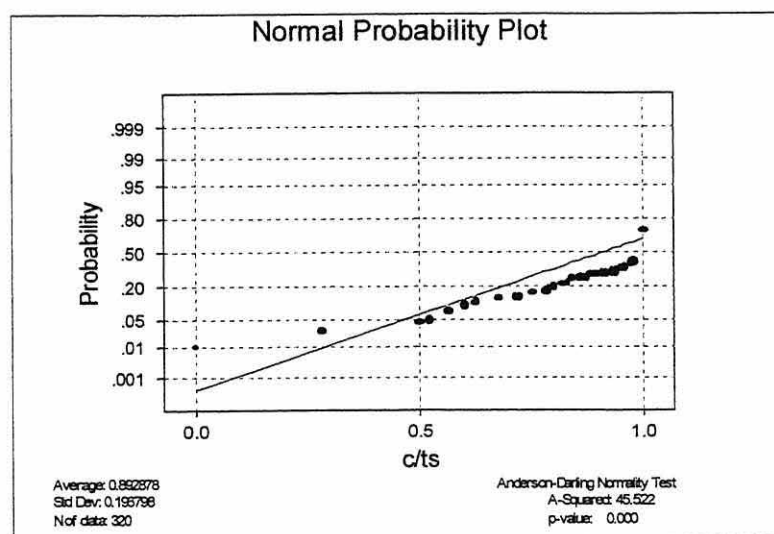
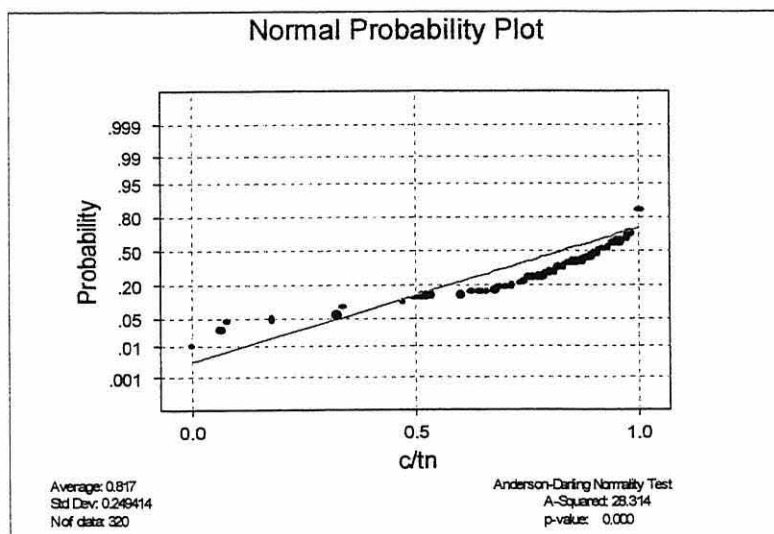
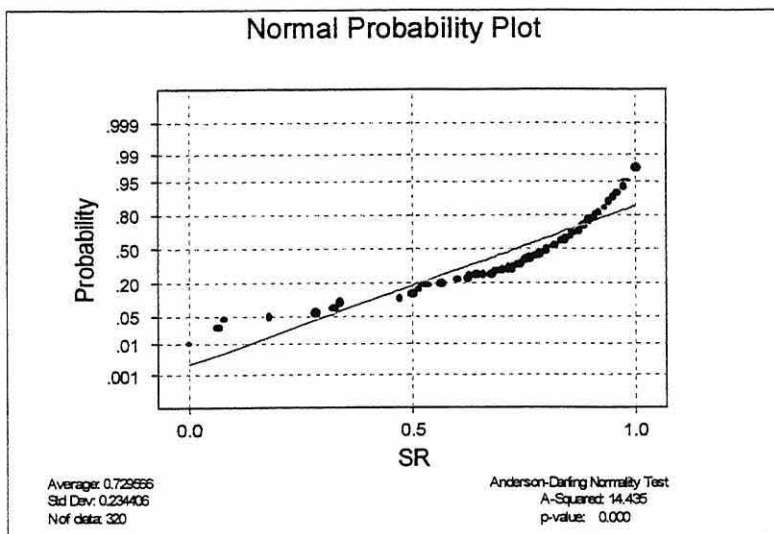
	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	MY							OR					
2	A	B	C	D	Count	% of P<0.05		1988	1989	1991	1992	Count	% of P<0.05
3	0	1	0	0	1	2.5		0	1	1	0	2	5
4	0	1	1	1	3	7.5		1	0	1	1	3	7.5
5	0	1	0	0	1	2.5		1	2	0	1	4	10
6	0	0	0	0	0	0		1	0	1	0	2	5
7	0	0	0	0	0	0		1	0	0	0	1	2.5
8	1	0	0	0	1	2.5		1	0	0	1	2	5
9	0	1	0	1	2	5		2	2	0	0	4	10
10	2	0	0	0	2	5		3	2	1	0	6	15
11	1	0	2	0	3	7.5		3	2	0	0	5	12.5
12	0	1	1	0	2	5		0	0	1	2	3	7.5
13	0	0	0	0	0	0		0	1	2	2	5	12.5
14	1	0	1	2	4	10		1	0	2	0	3	7.5
15	0	0	0	0	0	0		2	0	0	0	2	5
16	0	0	0	0	0	0		2	1	0	2	5	12.5
17	0	0	1	0	1	2.5		0	1	0	0	1	2.5
18	0	1	0	0	1	2.5		1	1	2	0	4	10
19	0	0	0	0	0	0		1	0	0	0	1	2.5
20	0	0	0	0	0	0		0	1	1	0	2	5
21	0	0	0	0	0	0		0	0	1	1	2	5
22	0	0	0	0	0	0		0	0	0	0	0	0
23	0	1	0	0	1	2.5		0	0	1	0	1	2.5
24	0	1	2	0	3	7.5		0	0	1	0	1	2.5
25	0	0	0	0	0	0		0	0	1	0	1	2.5
26	0	0	0	0	0	0		1	0	0	1	2	5
27	0	0	0	0	0	0		1	0	0	0	1	2.5
28	0	0	0	0	0	0		0	0	0	0	0	0
29	0	0	0	0	0	0		0	0	0	0	0	0
30	0	0	0	0	0	0		0	0	1	0	1	2.5
31	0	0	0	0	0	0		0	0	0	0	0	0
32	0	1	0	0	1	2.5		0	0	1	0	1	2.5
33	0	0	0	0	0	0		0	0	0	0	0	0
34	1	0	0	1	2	5		0	0	0	0	0	0
35	0	0	0	0	0	0		0	0	0	0	0	0
36	0	0	0	0	0	0		0	0	1	0	1	2.5
37	0	0	1	0	1	2.5		0	0	2	0	2	5
38	0	0	0	1	1	2.5		0	0	0	0	0	0
39	0	0	0	0	0	0		0	0	1	0	1	2.5
40	0	0	0	0	0	0		0	0	1	1	2	5
41	0	0	0	0	0	0		1	0	0	1	2	5
42	0	0	0	0	0	0		0	1	0	0	1	2.5
43	0	1	0	0	1	2.5		0	0	0	0	0	0
44	0	0	0	0	0	0		0	0	0	0	0	0
45	0	0	0	0	0	0		0	0	0	1	1	2.5
46	0	0	0	0	0	0		0	0	0	1	1	2.5
47	0	0	0	0	0	0		0	1	0	1	2	5
48	0	0	0	0	0	0		0	0	0	1	1	2.5
49													
50								MD = Muscle Depth, MY = Milk Yield, OR = Ovulation Rate					

APPENDIX 4

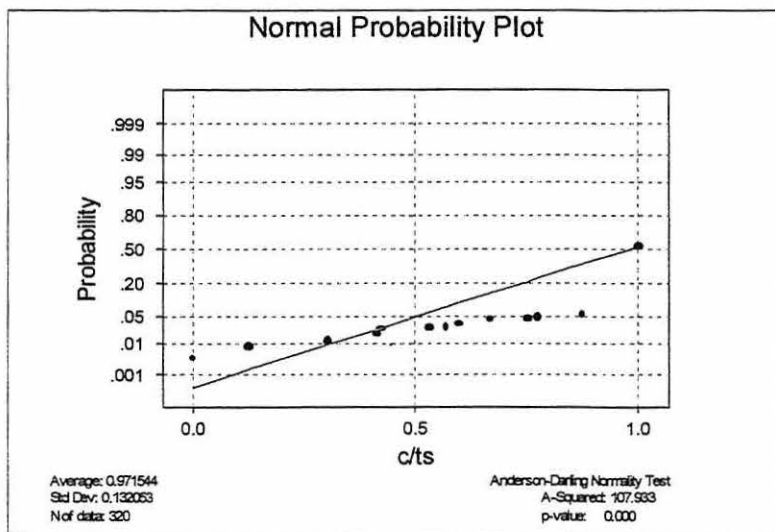
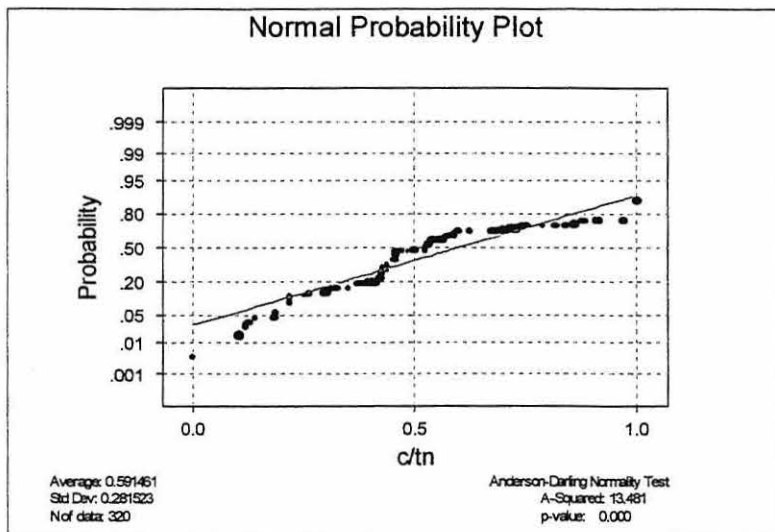
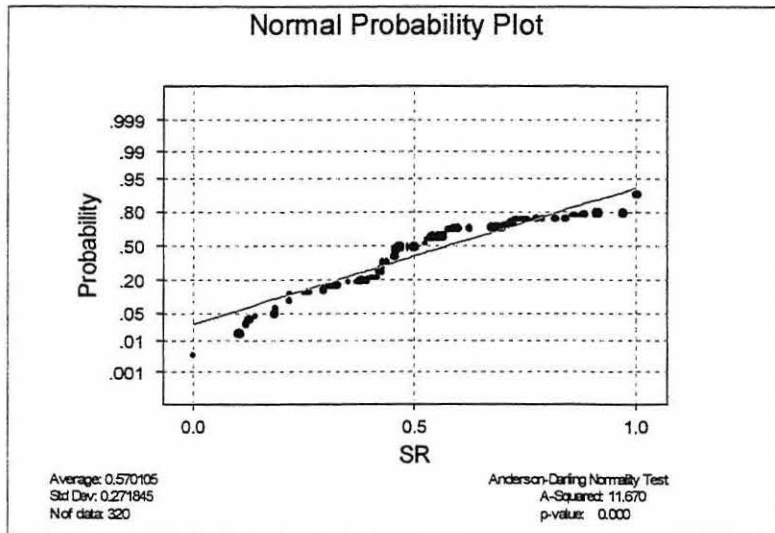
CHAPTER 5: Muscle Depth SR, C/TN and C/TS Anderson-Darling Normality Test Results



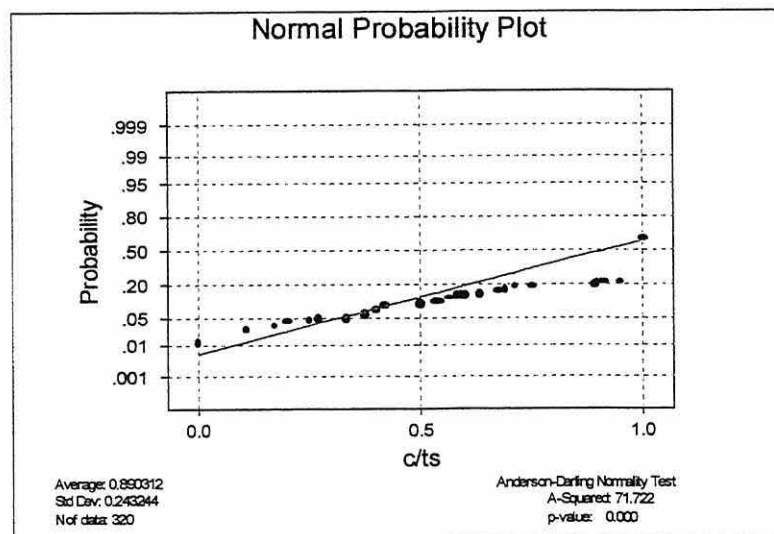
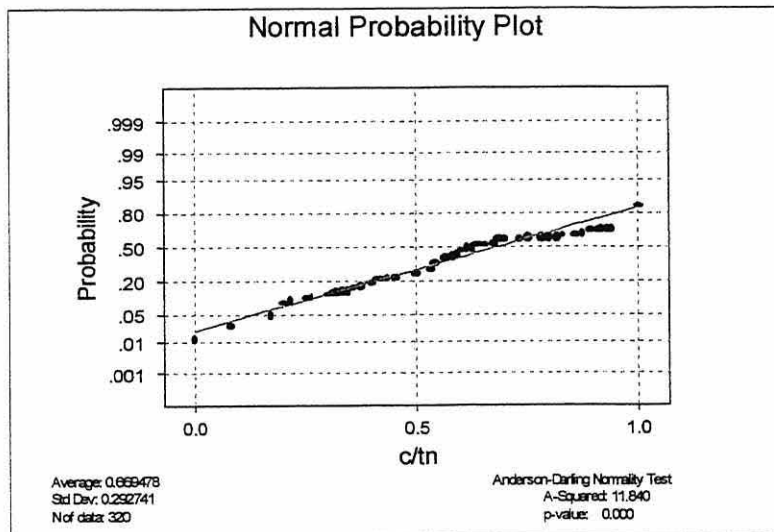
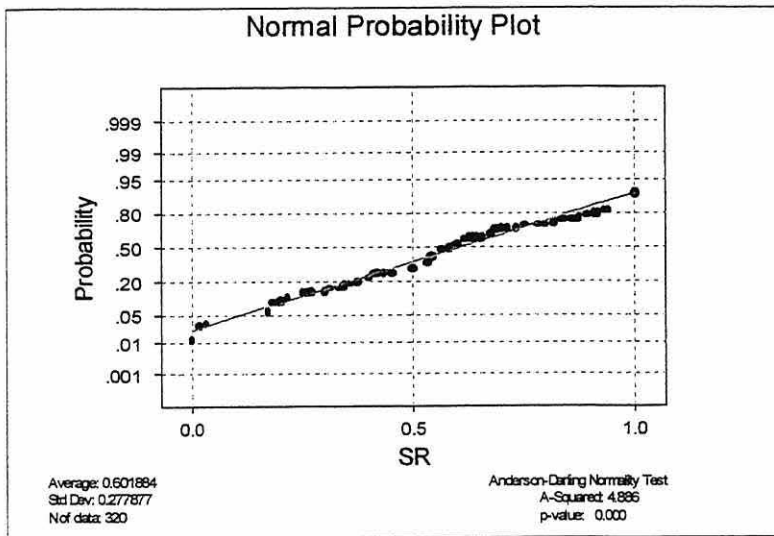
CHAPTER 5: Milk Yield SR, C/TN and C/TS Anderson-Darling Normality Test Results



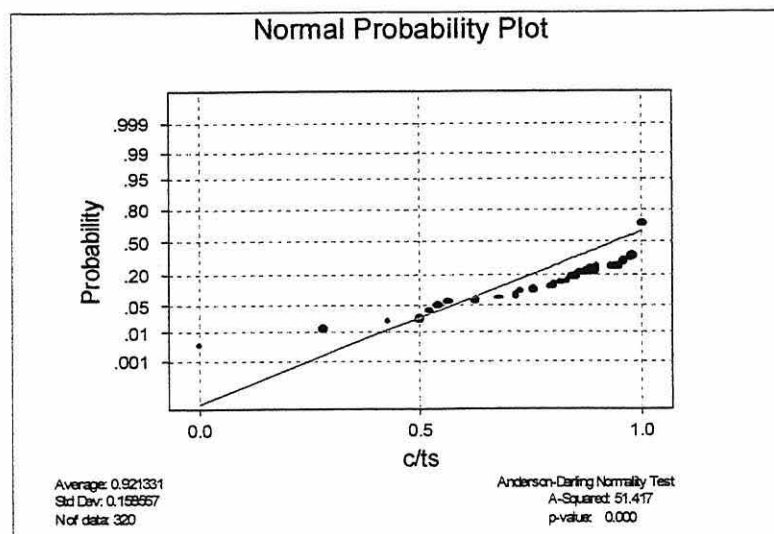
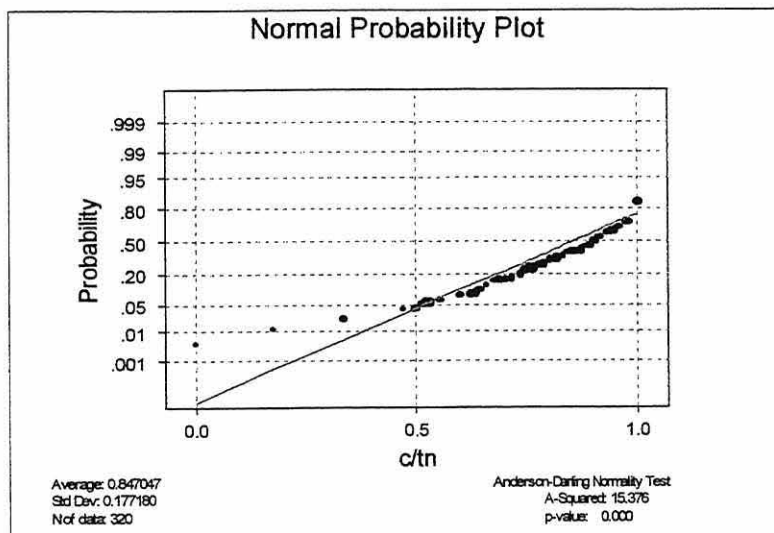
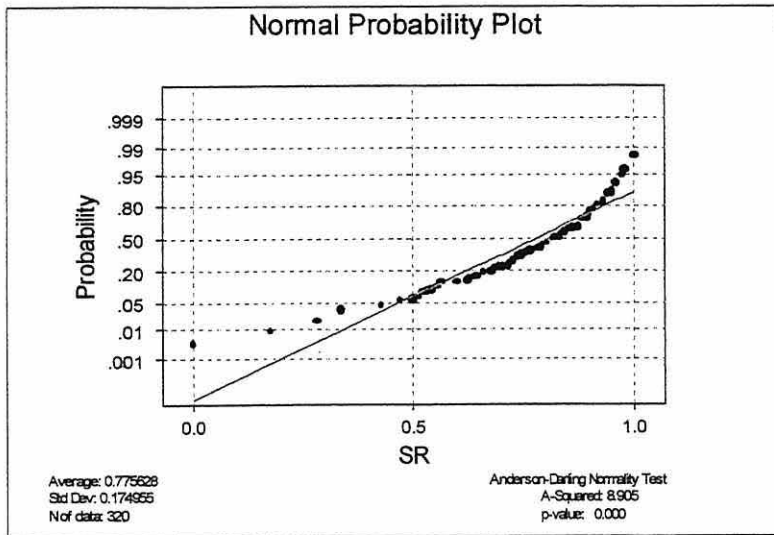
CHAPTER 5: Ovulation Rate SR, C/TN and C/TS Anderson-Darling Normality Test Results



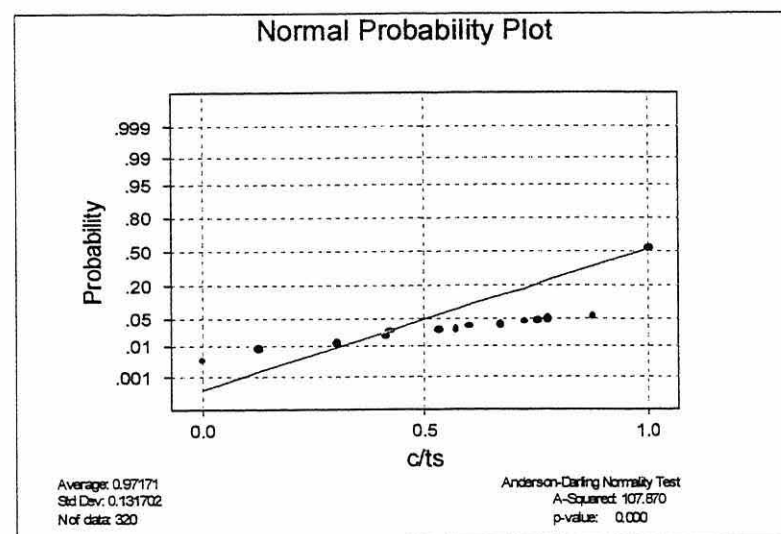
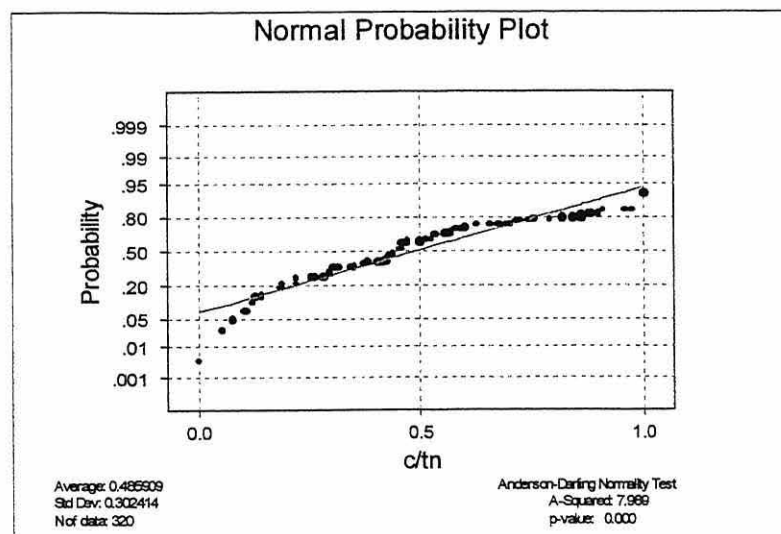
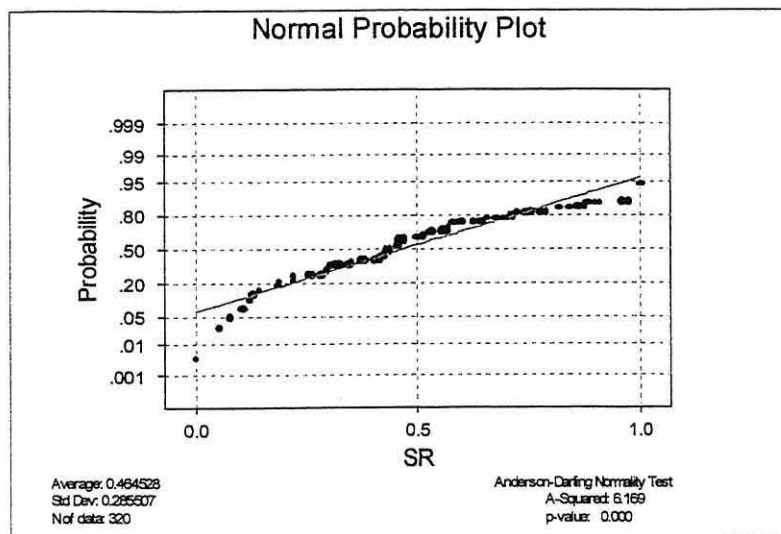
CHAPTER 6: Muscle Depth SR, C/TN and C/TS Anderson-Darling Normality Test Results



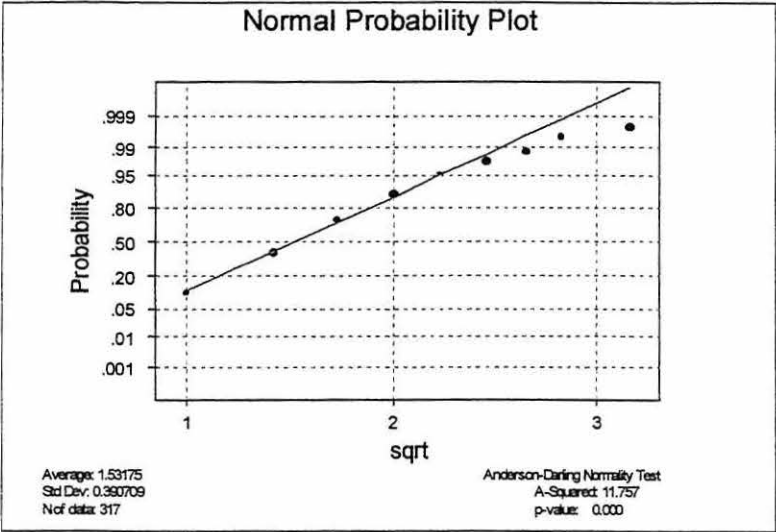
CHAPTER 6: Milk Yield SR, C/TN and C/TS Anderson-Darling Normality Test Results



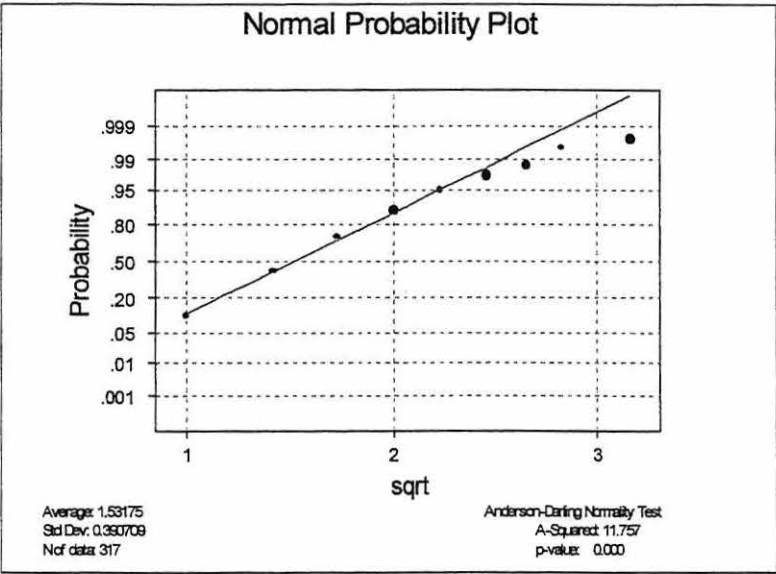
CHAPTER 6: Ovulation Rate SR, C/TN and C/TS Anderson-Darling Normality Test Results



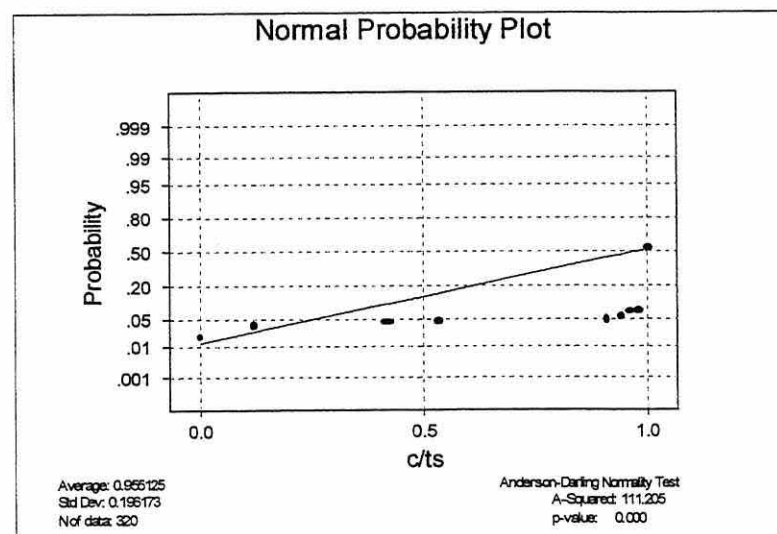
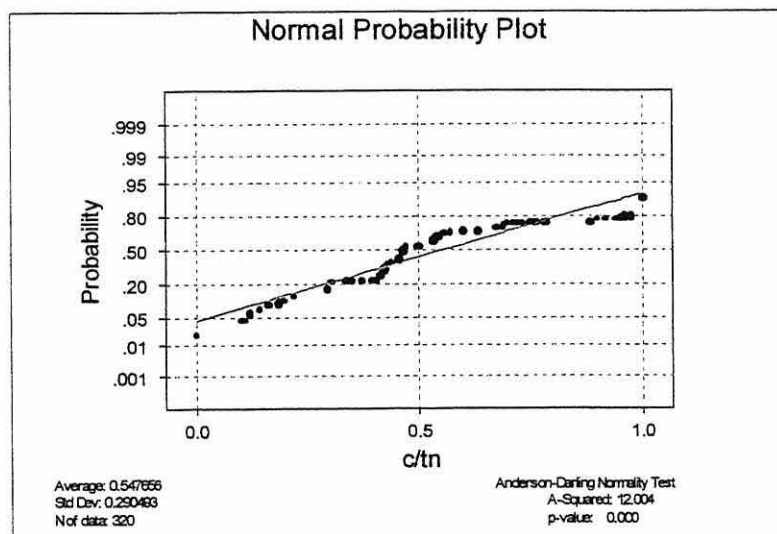
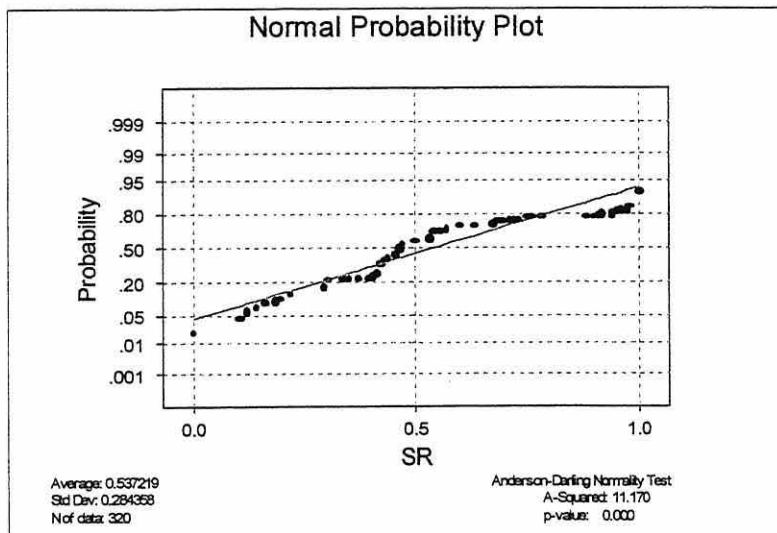
Chapter 7: Square Root Transformation of OR Data



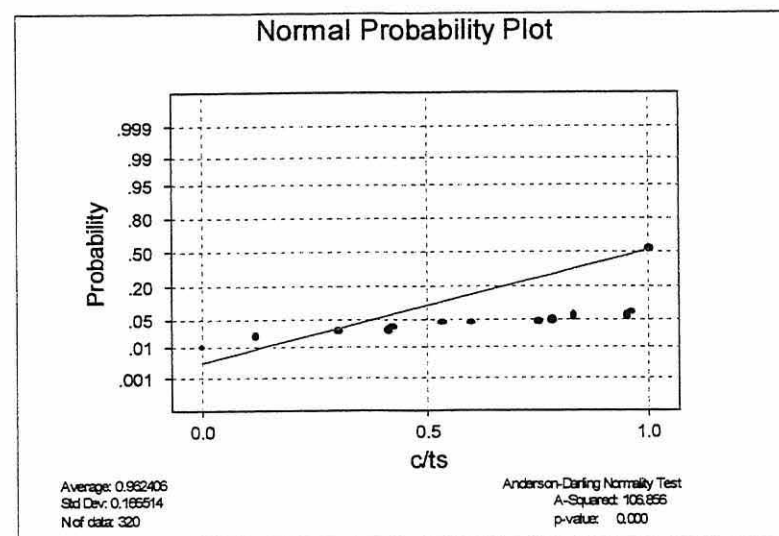
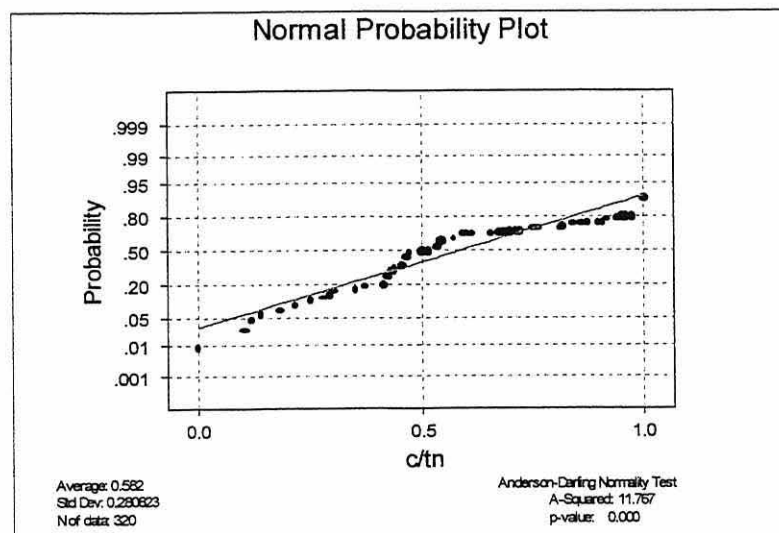
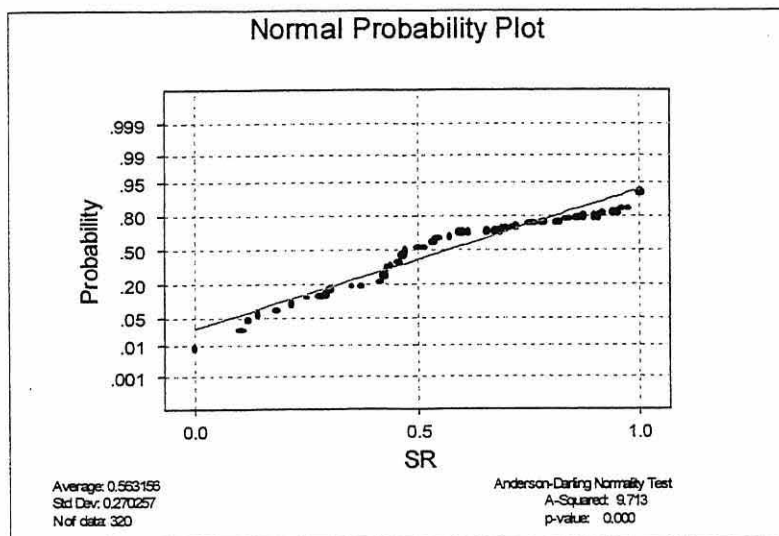
Chapter 7: Log Transformation of OR Data



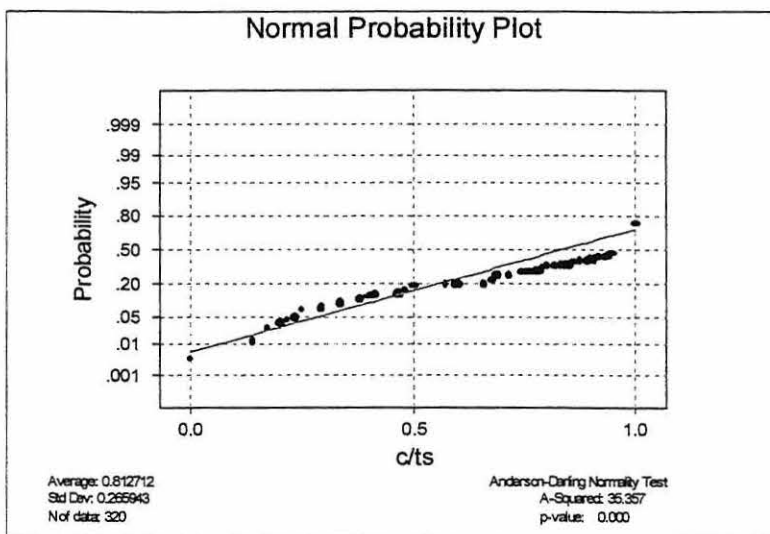
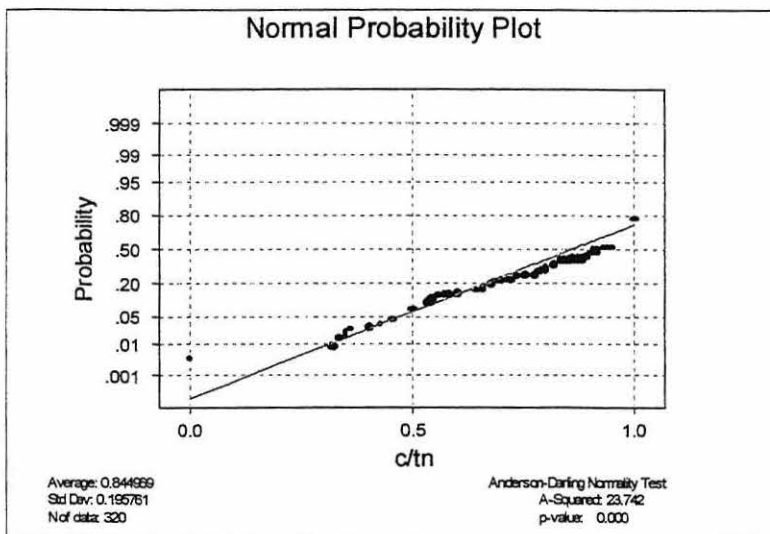
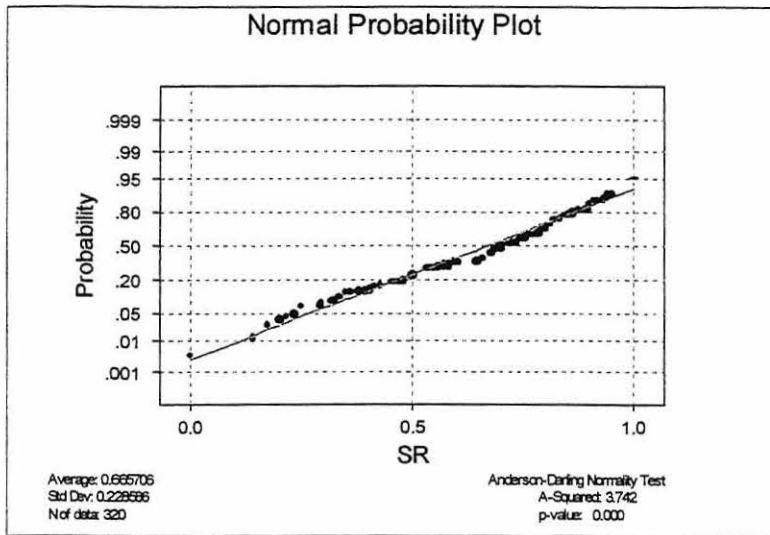
CHAPTER 7: LOG Ovulation Rate SR, C/TN and C/TS Anderson-Darling Normality Test Results



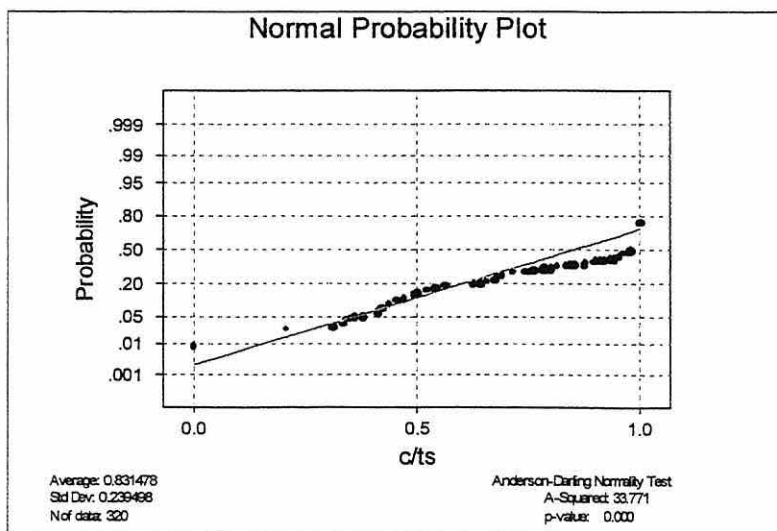
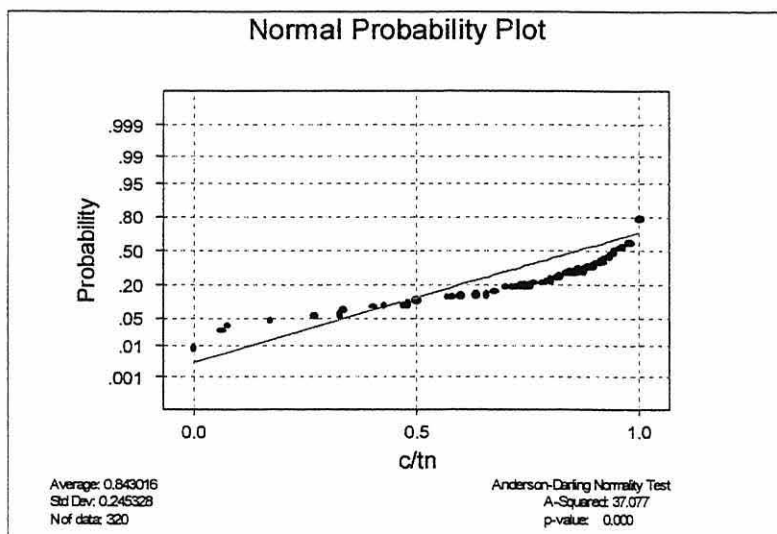
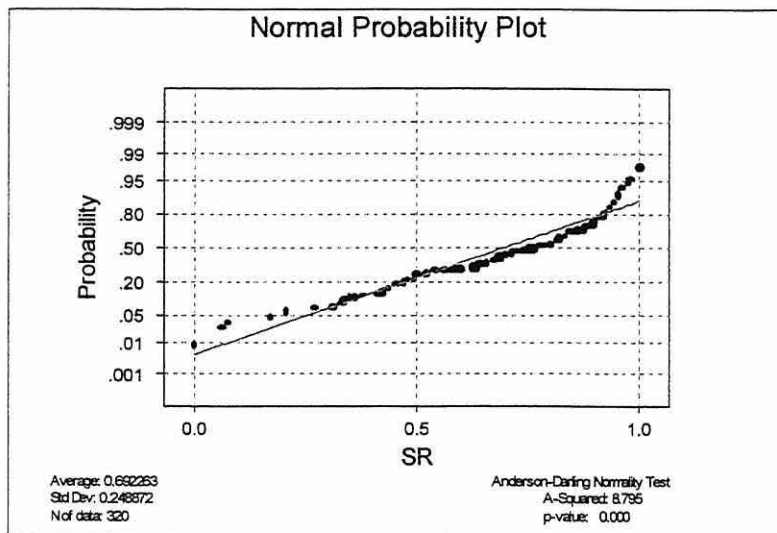
CHAPTER 7: Square Root Ovulation Rate SR, C/TN and C/TS Anderson-Darling Normality Test Results



CHAPTER 8: Muscle Depth SR, C/TN and C/TS Anderson-Darling Normality Test Results



CHAPTER 8: Milk Yield SR, C/TN and C/TS Anderson-Darling Normality Test Results



Appendix 5

Tabulated Results Pertaining to Chapter 5

Table 5.1. Interactions between Method and Year for Muscle Depth

Year Method	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.48	0.56	0.82	0.69	0.81	0.88	0.53	0.77	0.72	0.47	0.67	0.66	0.54	0.70	0.77
	T 0.55	0.68	0.95	0.81	0.93	0.97	0.58	0.90	0.84	0.54	0.84	0.79	0.63	0.85	0.90
2 UT	0.76	0.76	1.00	0.40	1.00	0.40	0.37	1.00	0.37	0.59	0.63	0.84	0.53	0.85	0.65
	T 0.85	0.85	1.00	0.41	1.00	0.41	0.38	1.00	0.38	0.75	0.78	0.96	0.62	0.95	0.79
3 UT	0.69	0.72	0.97	0.76	0.82	0.93	0.73	0.77	0.95	0.52	0.59	0.82	0.68	0.73	0.92
	T 0.76	0.80	1.00	0.84	0.91	0.97	0.79	0.84	0.99	0.59	0.66	0.94	0.75	0.81	0.98
4 UT	0.68	0.69	0.97	0.75	0.75	1.00	0.67	0.69	0.93	0.66	0.66	1.00	0.69	0.70	0.98
	T 0.76	0.76	1.00	0.85	0.85	1.00	0.74	0.77	0.99	0.76	0.76	1.00	0.78	0.79	1.00
ALL UT	0.65	0.68	0.94	0.65	0.84	0.80	0.58	0.81	0.74	0.56	0.64	0.83	0.61	0.74	0.83
	T 0.74	0.78	0.99	0.75	0.94	0.92	0.63	0.91	0.87	0.67	0.76	0.95	0.70	0.86	0.94

Content represents the mean of the results (to 2dp)

P<0.05

Table 5.2. Interactions between Method and % to Select for Muscle Depth

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.38	0.67	0.46	0.48	0.66	0.77	0.56	0.71	0.81	0.62	0.71	0.89	0.68	0.76	0.92	0.54	0.70	0.77
	T 0.47	0.85	0.60	0.54	0.81	0.89	0.64	0.85	0.92	0.69	0.83	0.96	0.78	0.89	0.98	0.63	0.85	0.90
2 UT	0.37	0.78	0.53	0.60	0.95	0.61	0.51	0.86	0.63	0.56	0.77	0.77	0.62	0.87	0.73	0.53	0.85	0.65
	T 0.49	0.94	0.70	0.75	1.00	0.76	0.59	0.95	0.77	0.56	0.88	0.86	0.68	0.96	0.84	0.62	0.95	0.79
3 UT	0.66	0.74	0.85	0.66	0.71	0.90	0.69	0.75	0.91	0.62	0.64	0.96	0.77	0.79	0.96	0.68	0.73	0.92
	T 0.80	0.91	0.95	0.76	0.82	0.97	0.72	0.81	0.96	0.63	0.65	0.99	0.82	0.84	0.99	0.75	0.81	0.98
4 UT	0.63	0.66	0.89	0.75	0.75	1.00	0.72	0.72	1.00	0.58	0.58	1.00	0.78	0.78	1.00	0.69	0.70	0.98
	T 0.79	0.83	0.98	0.85	0.85	1.00	0.78	0.78	1.00	0.58	0.58	1.00	0.85	0.85	1.00	0.78	0.79	1.00
ALL UT	0.51	0.71	0.68	0.62	0.77	0.82	0.62	0.76	0.83	0.59	0.67	0.91	0.71	0.80	0.91	0.61	0.74	0.83
	T 0.64	0.88	0.85	0.72	0.89	0.94	0.68	0.85	0.94	0.61	0.75	0.97	0.78	0.89	0.97	0.70	0.86	0.94

Content represents the mean of the results (to 2dp)

SR, C/TN & C/TS (UT and T) P>0.05 except C/TS (UT)

Table 5.3. Interactions between % to Select and Year for Muscle Depth

Year % to Select	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.71	0.79	0.77	0.69	0.97	0.72	0.46	0.84	0.49	0.18	0.24	0.75	0.51	0.71	0.68
	0.86	0.94	0.91	0.85	1.00	0.88	0.58	0.97	0.63	0.18	0.31	0.91	0.65	0.89	0.85
15 UT	0.81	0.84	0.97	0.44	0.64	0.80	0.60	0.84	0.76	0.63	0.75	0.74	0.62	0.77	0.82
	0.92	0.94	1.00	0.47	0.76	0.91	0.70	0.94	0.89	0.76	0.89	0.89	0.73	0.89	0.94
25 UT	0.58	0.58	1.00	0.69	0.91	0.78	0.55	0.80	0.75	0.66	0.75	0.81	0.62	0.76	0.83
	0.60	0.60	1.00	0.79	0.98	0.89	0.57	0.88	0.87	0.75	0.85	0.93	0.68	0.86	0.94
35 UT	0.61	0.64	0.97	0.64	0.76	0.88	0.58	0.71	0.87	0.53	0.58	0.91	0.59	0.67	0.91
	0.63	0.67	1.00	0.66	0.85	0.95	0.61	0.81	0.95	0.56	0.63	0.98	0.61	0.75	0.97
45 UT	0.55	0.55	1.00	0.79	0.94	0.85	0.69	0.85	0.84	0.82	0.87	0.93	0.71	0.80	0.91
	0.57	0.58	1.00	0.88	0.98	0.94	0.71	0.91	0.93	0.91	0.94	0.99	0.79	0.89	0.98
ALL UT	0.65	0.68	0.94	0.65	0.84	0.80	0.58	0.81	0.74	0.56	0.64	0.83	0.61	0.74	0.83
	0.74	0.78	0.99	0.75	0.94	0.92	0.63	0.91	0.87	0.67	0.76	0.95	0.70	0.86	0.94

Content represents the mean of the results (to 2dp)

All $P < 0.05$, except C/TS (UT and T)

Table 5.4. Interactions between Method and Farm for Milk Yield

Farm Method	A			B			C			D			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.76	0.76	1.00	0.76	0.81	0.95	0.83	0.89	0.94	0.67	0.67	1.00	0.75	0.78	0.97
	0.79	0.80	1.00	0.78	0.87	0.99	0.85	0.94	0.98	0.69	0.69	1.00	0.78	0.84	1.00
2 UT	0.57	1.00	0.57	0.83	1.00	0.83	0.64	0.99	0.65	0.18	0.18	0.80	0.56	0.79	0.71
	0.57	1.00	0.57	0.87	1.00	0.87	0.66	1.00	0.67	0.19	0.19	0.95	0.60	0.93	0.79
3 UT	0.86	0.92	0.94	0.72	0.72	0.99	0.78	0.88	0.85	0.78	0.80	0.97	0.78	0.83	0.94
	0.89	0.95	0.97	0.75	0.75	1.00	0.82	0.93	0.92	0.81	0.87	0.99	0.82	0.89	0.98
4 UT	0.83	0.86	0.98	0.86	0.89	0.96	0.81	0.89	0.87	0.79	0.80	0.99	0.82	0.86	0.95
	0.84	0.87	1.00	0.87	0.93	0.99	0.85	0.95	0.94	0.86	0.87	1.00	0.86	0.91	0.99
ALL UT	0.75	0.88	0.87	0.79	0.86	0.93	0.76	0.91	0.83	0.60	0.61	0.94	0.73	0.82	0.89
	0.79	0.93	0.95	0.82	0.92	0.98	0.80	0.96	0.90	0.67	0.70	0.99	0.77	0.89	0.96

Content represents the mean of the results (to 2dp)

$P < 0.05$

Table 5.5. Interactions between Method and % to Select for Milk Yield

% to Select		5			15			25			35			45			ALL		
Method		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1	UT	0.62	0.72	0.91	0.79	0.83	0.96	0.78	0.79	0.99	0.77	0.77	1.00	0.80	0.80	1.00	0.75	0.78	0.97
	T	0.66	0.84	0.96	0.81	0.90	0.99	0.81	0.83	1.00	0.79	0.79	1.00	0.82	0.83	1.00	0.78	0.84	1.00
2	UT	0.38	0.75	0.38	0.50	0.76	0.73	0.59	0.77	0.82	0.62	0.82	0.80	0.69	0.86	0.83	0.56	0.79	0.72
	T	0.40	0.92	0.40	0.52	0.93	0.80	0.69	0.93	0.91	0.64	0.93	0.85	0.71	0.95	0.88	0.60	0.93	0.79
3	UT	0.48	0.59	0.83	0.81	0.88	0.93	0.86	0.89	0.97	0.86	0.88	0.98	0.90	0.91	0.98	0.78	0.83	0.94
	T	0.52	0.69	0.94	0.83	0.91	0.97	0.88	0.92	0.99	0.88	0.91	0.99	0.91	0.94	0.99	0.82	0.89	0.98
4	UT	0.62	0.72	0.83	0.87	0.92	0.95	0.89	0.90	0.99	0.87	0.87	0.99	0.89	0.90	0.99	0.82	0.86	0.95
	T	0.66	0.85	0.92	0.88	0.95	0.98	0.91	0.93	1.00	0.88	0.89	1.00	0.90	0.91	1.00	0.86	0.91	0.99
ALL	UT	0.53	0.69	0.74	0.74	0.85	0.89	0.78	0.84	0.94	0.78	0.84	0.94	0.82	0.87	0.95	0.73	0.82	0.89
	T	0.57	0.83	0.85	0.77	0.92	0.95	0.83	0.91	0.99	0.81	0.89	0.98	0.84	0.91	0.98	0.77	0.89	0.96

Content represents the mean of the results (to 2dp)

P<0.05

Table 5.6. Interactions between % to Select and Farm for Milk Yield

Farm		A			B			C			D			ALL		
% to Select		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5	UT	0.68	0.87	0.81	0.66	0.80	0.86	0.50	0.84	0.54	0.26	0.26	0.75	0.53	0.69	0.74
	T	0.73	0.94	0.91	0.69	0.92	0.91	0.53	0.96	0.59	0.27	0.27	0.92	0.57	0.83	0.85
15	UT	0.77	0.88	0.89	0.84	0.93	0.91	0.74	0.96	0.78	0.62	0.62	1.00	0.74	0.84	0.89
	T	0.78	0.92	0.96	0.86	0.98	0.94	0.76	0.99	0.83	0.68	0.68	1.00	0.77	0.92	0.95
25	UT	0.75	0.86	0.88	0.87	0.87	1.00	0.86	0.96	0.90	0.64	0.66	0.98	0.78	0.84	0.94
	T	0.78	0.91	0.96	0.90	0.90	1.00	0.90	0.99	0.94	0.71	0.75	1.00	0.83	0.91	0.99
35	UT	0.78	0.89	0.88	0.77	0.82	0.95	0.86	0.91	0.95	0.72	0.73	0.98	0.78	0.84	0.94
	T	0.81	0.94	0.95	0.77	0.86	0.99	0.87	0.92	0.98	0.77	0.81	0.99	0.81	0.89	0.98
45	UT	0.80	0.91	0.89	0.83	0.87	0.96	0.85	0.89	0.96	0.79	0.80	0.99	0.82	0.87	0.95
	T	0.83	0.95	0.95	0.84	0.91	0.99	0.86	0.91	0.99	0.84	0.86	1.00	0.84	0.91	0.98
ALL	UT	0.75	0.88	0.87	0.79	0.86	0.93	0.76	0.91	0.83	0.60	0.61	0.94	0.73	0.82	0.89
	T	0.79	0.93	0.95	0.82	0.92	0.98	0.80	0.96	0.90	0.67	0.70	0.99	0.77	0.89	0.96

Content represents the mean of the results (to 2dp)

All P<0.05

Table 5.7. Interactions between Method and Year for Ovulation Rate

Year Method	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.42	0.42	1.00	0.41	0.41	0.95	0.71	0.77	0.94	0.59	0.76	0.83	0.53	0.59	0.93
	T 0.49	0.49	1.00	0.49	0.49	1.00	0.83	0.89	0.99	0.72	0.90	0.95	0.64	0.72	0.99
2 UT	0.78	0.78	1.00	0.31	0.31	1.00	0.68	0.68	1.00	0.67	0.67	1.00	0.61	0.61	1.00
	T 0.90	0.90	1.00	0.32	0.32	1.00	0.79	0.79	1.00	0.79	0.79	1.00	0.73	0.84	1.00
3 UT	0.50	0.50	0.95	0.56	0.56	0.99	0.53	0.54	0.99	0.73	0.74	0.99	0.58	0.59	0.98
	T 0.54	0.54	1.00	0.59	0.61	1.00	0.53	0.55	1.00	0.81	0.83	1.00	0.63	0.64	1.00
4 UT	0.47	0.47	1.00	0.51	0.51	1.00	0.56	0.58	0.94	0.68	0.74	0.94	0.56	0.58	0.98
	T 0.52	0.52	1.00	0.55	0.55	1.00	0.57	0.73	1.00	0.75	0.84	0.99	0.60	0.64	1.00
ALL UT	0.54	0.54	0.99	0.45	0.45	0.99	0.62	0.64	0.94	0.67	0.73	0.94	0.57	0.59	0.97
	T 0.64	0.64	1.00	0.49	0.49	1.00	0.69	0.72	1.00	0.77	0.84	0.99	0.65	0.68	1.00

Content represents the mean of the results (to 2dp)

P<0.05

Table 5.8. Interactions between Method and % to Select for Ovulation Rate

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.49	0.70	0.72	0.58	0.62	0.96	0.50	0.50	1.00	0.56	0.59	0.97	0.53	0.53	1.00	0.53	0.59	0.93
	T 0.57	0.84	0.88	0.74	0.79	1.00	0.63	0.63	1.00	0.68	0.73	1.00	0.58	0.58	1.00	0.64	0.72	0.99
2 UT	0.89	0.89	1.00	0.80	0.80	1.00	0.38	0.38	1.00	0.35	0.35	1.00	0.63	0.63	1.00	0.61	0.61	1.00
	T 0.97	0.97	1.00	0.94	0.94	1.00	0.38	0.38	1.00	0.35	0.71	1.00	0.71	0.71	1.00	0.73	0.73	1.00
3 UT	0.71	0.75	0.89	0.53	0.53	1.00	0.52	0.52	1.00	0.57	0.57	1.00	0.56	0.56	1.00	0.58	0.59	0.98
	T 0.79	0.85	0.97	0.59	0.59	1.00	0.55	0.55	1.00	0.61	0.57	1.00	0.57	0.57	1.00	0.63	0.64	1.00
4 UT	0.65	0.74	0.90	0.53	0.54	0.99	0.50	0.50	1.00	0.56	0.56	1.00	0.54	0.54	1.00	0.56	0.58	0.98
	T 0.72	0.84	0.97	0.57	0.60	1.00	0.52	0.52	1.00	0.62	0.56	1.00	0.56	0.56	1.00	0.60	0.64	1.00
ALL UT	0.68	0.77	0.88	0.61	0.62	0.99	0.48	0.48	1.00	0.51	0.52	0.99	0.56	0.56	1.00	0.57	0.59	0.97
	T 0.79	0.88	0.97	0.74	0.76	1.00	0.52	0.52	1.00	0.57	0.61	1.00	0.61	0.61	1.00	0.65	0.68	1.00

Content represents the mean of the results (to 2dp)

P<0.05

Table 5.9. Interactions between % to Select and Year for Ovulation Rate

Year		1988			1989			1991			1992			ALL		
		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
% to Select																
5	UT	0.59	0.59	0.94	0.67	0.67	0.93	0.71	0.84	0.86	0.76	0.98	0.79	0.68	0.77	0.88
	T	0.75	0.75	1.00	0.72	0.74	0.99	0.80	0.91	0.95	0.88	1.00	0.90	0.79	0.88	0.97
15	UT	0.59	0.59	1.00	0.27	0.27	1.00	0.79	0.79	1.00	0.81	0.86	0.95	0.61	0.62	0.99
	T	0.71	0.71	1.00	0.30	0.30	1.00	0.88	0.88	1.00	0.91	0.95	0.99	0.74	0.76	1.00
25	UT	0.35	0.35	1.00	0.54	0.54	1.00	0.49	0.49	1.00	0.53	0.53	1.00	0.48	0.48	1.00
	T	0.35	0.35	1.00	0.60	0.60	1.00	0.55	0.55	1.00	0.58	0.58	1.00	0.52	0.52	1.00
35	UT	0.43	0.43	1.00	0.31	0.31	1.00	0.59	0.59	1.00	0.71	0.74	0.97	0.51	0.52	0.99
	T	0.43	0.43	1.00	0.32	0.32	1.00	0.66	0.66	1.00	0.81	0.84	1.00	0.57	0.58	1.00
45	UT	0.75	0.75	1.00	0.46	0.46	1.00	0.50	0.50	1.00	0.54	0.54	1.00	0.56	0.56	1.00
	T	0.85	0.85	1.00	0.46	0.46	1.00	0.50	0.50	1.00	0.57	0.57	1.00	0.61	0.61	1.00
ALL	UT	0.54	0.54	0.99	0.45	0.45	0.99	0.62	0.64	0.97	0.67	0.73	0.94	0.57	0.59	0.97
	T	0.64	0.64	1.00	0.49	0.49	1.00	0.69	0.72	1.00	0.77	0.84	0.99	0.65	0.68	1.00

Content represents the mean of the results (to 2dp)

All P<0.05 except C/TS (UT and T)

Tabulated Results Pertaining to Chapter 6

Table 6.1. Interactions between Method and Year for Muscle Depth

Year Method	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.48	0.56	0.82	0.69	0.81	0.88	0.53	0.77	0.72	0.47	0.67	0.66	0.54	0.70	0.77
T	0.55	0.68	0.95	0.81	0.93	0.97	0.58	0.90	0.84	0.54	0.84	0.79	0.63	0.85	0.90
2 UT	0.69	0.84	0.85	0.48	0.48	1.00	0.51	0.63	0.88	0.52	0.55	0.84	0.55	0.62	0.89
T	0.76	0.93	0.95	0.56	0.56	1.00	0.52	0.70	0.97	0.64	0.67	0.96	0.63	0.74	0.98
3 UT	0.68	0.72	0.95	0.67	0.67	1.00	0.60	0.63	0.93	0.53	0.59	0.80	0.62	0.65	0.92
T	0.73	0.81	0.99	0.74	0.74	1.00	0.64	0.68	0.98	0.60	0.67	0.92	0.68	0.73	0.98
4 UT	0.68	0.69	0.97	0.75	0.75	1.00	0.67	0.69	0.93	0.66	0.66	1.00	0.69	0.70	0.98
T	0.76	0.76	1.00	0.85	0.85	1.00	0.74	0.77	0.99	0.76	0.76	1.00	0.78	0.79	1.00
ALL UT	0.63	0.70	0.90	0.65	0.68	0.97	0.58	0.68	0.86	0.55	0.62	0.82	0.60	0.67	0.89
T	0.70	0.80	0.98	0.75	0.85	0.99	0.62	0.77	0.96	0.64	0.74	0.94	0.68	0.78	0.98

Content represents the mean of the results (to 2dp)

P<0.05, except C/TS (UT and T)

Table 6.2. Interactions between Method and % to Select for Muscle Depth

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.38	0.67	0.46	0.48	0.66	0.77	0.56	0.71	0.81	0.62	0.71	0.89	0.68	0.76	0.92	0.54	0.70	0.77
T	0.47	0.85	0.60	0.54	0.81	0.89	0.64	0.85	0.92	0.69	0.83	0.96	0.78	0.89	0.98	0.63	0.85	0.90
2 UT	0.48	0.78	0.63	0.62	0.65	0.92	0.61	0.63	0.96	0.50	0.51	0.97	0.53	0.54	0.97	0.55	0.62	0.89
T	0.58	0.94	0.77	0.71	0.79	0.98	0.68	0.70	1.00	0.61	0.61	1.00	0.54	0.54	1.00	0.63	0.74	0.98
3 UT	0.59	0.66	0.79	0.62	0.66	0.92	0.64	0.66	0.95	0.56	0.58	0.97	0.70	0.72	0.96	0.62	0.65	0.92
T	0.73	0.83	0.92	0.70	0.76	0.98	0.65	0.68	0.99	0.57	0.59	1.00	0.73	0.75	0.99	0.68	0.73	0.98
4 UT	0.63	0.66	0.89	0.75	0.75	1.00	0.72	0.72	1.00	0.58	0.58	1.00	0.78	0.78	1.00	0.69	0.70	0.98
T	0.79	0.83	0.98	0.85	0.85	1.00	0.78	0.78	1.00	0.58	0.58	1.00	0.85	0.85	1.00	0.78	0.79	1.00
ALL UT	0.52	0.69	0.69	0.62	0.68	0.90	0.63	0.68	0.93	0.56	0.59	0.96	0.67	0.70	0.97	0.60	0.67	0.89
T	0.66	0.87	0.85	0.71	0.81	0.98	0.69	0.75	0.99	0.61	0.66	0.99	0.73	0.77	1.00	0.68	0.78	0.98

Content represents the mean of the results (to 2dp)

P>0.05, except SR (T)

Table 6.3. Interactions between % to Select and Year for Muscle Depth

Year % to Select	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.54	0.79	0.60	0.92	0.97	0.95	0.43	0.75	0.49	0.19	0.25	0.73	0.52	0.69	0.69
T	0.67	0.94	0.74	0.99	1.00	1.00	0.49	0.91	0.60	0.19	0.32	0.89	0.66	0.87	0.85
15 UT	0.78	0.84	0.94	0.37	0.40	0.97	0.68	0.73	0.96	0.63	0.75	0.74	0.62	0.68	0.90
T	0.85	0.94	0.98	0.40	0.46	1.00	0.32	0.82	0.99	0.76	0.89	0.89	0.71	0.81	0.98
25 UT	0.58	0.58	1.00	0.66	0.69	0.97	0.64	0.70	0.94	0.66	0.76	0.81	0.63	0.68	0.93
T	0.60	0.60	1.00	0.74	0.78	1.00	0.65	0.75	0.99	0.76	0.86	0.93	0.69	0.75	0.99
35 UT	0.71	0.74	0.97	0.51	0.53	0.98	0.50	0.52	0.98	0.53	0.58	0.91	0.56	0.59	0.96
T	0.79	0.83	1.00	0.54	0.59	1.00	0.53	0.57	1.00	0.56	0.63	0.98	0.61	0.66	0.99
45 UT	0.54	0.55	0.99	0.77	0.79	0.98	0.66	0.70	0.96	0.72	0.76	0.93	0.67	0.70	0.97
T	0.57	0.58	1.00	0.83	0.86	1.00	0.68	0.75	0.99	0.81	0.85	0.99	0.73	0.77	1.00
ALL UT	0.63	0.70	0.90	0.65	0.68	0.97	0.58	0.68	0.86	0.55	0.62	0.82	0.60	0.67	0.89
T	0.70	0.80	0.98	0.75	0.79	1.00	0.62	0.77	0.96	0.64	0.74	0.94	0.68	0.78	0.98

Content represents the mean of the results (to 2dp)

All P<0.05

Table 6.4. Interactions between Method and Farm for Milk Yield

Farm Method	A			B			C			D			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.76	0.76	1.00	0.76	0.81	0.95	0.83	0.89	0.94	0.67	0.67	1.00	0.75	0.78	0.97
T	0.79	0.80	1.00	0.78	0.87	0.99	0.85	0.94	0.98	0.69	0.69	1.00	0.78	0.84	1.00
2 UT	0.71	0.71	1.00	0.71	0.71	1.00	0.64	0.99	0.65	0.77	1.00	0.77	0.71	0.85	0.85
T	0.71	0.71	1.00	0.73	0.73	1.00	0.66	1.00	0.67	0.79	1.00	0.79	0.72	0.92	0.93
3 UT	0.85	0.89	0.96	0.81	0.94	0.87	0.78	0.88	0.85	0.83	0.86	0.96	0.82	0.89	0.91
T	0.87	0.91	0.99	0.84	0.97	0.93	0.82	0.93	0.92	0.86	0.92	0.98	0.85	0.93	0.96
4 UT	0.83	0.86	0.98	0.86	0.89	0.96	0.81	0.89	0.87	0.79	0.80	0.99	0.82	0.86	0.95
T	0.84	0.87	1.00	0.87	0.93	0.99	0.85	0.95	0.94	0.86	0.87	1.00	0.86	0.91	0.99
ALL UT	0.79	0.80	0.98	0.79	0.84	0.94	0.76	0.91	0.83	0.76	0.83	0.93	0.78	0.85	0.92
T	0.81	0.83	0.99	0.81	0.89	0.98	0.80	0.96	0.90	0.81	0.91	0.97	0.81	0.90	0.97

Content represents the mean of the results (to 2dp)

P<0.05

Table 6.5. Interactions between Method and % to Select for Milk Yield

% to Select		5			15			25			35			45			ALL		
Method		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1	UT	0.62	0.72	0.91	0.79	0.83	0.96	0.78	0.79	0.99	0.77	0.77	1.00	0.80	0.80	1.00	0.75	0.78	0.97
	T	0.66	0.84	0.96	0.81	0.90	0.99	0.81	0.83	1.00	0.79	0.79	1.00	0.82	0.83	1.00	0.78	0.84	1.00
2	UT	0.61	0.91	0.70	0.71	0.90	0.81	0.71	0.83	0.88	0.74	0.81	0.92	0.77	0.81	0.96	0.71	0.85	0.85
	T	0.64	0.95	0.84	0.73	0.95	0.90	0.71	0.91	0.94	0.75	0.88	0.96	0.79	0.88	0.98	0.72	0.92	0.93
3	UT	0.55	0.77	0.71	0.82	0.92	0.90	0.91	0.94	0.97	0.90	0.91	0.98	0.90	0.91	0.98	0.82	0.89	0.91
	T	0.59	0.89	0.82	0.83	0.94	0.94	0.92	0.96	0.99	0.90	0.93	0.99	0.91	0.93	0.98	0.85	0.93	0.96
4	UT	0.62	0.72	0.83	0.87	0.92	0.95	0.89	0.90	0.99	0.87	0.87	0.99	0.89	0.90	0.99	0.82	0.86	0.95
	T	0.66	0.85	0.92	0.88	0.95	0.98	0.91	0.93	1.00	0.88	0.89	1.00	0.90	0.91	1.00	0.86	0.91	0.99
ALL	UT	0.60	0.78	0.79	0.80	0.89	0.90	0.82	0.86	0.96	0.82	0.84	0.97	0.84	0.85	0.98	0.78	0.85	0.92
	T	0.64	0.89	0.89	0.81	0.95	0.96	0.85	0.91	0.99	0.84	0.88	0.99	0.86	0.89	0.99	0.81	0.90	0.97

Content represents the mean of the results (to 2dp)

P<0.05, except C/TN (T) and C/TS (T)

Table 6.6. Interactions between % to Select and Farm for Milk Yield

Farm		A			B			C			D			ALL		
% to Select		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5	UT	0.76	0.82	0.93	0.71	0.90	0.80	0.50	0.84	0.54	0.44	0.55	0.88	0.60	0.78	0.79
	T	0.79	0.87	0.99	0.74	0.97	0.88	0.53	0.96	0.59	0.44	0.65	0.97	0.64	0.89	0.89
15	UT	0.79	0.80	0.99	0.87	0.94	0.92	0.74	0.96	0.78	0.78	0.87	0.92	0.80	0.89	0.90
	T	0.80	0.81	1.00	0.88	0.97	0.95	0.76	0.99	0.83	0.80	0.91	0.97	0.81	0.94	0.96
25	UT	0.75	0.76	1.00	0.83	0.83	1.00	0.86	0.96	0.90	0.84	0.90	0.93	0.82	0.86	0.96
	T	0.77	0.77	1.00	0.86	0.86	1.00	0.90	0.99	0.94	0.86	0.95	0.96	0.85	0.91	0.95
35	UT	0.80	0.80	1.00	0.76	0.76	1.00	0.86	0.91	0.95	0.85	0.91	0.94	0.82	0.84	0.97
	T	0.83	0.83	1.00	0.77	0.78	1.00	0.87	0.92	0.98	0.86	0.95	0.96	0.84	0.88	0.99
45	UT	0.82	0.83	0.99	0.76	0.77	0.99	0.85	0.89	0.96	0.91	0.93	0.98	0.84	0.85	0.98
	T	0.84	0.86	1.00	0.78	0.79	1.00	0.94	0.91	0.99	0.93	0.97	0.99	0.86	0.89	0.99
ALL	UT	0.79	0.80	0.98	0.79	0.84	0.94	0.76	0.91	0.83	0.76	0.83	0.93	0.78	0.85	0.92
	T	0.81	0.83	0.99	0.81	0.89	0.98	0.80	0.96	0.90	0.81	0.91	0.97	0.81	0.90	0.97

Content represents the mean of the results (to 2dp)

All P<0.05

Table 6.7. Interactions between Method and Year for Ovulation Rate

Year Method	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.42	0.42	1.00	0.41	0.41	0.95	0.71	0.77	0.94	0.59	0.76	0.83	0.53	0.59	0.93
T	0.49	0.49	1.00	0.49	0.49	1.00	0.83	0.89	0.99	0.72	0.90	0.95	0.64	0.72	0.99
2 UT	0.19	0.19	1.00	0.24	0.24	1.00	0.11	0.11	1.00	0.32	0.32	1.00	0.22	0.22	1.00
T	0.19	0.19	1.00	0.25	0.25	1.00	0.11	0.11	1.00	0.42	0.42	1.00	0.24	0.24	1.00
3 UT	0.48	0.48	0.95	0.56	0.57	0.99	0.48	0.49	0.99	0.68	0.70	0.99	0.55	0.56	0.98
T	0.51	0.51	1.00	0.60	0.62	1.00	0.49	0.50	1.00	0.74	0.77	1.00	0.59	0.61	1.00
4 UT	0.47	0.47	1.00	0.51	0.51	1.00	0.56	0.58	0.94	0.68	0.74	0.94	0.56	0.58	0.98
T	0.52	0.52	1.00	0.55	0.55	1.00	0.57	0.73	1.00	0.75	0.84	0.99	0.60	0.64	1.00
ALL UT	0.39	0.39	0.99	0.43	0.43	0.99	0.47	0.49	0.97	0.57	0.63	0.94	0.46	0.49	0.97
T	0.43	0.43	1.00	0.48	0.48	1.00	0.52	0.56	0.99	0.67	0.75	0.99	0.53	0.56	0.99

Content represents the mean of the results (to 2dp)

P<0.05

Table 6.8. Interactions between Method and % to Select for Ovulation Rate

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.49	0.70	0.72	0.58	0.62	0.96	0.50	0.50	1.00	0.56	0.59	0.97	0.53	0.53	1.00	0.53	0.59	0.93
T	0.57	0.84	0.88	0.74	0.79	1.00	0.63	0.63	1.00	0.68	0.73	1.00	0.58	0.58	1.00	0.64	0.72	0.99
2 UT	0.54	0.54	1.00	0.19	0.19	1.00	0.14	0.14	1.00	0.11	0.11	1.00	0.10	0.10	1.00	0.22	0.22	1.00
T	0.64	0.63	1.00	0.19	0.19	1.00	0.14	0.14	1.00	0.11	0.11	1.00	0.10	0.10	1.00	0.24	0.24	1.00
3 UT	0.71	0.75	0.90	0.49	0.49	1.00	0.53	0.53	1.00	0.51	0.51	1.00	0.52	0.52	1.00	0.55	0.56	0.98
T	0.79	0.85	0.98	0.51	0.51	1.00	0.57	0.57	1.00	0.52	0.52	1.00	0.52	0.52	1.00	0.59	0.61	1.00
4 UT	0.65	0.74	0.90	0.53	0.54	0.99	0.50	0.50	1.00	0.56	0.56	1.00	0.54	0.54	1.00	0.56	0.58	0.98
T	0.72	0.84	0.97	0.57	0.60	1.00	0.52	0.52	1.00	0.62	0.56	1.00	0.56	0.56	1.00	0.60	0.64	1.00
ALL UT	0.60	0.68	0.88	0.45	0.46	0.99	0.42	0.42	1.00	0.44	0.44	0.99	0.42	0.42	1.00	0.46	0.49	0.97
T	0.69	0.80	0.97	0.52	0.54	1.00	0.47	0.47	1.00	0.50	0.51	1.00	0.45	0.45	1.00	0.53	0.56	0.99

Content represents the mean of the results (to 2dp)

P<0.05, except C/TN (UT and T)

Table 6.9. Interactions between % to Select and Year for Ovulation Rate

Year	% to Select	1988			1989			1991			1992			ALL		
		SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5	UT	0.41	0.41	0.94	0.68	0.68	0.93	0.53	0.65	0.86	0.76	0.98	0.79	0.60	0.68	0.88
	T	0.50	0.50	1.00	0.73	0.75	0.99	0.57	0.76	0.95	0.88	1.00	0.90	0.69	0.80	0.97
15	UT	0.37	0.37	1.00	0.27	0.27	1.00	0.55	0.55	1.00	0.61	0.66	0.95	0.45	0.46	0.99
	T	0.41	0.41	1.00	0.30	0.30	1.00	0.63	0.63	1.00	0.68	0.76	0.95	0.52	0.54	1.00
25	UT	0.27	0.27	1.00	0.54	0.54	1.00	0.39	0.39	1.00	0.47	0.47	1.00	0.42	0.42	1.00
	T	0.27	0.27	1.00	0.60	0.60	1.00	0.46	0.46	1.00	0.55	0.55	1.00	0.47	0.47	1.00
35	UT	0.36	0.36	1.00	0.31	0.31	1.00	0.48	0.48	1.00	0.60	0.62	0.97	0.44	0.44	0.99
	T	0.36	0.36	1.00	0.32	0.32	1.00	0.57	0.57	1.00	0.70	0.75	1.00	0.50	0.51	1.00
45	UT	0.53	0.53	1.00	0.37	0.37	1.00	0.37	0.37	1.00	0.42	0.42	1.00	0.42	0.42	1.00
	T	0.59	0.59	1.00	0.37	0.37	1.00	0.38	0.38	1.00	0.45	0.45	1.00	0.45	0.45	1.00
ALL	UT	0.39	0.39	0.99	0.43	0.43	0.99	0.47	0.49	0.97	0.57	0.63	0.94	0.46	0.49	0.97
	T	0.43	0.43	1.00	0.48	0.48	0.99	0.52	0.56	0.99	0.67	0.75	0.99	0.53	0.56	0.97

Content represents the mean of the results (to 2dp)

All $P < 0.05$ except C/TS (UT and T)

Tabulated Results Pertaining to Chapter 7

Table 7.1. Interactions between Method and Year for Square Rooted Ovulation Rate

Year Method	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.43	0.43	1.00	0.43	0.43	0.90	0.71	0.77	0.94	0.57	0.76	0.81	0.54	0.60	0.91
	T 0.50	0.50	1.00	0.51	0.51	1.00	0.83	0.89	0.99	0.68	0.90	0.94	0.64	0.73	0.99
2 UT	0.52	0.52	1.00	0.18	0.18	0.80	0.47	0.47	1.00	0.53	0.53	1.00	0.43	0.43	0.95
	T 0.60	0.60	1.00	0.18	0.18	1.00	0.47	0.47	1.00	0.61	0.61	1.00	0.47	0.47	1.00
3 UT	0.67	0.67	0.99	0.60	0.60	1.00	0.61	0.62	0.99	0.77	0.79	0.98	0.66	0.67	0.99
	T 0.74	0.74	0.99	0.66	0.66	1.00	0.62	0.65	0.99	0.84	0.88	0.99	0.72	0.74	0.99
4 UT	0.59	0.59	1.00	0.55	0.55	1.00	0.68	0.69	0.99	0.78	0.83	0.96	0.65	0.66	0.99
	T 0.67	0.67	1.00	0.59	0.59	1.00	0.72	0.74	0.99	0.86	0.92	0.99	0.72	0.75	0.99
ALL UT	0.55	0.55	1.00	0.44	0.44	0.92	0.62	0.64	0.98	0.66	0.73	0.94	0.57	0.59	0.96
	T 0.63	0.63	1.00	0.49	0.49	1.00	0.67	0.70	0.99	0.76	0.84	0.99	0.64	0.68	0.99

Content represents the mean of the results (to 2dp)

P<0.05

Table 7.2. Interactions between Method and % to Select for Square Rooted Ovulation Rate

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.49	0.70	0.72	0.58	0.62	0.96	0.47	0.50	0.97	0.60	0.63	0.97	0.54	0.54	1.00	0.54	0.60	0.91
	T 0.57	0.84	0.88	0.74	0.79	0.99	0.58	0.63	0.97	0.71	0.76	0.97	0.59	0.59	1.00	0.64	0.73	0.98
2 UT	0.46	0.46	0.75	0.31	0.31	1.00	0.38	0.38	1.00	0.35	0.35	1.00	0.63	0.63	1.00	0.43	0.43	0.95
	T 0.58	0.58	1.00	0.31	0.31	1.00	0.38	0.38	1.00	0.35	0.35	1.00	0.71	0.71	1.00	0.47	0.47	1.00
3 UT	0.75	0.78	0.97	0.65	0.66	0.99	0.59	0.59	1.00	0.68	0.68	1.00	0.64	0.65	0.99	0.66	0.67	0.99
	T 0.84	0.88	0.92	0.70	0.71	0.99	0.61	0.61	1.00	0.72	0.73	0.99	0.70	0.71	0.99	0.72	0.74	0.99
4 UT	0.71	0.76	0.95	0.65	0.66	0.99	0.59	0.59	1.00	0.69	0.69	1.00	0.62	0.62	1.00	0.65	0.66	0.99
	T 0.77	0.86	0.99	0.74	0.76	0.99	0.63	0.63	1.00	0.75	0.76	0.99	0.69	0.69	1.00	0.72	0.75	0.99
ALL UT	0.60	0.68	0.85	0.55	0.56	0.99	0.51	0.51	0.99	0.57	0.59	0.99	0.61	0.61	0.98	0.57	0.59	0.96
	T 0.70	0.80	0.96	0.64	0.66	0.99	0.55	0.57	0.99	0.65	0.66	0.99	0.67	0.68	0.99	0.64	0.68	0.99

Content represents the mean of the results (to 2dp)

P<0.05

Table 7.3. Interactions between % to Select and Year for Square Rooted Ovulation Rate

Year % to Select	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.46	0.46	1.00	0.52	0.52	0.69	0.65	0.75	0.90	0.78	0.98	0.80	0.60	0.68	0.85
T	0.54	0.54	1.00	0.62	0.62	0.88	0.68	0.83	0.97	0.90	1.00	0.92	0.70	0.80	0.96
15 UT	0.52	0.52	1.00	0.27	0.27	1.00	0.72	0.72	1.00	0.70	0.75	0.95	0.55	0.56	0.99
T	0.56	0.56	1.00	0.30	0.30	1.00	0.79	0.79	1.00	0.81	0.88	0.99	0.64	0.60	0.99
25 UT	0.40	0.40	1.00	0.60	0.60	1.00	0.51	0.51	1.00	0.52	0.55	0.97	0.51	0.51	0.99
T	0.41	0.41	1.00	0.68	0.68	1.00	0.56	0.56	1.00	0.55	0.60	0.99	0.55	0.57	0.99
35 UT	0.51	0.51	1.00	0.35	0.35	1.00	0.69	0.69	1.00	0.77	0.80	0.97	0.58	0.59	0.99
T	0.52	0.52	1.00	0.35	0.35	1.00	0.76	0.76	1.00	0.86	0.91	0.99	0.65	0.66	0.99
45 UT	0.87	0.87	1.00	0.48	0.48	0.94	0.53	0.53	1.00	0.56	0.56	1.00	0.61	0.61	0.98
T	0.96	0.96	1.00	0.48	0.48	1.00	0.53	0.53	1.00	0.58	0.58	1.00	0.67	0.68	0.99
ALL UT	0.55	0.55	1.00	0.44	0.44	0.92	0.62	0.64	0.98	0.66	0.73	0.94	0.57	0.59	0.96
T	0.63	0.63	1.00	0.49	0.49	0.97	0.67	0.70	0.99	0.76	0.84	0.99	0.64	0.68	0.99

Content represents the mean of the results (to 2dp)

All $P < 0.05$

Table 7.4. Interactions between Method and Year for Logged Ovulation Rate

Year Method	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.39	0.39	1.00	0.42	0.42	1.00	0.72	0.75	0.97	0.64	0.76	0.83	0.54	0.58	0.89
T	0.47	0.47	1.00	0.51	0.51	1.00	0.83	0.86	0.97	0.79	0.91	0.95	0.67	0.72	0.98
2 UT	0.52	0.52	1.00	0.18	0.18	1.00	0.41	0.41	1.00	0.47	0.47	1.00	0.39	0.39	0.95
T	0.60	0.60	1.00	0.18	0.18	1.00	0.42	0.42	1.00	0.43	0.47	0.98	0.42	0.42	1.00
3 UT	0.51	0.51	1.00	0.45	0.45	1.00	0.65	0.66	0.99	0.71	0.71	1.00	0.58	0.58	0.99
T	0.57	0.57	1.00	0.48	0.48	1.00	0.70	0.72	0.99	0.79	0.79	1.00	0.64	0.65	0.99
4 UT	0.50	0.50	1.00	0.49	0.49	1.00	0.71	0.71	1.00	0.77	0.78	0.94	0.62	0.62	0.98
T	0.56	0.56	1.00	0.51	0.51	1.00	0.78	0.78	1.00	0.87	0.90	0.98	0.70	0.71	0.99
ALL UT	0.48	0.48	0.97	0.38	0.38	0.91	0.62	0.63	0.99	0.65	0.68	0.94	0.53	0.54	0.95
T	0.55	0.55	1.00	0.43	0.43	1.00	0.70	0.71	0.99	0.74	0.79	0.98	0.61	0.63	0.99

Content represents the mean of the results (to 2dp)

$P < 0.05$

Table 7.5. Interactions between Method and % to Select for Logged Ovulation Rate

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.35	0.44	0.53	0.54	0.58	0.96	0.51	0.54	0.97	0.66	0.69	0.97	0.65	0.65	1.00	0.54	0.58	0.89
T	0.44	0.58	0.73	0.69	0.74	0.95	0.64	0.69	0.99	0.77	0.81	0.98	0.75	0.75	1.00	0.67	0.72	0.98
2 UT	0.31	0.31	1.00	0.31	0.31	1.00	0.38	0.38	1.00	0.35	0.35	1.00	0.63	0.63	1.00	0.39	0.39	0.95
T	0.32	0.32	1.00	0.31	0.31	1.00	0.38	0.38	1.00	0.35	0.35	1.00	0.71	0.71	1.00	0.42	0.42	1.00
3 UT	0.47	0.47	1.00	0.50	0.51	0.99	0.58	0.59	0.99	0.72	0.72	1.00	0.63	0.63	1.00	0.58	0.58	0.99
T	0.51	0.51	1.00	0.56	0.57	0.99	0.61	0.62	0.99	0.80	0.82	0.99	0.69	0.69	1.00	0.64	0.65	0.99
4 UT	0.54	0.54	0.94	0.56	0.57	0.99	0.63	0.63	1.00	0.73	0.73	1.00	0.63	0.63	1.00	0.62	0.62	0.98
T	0.62	0.62	1.00	0.67	0.69	0.99	0.68	0.69	0.99	0.82	0.84	0.99	0.69	0.69	1.00	0.70	0.71	0.99
ALL UT	0.42	0.44	0.80	0.48	0.49	0.99	0.52	0.53	0.99	0.61	0.62	0.99	0.64	0.64	1.00	0.53	0.54	0.95
T	0.48	0.51	0.95	0.56	0.59	0.99	0.58	0.60	0.99	0.71	0.73	0.99	0.71	0.71	1.00	0.61	0.63	0.99

Content represents the mean of the results (to 2dp)

P<0.05

Table 7.6. Interactions between % to Select and Year for Logged Ovulation Rate

Year % to Select	1988			1989			1991			1992			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.24	0.24	1.00	0.29	0.29	1.00	0.53	0.56	0.96	0.61	0.67	0.82	0.42	0.44	0.80
T	0.25	0.25	1.00	0.33	0.33	1.00	0.56	0.61	0.96	0.73	0.79	0.96	0.48	0.51	0.95
15 UT	0.36	0.36	1.00	0.21	0.21	1.00	0.69	0.70	0.99	0.64	0.69	0.96	0.48	0.49	0.99
T	0.36	0.36	1.00	0.25	0.25	1.00	0.79	0.81	0.99	0.76	0.82	0.96	0.56	0.59	0.96
25 UT	0.39	0.39	1.00	0.57	0.57	1.00	0.56	0.56	1.00	0.59	0.62	0.97	0.53	0.53	0.99
T	0.39	0.39	1.00	0.63	0.63	1.00	0.61	0.61	1.00	0.68	0.74	0.97	0.58	0.60	0.99
35 UT	0.51	0.51	1.00	0.36	0.36	1.00	0.81	0.81	1.00	0.77	0.81	0.96	0.61	0.62	0.99
T	0.54	0.54	1.00	0.37	0.37	1.00	0.91	0.92	0.99	0.87	0.92	0.96	0.71	0.73	0.99
45 UT	0.91	0.91	1.00	0.49	0.49	1.00	0.53	0.53	1.00	0.62	0.62	1.00	0.64	0.64	1.00
T	0.97	0.97	1.00	0.52	0.52	1.00	0.53	0.53	1.00	0.66	0.66	1.00	0.71	0.71	1.00
ALL UT	0.48	0.48	1.00	0.38	0.38	1.00	0.62	0.63	0.99	0.65	0.68	0.94	0.53	0.54	0.95
T	0.55	0.55	1.00	0.43	0.43	1.00	0.70	0.71	0.99	0.74	0.79	0.97	0.61	0.63	0.98

Content represents the mean of the results (to 2dp)

All P<0.05

Tabulated Results Pertaining to Chapter 8

Table 8.1. Interactions between Method and Year for Muscle Depth

Year Method	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.69	0.97	0.72	0.66	0.93	0.72	0.56	0.66	0.85	0.51	0.61	0.90	0.61	0.79	0.80
T	0.72	0.99	0.79	0.71	0.98	0.83	0.61	0.77	0.96	0.52	0.70	0.97	0.65	0.90	0.90
2 UT	0.80	0.86	0.93	0.32	1.00	0.32	0.31	1.00	0.31	0.81	0.90	0.91	0.56	0.94	0.62
T	0.84	0.92	0.99	0.32	1.00	0.32	0.31	1.00	0.31	0.89	0.98	0.96	0.63	0.99	0.74
3 UT	0.73	0.82	0.91	0.80	0.87	0.92	0.72	0.83	0.89	0.77	0.82	0.95	0.76	0.83	0.92
T	0.75	0.88	0.96	0.85	0.92	0.96	0.73	0.87	0.96	0.79	0.86	0.98	0.78	0.88	0.97
4 UT	0.73	0.88	0.85	0.79	0.84	0.94	0.67	0.71	0.91	0.77	0.80	0.96	0.74	0.81	0.91
T	0.65	0.93	0.92	0.83	0.88	0.98	0.72	0.78	0.99	0.81	0.86	0.99	0.78	0.87	0.97
ALL UT	0.74	0.88	0.85	0.64	0.91	0.72	0.56	0.80	0.78	0.71	0.78	0.93	0.67	0.84	0.81
T	0.74	0.93	0.91	0.68	0.94	0.77	0.59	0.85	0.80	0.75	0.85	0.97	0.71	0.91	0.89

Content represents the mean of the results (to 2dp)

P<0.05

Table 8.2. Interactions between Method and % to Select for Muscle Depth

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.49	0.84	0.58	0.51	0.75	0.76	0.63	0.79	0.85	0.67	0.78	0.88	0.73	0.81	0.92	0.61	0.79	0.80
T	0.60	0.96	0.74	0.52	0.88	0.86	0.65	0.88	0.93	0.69	0.89	0.95	0.76	0.90	0.97	0.65	0.90	0.90
2 UT	0.37	0.87	0.49	0.62	1.00	0.62	0.63	0.97	0.66	0.56	0.91	0.65	0.62	0.94	0.68	0.56	0.94	0.62
T	0.38	0.97	0.61	0.79	1.00	0.79	0.74	0.99	0.81	0.57	0.98	0.74	0.63	0.99	0.76	0.63	0.99	0.84
3 UT	0.65	0.81	0.83	0.74	0.84	0.90	0.79	0.84	0.94	0.79	0.83	0.96	0.82	0.85	0.96	0.76	0.83	0.92
T	0.71	0.92	0.92	0.76	0.90	0.96	0.80	0.86	0.98	0.80	0.85	0.98	0.84	0.89	0.99	0.78	0.88	0.97
4 UT	0.69	0.84	0.79	0.72	0.81	0.90	0.74	0.79	0.94	0.78	0.80	0.97	0.77	0.79	0.98	0.74	0.81	0.91
T	0.82	0.96	0.92	0.76	0.89	0.96	0.75	0.83	0.98	0.79	0.83	0.99	0.78	0.81	0.99	0.78	0.87	0.97
ALL UT	0.55	0.84	0.67	0.65	0.85	0.79	0.70	0.85	0.85	0.70	0.83	0.91	0.73	0.85	0.88	0.67	0.84	0.81
T	0.63	0.95	0.80	0.71	0.92	0.89	0.73	0.89	0.92	0.71	0.89	0.91	0.75	0.90	0.93	0.71	0.91	0.92

Content represents the mean of the results (to 2dp)

P<0.05, except for C/TN and C/TS (UT and T)

Table 8.3. Interactions between % to Select and Year for Muscle Depth

Year % to Select	1991			1992			1993			1994			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.63	0.88	0.68	0.65	0.95	0.70	0.45	0.84	0.49	0.38	0.43	0.85	0.53	0.78	0.68
T	0.74	0.98	0.79	0.81	1.00	0.86	0.56	0.97	0.61	0.43	0.52	0.97	0.65	0.92	0.83
15 UT	0.79	0.90	0.89	0.48	0.74	0.73	0.59	0.82	0.76	0.68	0.78	0.83	0.63	0.81	0.81
T	0.88	0.97	0.97	0.50	0.84	0.85	0.66	0.92	0.90	0.79	0.90	0.94	0.72	0.92	0.92
25 UT	0.71	0.74	0.96	0.66	0.91	0.74	0.55	0.78	0.77	0.72	0.79	0.89	0.66	0.80	0.84
T	0.73	0.80	0.99	0.73	0.96	0.85	0.57	0.86	0.90	0.80	0.88	0.97	0.71	0.88	0.94
35 UT	0.67	0.71	0.97	0.68	0.85	0.83	0.60	0.75	0.84	0.64	0.70	0.91	0.65	0.75	0.89
T	0.69	0.75	0.99	0.70	0.92	0.91	0.62	0.84	0.94	0.66	0.77	0.97	0.67	0.83	0.96
45 UT	0.67	0.68	0.98	0.77	0.94	0.82	0.67	0.82	0.85	0.78	0.85	0.92	0.72	0.82	0.89
T	0.70	0.73	1.00	0.84	0.98	0.91	0.69	0.89	0.94	0.84	0.92	0.97	0.77	0.90	0.96
ALL UT	0.69	0.78	0.90	0.65	0.88	0.77	0.57	0.80	0.74	0.64	0.71	0.88	0.64	0.79	0.82
T	0.75	0.87	0.97	0.73	0.95	0.88	0.62	0.90	0.87	0.72	0.82	0.96	0.71	0.89	0.93

Content represents the mean of the results (to 2dp)

All P<0.05

Table 8.4. Interactions between Method and Farm for Milk Yield

Farm Method	A			B			C			D			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.70	0.80	0.91	0.67	0.83	0.84	0.78	0.93	0.84	0.78	0.83	0.94	0.73	0.85	0.88
T	0.74	0.87	0.97	0.70	0.92	0.92	0.80	0.97	0.92	0.83	0.91	0.99	0.77	0.92	0.96
2 UT	0.47	1.00	0.47	0.64	1.00	0.64	0.39	1.00	0.39	0.18	0.18	0.80	0.42	0.80	0.58
T	0.47	1.00	0.47	0.65	1.00	0.65	0.39	1.00	0.39	0.19	0.19	0.95	0.43	0.94	0.65
3 UT	0.84	0.92	0.92	0.73	0.73	1.00	0.76	0.88	0.82	0.78	0.80	0.97	0.78	0.83	0.93
T	0.87	0.94	0.96	0.77	0.77	1.00	0.78	0.93	0.88	0.81	0.87	0.99	0.81	0.89	0.97
4 UT	0.86	0.89	0.96	0.84	0.91	0.94	0.81	0.91	0.89	0.84	0.86	0.98	0.84	0.89	0.94
T	0.89	0.93	0.99	0.88	0.95	0.98	0.83	0.95	0.94	0.88	0.92	0.99	0.87	0.94	0.98
ALL UT	0.72	0.90	0.81	0.72	0.87	0.85	0.68	0.93	0.73	0.64	0.67	0.92	0.69	0.84	0.83
T	0.74	0.93	0.85	0.75	0.91	0.89	0.70	0.96	0.78	0.68	0.72	0.98	0.72	0.92	0.89

Content represents the mean of the results (to 2dp)

P<0.05

Table 8.5. Interactions between Method and % to Select for Milk Yield

% to Select Method	5			15			25			35			45			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
1 UT	0.52	0.76	0.75	0.73	0.88	0.85	0.78	0.87	0.91	0.80	0.87	0.94	0.83	0.87	0.96	0.73	0.85	0.88
T	0.54	0.87	0.89	0.76	0.95	0.93	0.81	0.94	0.96	0.83	0.92	0.98	0.86	0.92	0.99	0.77	0.84	0.96
2 UT	0.28	0.75	0.28	0.38	0.76	0.61	0.40	0.77	0.63	0.49	0.83	0.66	0.55	0.87	0.69	0.42	0.80	0.58
T	0.29	0.92	0.29	0.39	0.93	0.70	0.41	0.93	0.72	0.50	0.95	0.74	0.56	0.96	0.76	0.43	0.94	0.65
3 UT	0.47	0.59	0.81	0.80	0.87	0.92	0.84	0.89	0.95	0.87	0.89	0.97	0.90	0.92	0.98	0.78	0.83	0.93
T	0.48	0.69	0.91	0.83	0.91	0.97	0.85	0.92	0.97	0.89	0.92	0.99	0.91	0.94	0.99	0.81	0.89	0.97
4 UT	0.61	0.76	0.83	0.88	0.95	0.93	0.90	0.92	0.97	0.89	0.91	0.98	0.91	0.92	0.99	0.84	0.89	0.94
T	0.62	0.85	0.90	0.91	0.98	0.97	0.91	0.95	0.99	0.91	0.94	1.00	0.92	0.94	1.00	0.87	0.94	0.98
ALL UT	0.47	0.71	0.67	0.70	0.86	0.83	0.73	0.86	0.86	0.76	0.87	0.89	0.80	0.89	0.90	0.69	0.84	0.83
T	0.48	0.83	0.75	0.72	0.94	0.89	0.74	0.93	0.91	0.78	0.93	0.93	0.81	0.94	0.93	0.72	0.90	0.89

Content represents the mean of the results (to 2dp)

P<0.05

Table 8.6. Interactions between % to Select and Farm for Milk Yield

Farm % to Select	A			B			C			D			ALL		
	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS	SR	C/TN	C/TS
5 UT	0.64	0.88	0.75	0.57	0.77	0.80	0.47	0.86	0.51	0.31	0.31	0.75	0.50	0.70	0.70
T	0.67	0.95	0.84	0.60	0.89	0.89	0.49	0.96	0.56	0.32	0.32	0.92	0.53	0.84	0.82
15 UT	0.75	0.89	0.85	0.81	0.93	0.88	0.69	0.97	0.72	0.63	0.64	0.98	0.72	0.86	0.86
T	0.79	0.94	0.94	0.85	0.98	0.93	0.71	0.99	0.77	0.68	0.71	1.00	0.76	0.93	0.93
25 UT	0.72	0.87	0.85	0.83	0.88	0.94	0.81	0.96	0.85	0.65	0.69	0.97	0.75	0.85	0.90
T	0.75	0.92	0.94	0.86	0.93	0.99	0.85	0.99	0.91	0.73	0.79	0.99	0.80	0.92	0.97
35 UT	0.78	0.91	0.87	0.76	0.84	0.92	0.82	0.92	0.90	0.73	0.76	0.97	0.77	0.86	0.91
T	0.83	0.96	0.95	0.76	0.89	0.97	0.84	0.94	0.95	0.79	0.84	0.99	0.81	0.91	0.97
45 UT	0.79	0.91	0.88	0.83	0.90	0.93	0.82	0.90	0.92	0.80	0.82	0.98	0.81	0.88	0.93
T	0.81	0.95	0.95	0.84	0.94	0.97	0.84	0.92	0.97	0.86	0.89	1.00	0.84	0.93	0.98
ALL UT	0.74	0.89	0.84	0.76	0.86	0.89	0.72	0.92	0.78	0.62	0.64	0.93	0.71	0.83	0.86
T	0.77	0.94	0.93	0.79	0.93	0.96	0.76	0.97	0.86	0.69	0.74	0.99	0.76	0.91	0.94

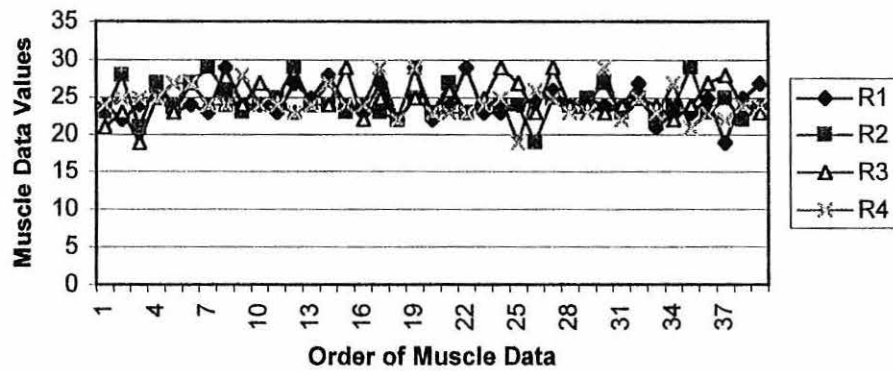
Content represents the mean of the results (to 2dp)

All P<0.05

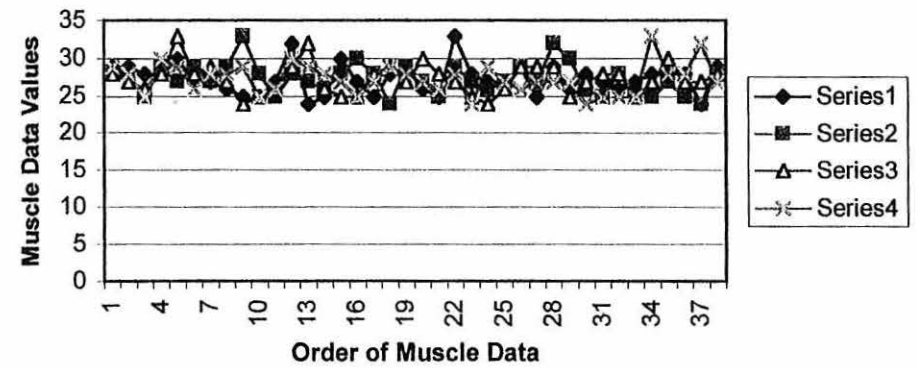
Appendix 6

Graphs Illustrating the Random Sorting of the Data Sets

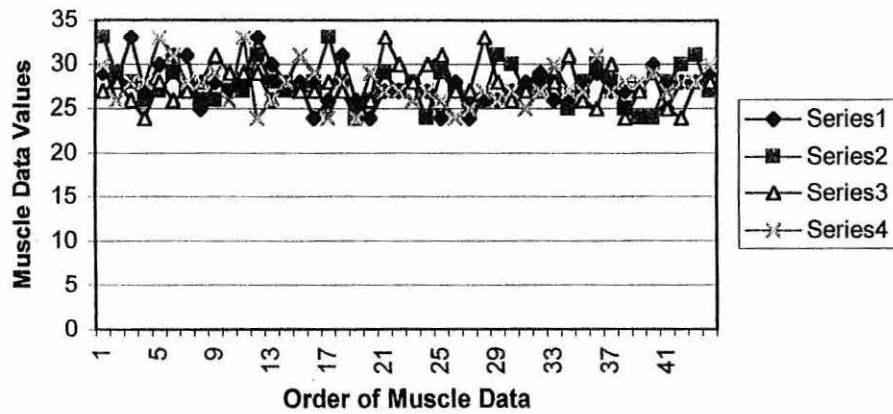
Random Sorting of Muscle Data 1991



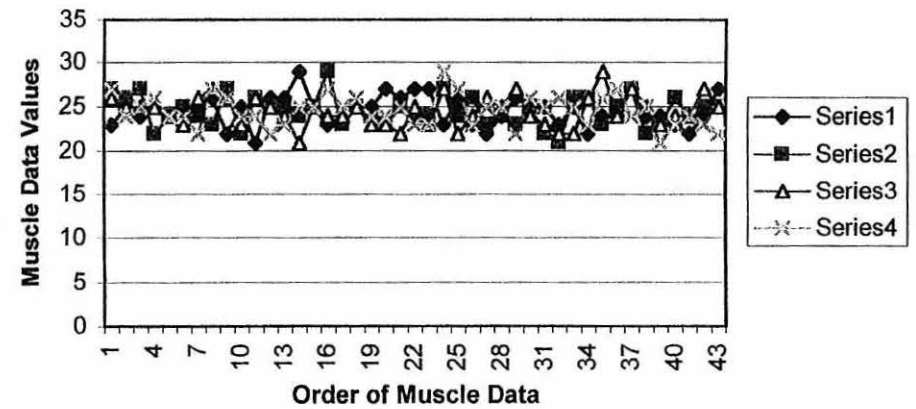
Random Sorting of Muscle Data 1992



Random Sorting of Muscle Data 1993

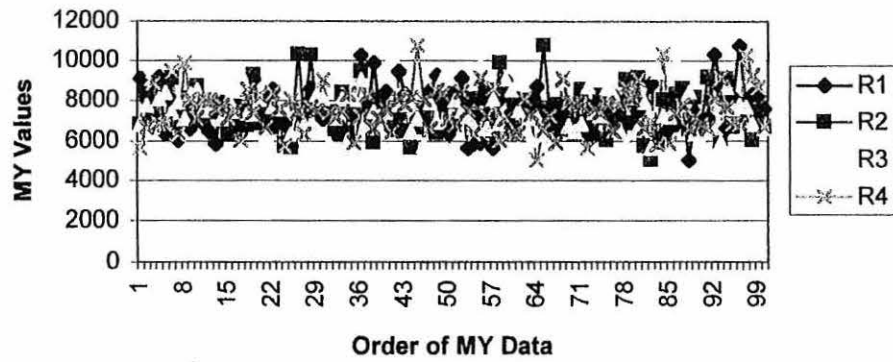


Random Sorting of Muscle Data 1994

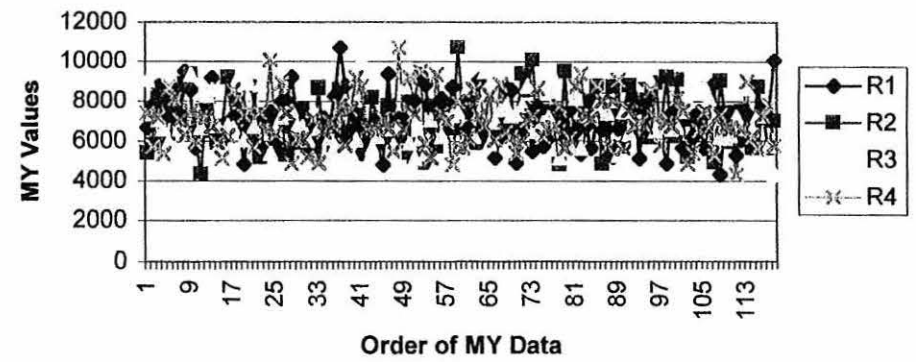


MD=Muscle Depth

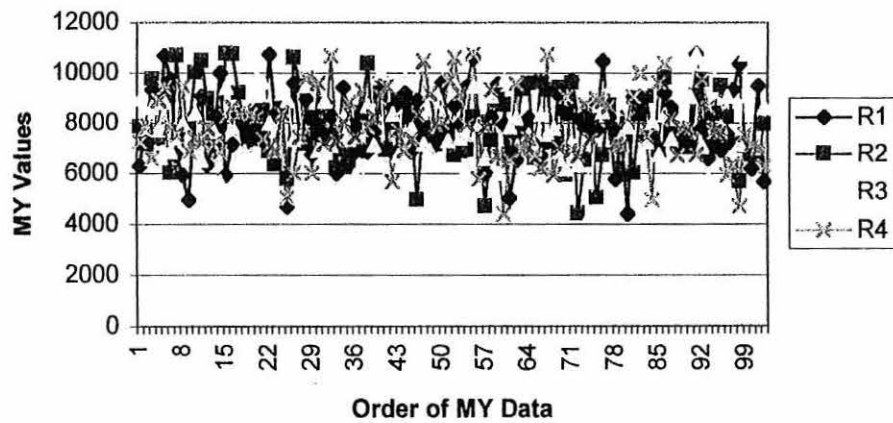
Random Sorting of MY Data MY328



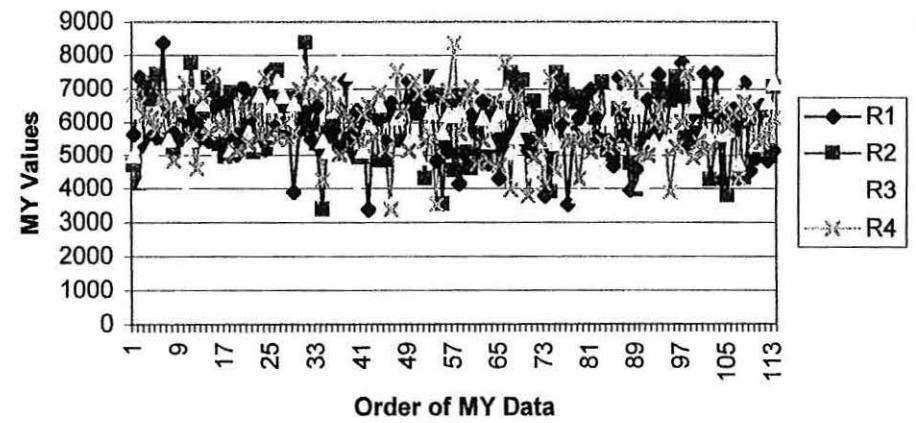
Random Sorting of MY Data MY331



Random Sorting of MY Data MY353

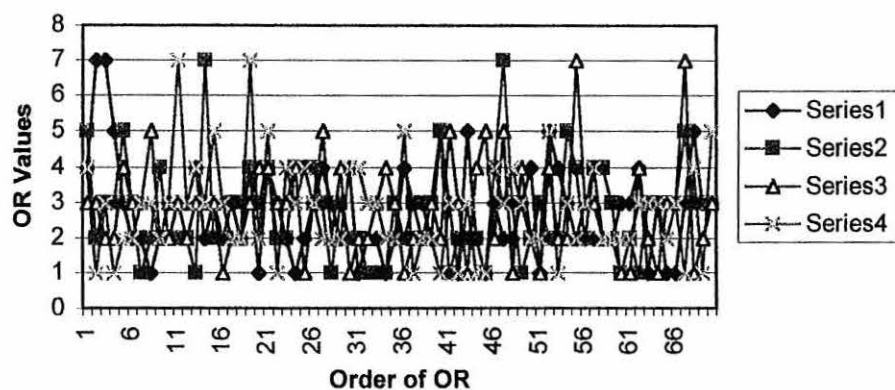


Random Sorting of MY Data MY479

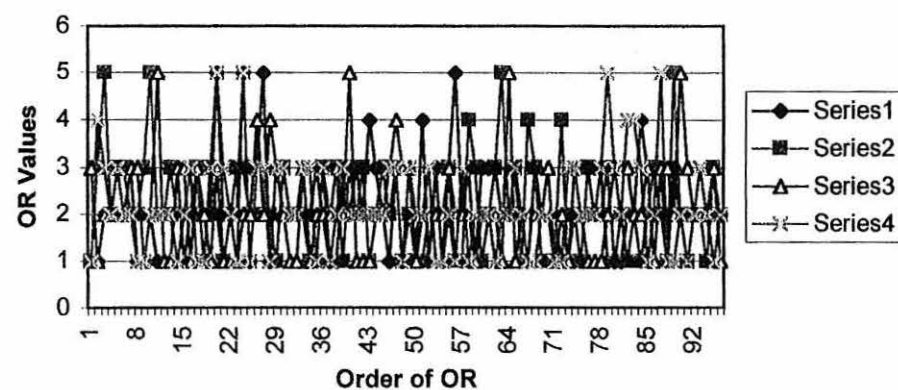


MY = Milk Yield

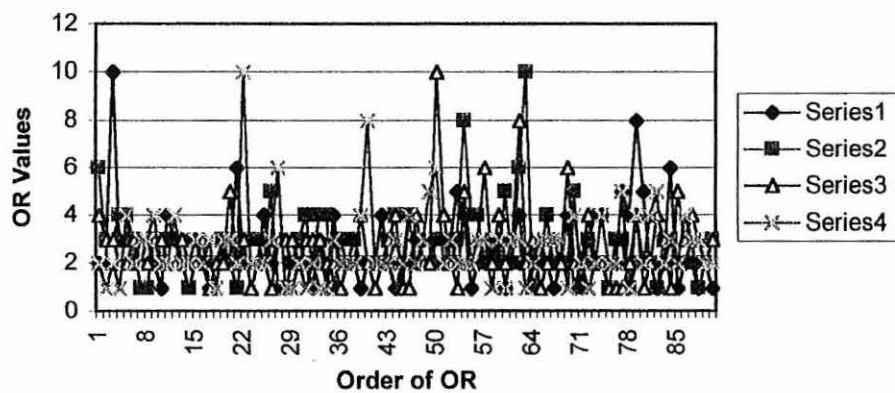
Random Sorting of OR Data 1988



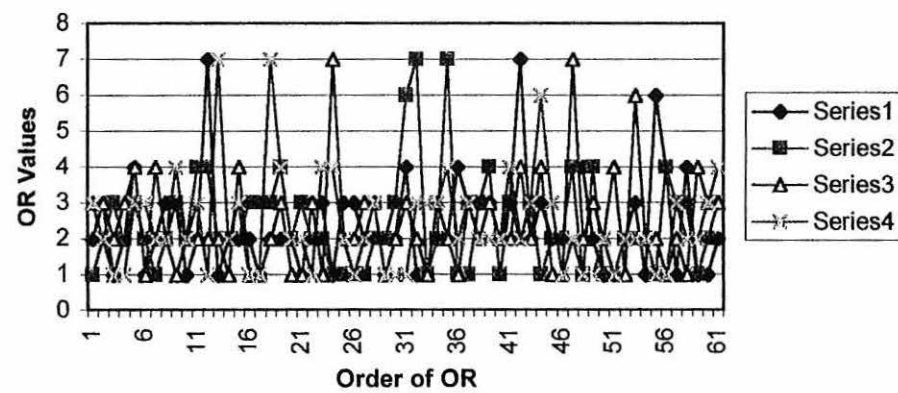
Random Sorting of OR Data 1989



Random Sorting of OR Data 1991



Random Sorting of OR Data 1992



OR=Ovulation Rate

APPENDIX 7

Ovulation Rate Data Illustrated by a Parabolic Shape Graph

Of the 317 records for OR over the four years, the vast majority of values fall within the range of 1 to 3.

