

**Bangor University**

## **DOCTOR OF PHILOSOPHY**

### **Improved procedures for the transport and storage of fruit and vegetables**

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# **Improved Procedures for the Transport and Storage of Fruit and Vegetables**



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A thesis submitted to Bangor University by Karen Harper in candidature for  
the degree of Doctor of Philosophy

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## Abstract

Natural methods (biocontrol) for the preservation of harvested fruits and vegetables were investigated. This was in order to potentially help the industry overcome the environmental problems and pathogen resistance being encountered with the use of synthetic fungicides.

The main focus of research was the use of volatile compounds found in citrus fruit. These were utilised in *in vivo* studies with citrus fruit artificially inoculated with *Penicillium digitatum* and *P. italicum*, as well as strawberries inoculated with *Botrytis cinerea*. The extent of pathogen growth was measured after exposure to the volatiles for a number of days (7 for citrus fruit and 3 for strawberries) in environmentally-controlled containers. The 'freshness' of the fruit was also ascertained via measurements of water/weight loss. The essential oil of orange itself was highly effective at reducing *Penicillium* growth (> 30% inhibition) and water/weight loss in the fruit (> 20% reduction), as were some of its individual components - (E)-2-hexenal, neryl acetate and linalool. The aldehyde (E)-2-hexenal also had high efficacy against *B. cinerea* and reduced water/weight loss in strawberries, although in these investigations the ketone, (R)-carvone was the most effective overall (> 30% mean pathogen inhibition and > 35% mean reduction in water/weight loss).

Organic and non-organic fruit were utilised in the *in vivo* experiments and discrepancies were observed in the results for each type. *In vitro* studies were therefore conducted with the volatiles, both alone and in combination with commercial fungicides (imazalil, thiabendazole and fludioxonil) in amended-agar investigations. Aldehydes (including (E)-2-hexenal) displayed the highest efficacy against *Penicillium species* and *B. cinerea* (> 90% inhibition), followed by carvone and methyl salicylate (> 40% inhibition). These observations were repeated in the fungicide-amended-agar work, where it was shown that these volatiles could be utilised to supplement the activity of synthetic fungicides and therefore reduce their overall use within the industry.

Chitosan was also investigated as a biological coating for harvested fruit. At 2% concentrations it reduced water/weight loss in oranges compared to uncoated fruit, whilst at 0.1% it reduced *Penicillium* infection in inoculated fruit by almost 50%. Acid and enzyme hydrolysis techniques were performed to obtain chitooligosaccharides with a degree of polymerisation (DP) of 3-10, reported to possess superior antifungal properties than commercially-available chitosan. The hydrolysates were analysed via MALDI-TOF-MS. Chitooligosaccharides produced by one of the acid hydrolysis methods and one obtained using the enzyme Laminarinase were found to be of the desired DP.

Overall, the work revealed the potential of some alternative methods for maintaining the freshness and extending the storage-life of fresh fruits. A number of citrus volatiles were found to be effective at reducing pathogen growth as well as protecting the fruit from water/weight loss. They were also found to operate in parallel with synthetic fungicides, thus implying that the domination of these chemicals in the post-harvest industry could be diminished by combined applications. Chitosan as an edible coating for fresh produce has also been shown to have potential, although additional work is required to elucidate this further.

# **TABLE OF CONTENTS**

## **Chapter One**

### **Introduction**

<b>1.1: Overview</b>	<b>1</b>
<b>1.2: The Physiology of Fruits and Vegetables</b>	<b>2</b>
1.2.1: Structure and Composition	2
1.2.2: Life after Harvest	3
<b>1.3: Physical Means to Prevent Deterioration</b>	<b>4</b>
1.3.1: Controlling Temperature and Relative Humidity	4
1.3.2: High Temperature Treatments	5
1.3.3: Modified Atmosphere Treatments	6
1.3.4: Ultraviolet Light	6
<b>1.4: Chemical Means to Prevent Deterioration</b>	<b>8</b>
<b>1.5: Biological Means to Prevent Deterioration</b>	<b>10</b>
1.5.1: Antagonistic Microorganisms	10
1.5.2: Natural Plant Products	12
1.5.3: Inducement of Plant Defence Mechanisms	13
<b>1.6: Research Objectives</b>	<b>14</b>

## **Chapter Two**

### **Water Loss in Selected Fresh Produce and Technique Development**

<b>2.1: Introduction</b>	<b>17</b>
<b>2.2: Materials and Methods</b>	<b>21</b>
2.2.1: Fresh Produce	21
2.2.2: Experimental Conditions	21
2.2.2.1: Containers	21
2.2.2.2: Relative Humidity	21
a. Dilute NaCl Solutions	22
b. Saturated Salt Solutions	22
2.2.3: Air Circulation	24
2.2.4: Data Collection and Analysis	25
<b>2.3: Results</b>	<b>27</b>
2.3.1: Weight Loss (RH regulated by dilute NaCl solutions) Days 1-28	27
2.3.2: Weight Loss of Infected Fruit (RH regulated by dilute NaCl solutions)	28
2.3.3: Weight Loss (RH regulated by saturated salt solutions in beakers) Days 29-42	29
2.3.4: Weight Loss (RH regulated by saturated salt solutions covering bases of boxes)	30
2.3.5: Weight Loss (RH regulated via different methods) Days 1-45	31
2.3.6: Weight Loss in Strawberries and Lettuce Compared to Oranges	33
<b>2.4 Discussion</b>	<b>34</b>

## **Chapter Three**

### **The Effect of Volatile Compounds on Water Loss and *Penicillium* Infection in Citrus Fruits**

<b>3.1: Introduction</b>	<b>37</b>
<b>3.2 Materials and methods</b>	<b>40</b>
3.2.1: Fruit material	40
3.2.2: Pathogens	40
3.2.2.1: Initial Isolation and Identification	40
3.2.2.2: Maintenance of Cultures	41
3.2.2.3: Fungal Suspensions	41
3.2.3: Chemicals	41
3.2.4: Incubation Conditions	43
3.2.5: Inoculation of Fruit	43
3.2.6: Volatile Delivery Method	43
3.2.7: Data Collection and Analysis	43
<b>3.3 Results</b>	<b>45</b>
3.3.1: Organic Oranges and Volatiles	45
3.3.2: Non-Organic Oranges and Volatiles	45
<b>3.4 Discussion</b>	<b>50</b>

## **Chapter Four**

### **Effect of Citrus Volatiles on the Growth of *Penicillium digitatum* and *P. italicum* in vitro**

<b>4.1: Introduction</b>	<b>55</b>
<b>4.2: Materials and Methods</b>	<b>59</b>
4.2.1: Media	59
4.2.1.1: Standard Agar	59
4.2.1.2: Amended Agar – ascertaining minimum inhibitory concentrations (MICs)	59
4.2.1.3: Amended Agar – ascertaining minimum concentrations required to inhibit 50% growth of the organisms (MIC50s)	59
4.2.2: Pathogens	60
4.2.2.1: Initial Isolation and Identification	60
4.2.2.2: Maintenance of Cultures	60
4.2.2.3: Fungal Suspensions	61
4.2.3: Chemicals	61
4.2.4: Inoculation of Media and Volatile Delivery Method	61
4.2.5: Data Collection and Analysis	62
<b>4.3: Results</b>	<b>64</b>
4.3.1: <i>Penicillium digitatum</i> and <i>P. italicum</i> and Volatiles	64
4.3.2: <i>Penicillium digitatum</i> and <i>P. italicum</i> and Amended Agar	65
4.3.3: <i>Penicillium digitatum</i> and <i>P. italicum</i> , Amended Agar and Volatiles	66
<b>4.4: Discussion</b>	<b>69</b>

## Chapter Five

### The Effect of Volatile Compounds on *Botrytis cinerea* Infection and Water Loss in Strawberry Fruits

<b>5.1: Introduction</b>	<b>77</b>
<b>5.2: Materials and Methods</b>	<b>79</b>
5.2.1: Fruit Material	79
5.2.2: Pathogens	79
5.2.3: Chemicals	79
5.2.4: Incubation Conditions	80
5.2.5: Inoculation of Fruit	80
5.2.6: Volatile Delivery Method	80
5.2.7: Data Collection and Analysis	80
<b>5.3: Results</b>	<b>82</b>
5.3.1: Organic Strawberries and Volatiles	82
5.3.2: Non-organic Strawberries and Volatiles	85
<b>5.4: Discussion</b>	<b>88</b>

## Chapter Six

### Effect of Citrus Volatiles on the Growth of *Botrytis cinerea* *in vitro*

<b>6.1: Introduction</b>	<b>93</b>
<b>6.2: Materials and Methods</b>	<b>95</b>
6.2.1: Media	95
6.2.1.1: Standard agar	95
6.2.1.2: Amended Agar – ascertaining MIC	95
6.2.1.3: Amended Agar - MIC50	95
6.2.2: Pathogens	96
6.2.2.1: Initial Isolation and Identification	96
6.2.2.2: Maintenance of Cultures	96
6.2.2.3: Fungal Suspensions	96
6.2.3: Chemicals	97
6.2.4: Inoculation of Media and Volatile Delivery Method	97
6.2.5: Data Collection and Analysis	98
<b>6.3: Results</b>	<b>99</b>
6.3.1: <i>Botrytis cinerea</i> and Volatiles	99
6.3.2: <i>Botrytis cinerea</i> and Amended Agar – MIC establishment	100
6.3.3: <i>Botrytis cinerea</i> , Amended Agar and Volatiles	101
<b>6.4: Discussion</b>	<b>103</b>

## Chapter Seven

### The Effects of Chitosan and/or Pectin Coatings on Orange fruit, Plus Chitosan Hydrolysis and Analysis

<b>7.1: Introduction</b>	<b>107</b>
<b>7.2: Materials and Methods</b>	<b>111</b>
7.2.1: Chemicals	111
7.2.2: Fruit material	111
7.2.3: Pathogens	111
7.2.4: Organic Oranges with Chitosan and/or Pectin Coatings	112

7.2.4.1: Preparation of Coatings	112
7.2.4.2: Incubation Conditions	112
7.2.4.3: Inoculation of Fruit	112
7.2.4.4: Volatile Delivery Method	112
7.2.4.5: Date Collection and Analysis	112
7.2.5: Chitosan Hydrolysis and Analysis	113
7.2.5.1 Mass Spectrometry	113
7.2.5.2: Acid Hydrolysis of Chitosan with Hydrogen Chloride	114
Method a.	114
Method b.	114
7.2.5.3: Enzyme Hydrolysis of Chitosan with Pepsin	115
7.2.5.4: Enzyme Hydrolysis of Chitosan with Amano Lipase A	115
7.2.5.5: Enzyme Hydrolysis of Chitosan with Laminarinase	116
<b>7.3: Results</b>	<b>117</b>
7.3.1 The Effects of Chitosan Coatings on Weight/Water Loss in Orange Fruit	117
7.3.2: The Effects of Chitosan Coatings on Weight/Water Loss and <i>Penicillium</i> Infection in Orange Fruit	118
7.3.3: The Effects of Chitosan or Pectin Coatings Plus Volatile Compounds on Weight/Water Loss and <i>Penicillium</i> Infection in Orange Fruit	119
7.3.4: MALDI-TOF-MS Analyses	123
7.3.4.1: Inulin and Commercial Chitosan	123
7.3.4.2: Chitosan Oligosaccharides Produced by Acid Hydrolysis	126
7.3.4.3: Chitosan Oligosaccharides Produced by Enzyme Hydrolysis	133
<b>7.4: Discussion</b>	<b>141</b>
 <b>Chapter Eight</b>	
 <b>General Discussion and Conclusions</b>	<b>147</b>
 <b>Chapter Nine</b>	
 <b>References</b>	<b>157</b>
<b>Appendices</b>	<b>177</b>

## **List of Figures**

<b>Figure 2.01:</b> Container used to analyse water loss from fresh produce (oranges illustrated)	26
<b>Figure 2.02:</b> Weight loss of oranges incubated for 9 days at 20°C and 94% RH (unstirred)	28
<b>Figure 2.03:</b> Rates of weight/water loss of oranges incubated at 20°C and various RH conditions maintained by saturated salt solutions poured directly into the experimental boxes (stirred)	30
<b>Figure 2.04:</b> Weight/water loss of oranges over the course of 45 days, illustrating how the introduction of saturated salt solutions (for RH regulation) for all treatments (after 28 days) and the introduction of an air circulation system for treatments at 20°C (after 35 days) affected the rates of weight/water loss in the fruit	32
<b>Figure 2.5:</b> Weight/water losses of three different fresh commodities after three days of incubation at the same temperature (20°C) and various RH levels	33
<b>Figure 2.06:</b> Containers set up in a (dark) controlled-temperature room	34
<b>Figure 3.01:</b> Effects of volatile compounds on the infection of <i>P. digitatum</i> and <i>P. italicum</i> on organic oranges compared to untreated fruit	46
<b>Figure 3.02:</b> Effects of volatile compounds on the weight/water loss of organic oranges inoculated with <i>P. digitatum</i> and <i>P. italicum</i> compared to untreated fruit	47
<b>Figure 3.03:</b> Effects of volatile compounds on the infection of <i>P. digitatum</i> and <i>P. italicum</i> on non-organic oranges compared to untreated fruit	48
<b>Figure 3.04:</b> Effects of volatile compounds on the weight/water loss of organic oranges inoculated with <i>P. digitatum</i> and <i>P. italicum</i> compared to untreated fruit	49
<b>Figure 4.01:</b> Petri dishes containing samples from <i>in vitro</i> <i>Penicillium</i> and volatiles assay showing inoculated PDA plates with slow-release packets	63
<b>Figure 4.02:</b> Effects of volatile compounds on the growth of <i>P. digitatum</i> and <i>P. italicum</i> <i>in vitro</i>	64
<b>Figure 4.03:</b> Effects of different concentrations (0.001, 0.01, 0.1, 1.0, 10 and 100 µg/ml; converted to log10 values) of PacRite® Fungaflor 500EC (IMZ 50), PacRite® Fungaflor 75WSG (IMZ 75) and Shield-Brite® TBZ on the growth of <i>P. digitatum</i> and <i>P. italicum</i> <i>in vitro</i>	65
<b>Figure 4.04:</b> Effects of volatile compounds on the growth of <i>P. digitatum</i> and <i>P. italicum</i> on PDA amended with Shield-Brite® TBZ fungicide at MIC50	66
<b>Figure 4.05:</b> Effects of volatile compounds on the growth of <i>P. digitatum</i> and <i>P. italicum</i> on PDA amended with PacRite® Fungaflor 500EC (IMZ 50) fungicide at MIC50	67
<b>Figure 4.06:</b> Effects of volatile compounds on the growth of <i>P. digitatum</i> and <i>P. italicum</i> on PDA amended with PacRite® Fungaflor 75WSG (IMZ 75) fungicide at MIC50	68
<b>Figure 5.01:</b> Effects of different volatile compounds on the infection of <i>B. cinerea</i> on organic strawberries compared to untreated fruit	82
<b>Figure 5.02:</b> Effects of volatile compounds on the weight/water loss of organic strawberries inoculated with <i>B. cinerea</i> compared to untreated fruit	83
<b>Figure 5.03:</b> Effects of volatile compounds on the infection of <i>B. cinerea</i> on non-organic strawberries compared to untreated fruit	86



<b>Figure 5.04:</b> Effects of volatile compounds on the weight/water loss of non-organic strawberries inoculated with <i>B. cinerea</i> compared to untreated fruit	87
<b>Figure 6.01:</b> Effects of volatile compounds on the growth of <i>B. cinerea</i> <i>in vitro</i>	99
<b>Figure 6.02:</b> Effects of different concentrations (0.01, 0.1, 1.0, 10 and 100 µg/ml; converted to log10 values) of Geox 50 WG fungicide (FLU) on the growth of <i>B. cinerea</i> <i>in vitro</i>	100
<b>Figure 6.03:</b> The effects of volatile compounds on the growth of <i>B. cinerea</i> on PDA amended with Geox 50 WG fungicide (FLU) at MIC50	102
<b>Figure 7.01:</b> Weight loss of oranges over the course of 14 days when coated in different concentrations of chitosan and stored at 5 and 20°C	117
<b>Figure 7.02:</b> Weight loss in oranges treated with different concentrations of chitosan and subsequently infected (or not) with <i>P. digitatum</i> and <i>P. italicum</i>	118
<b>Figure 7.03:</b> Effects of chitosan and pectin coatings of different concentrations plus volatile compounds on <i>Penicillium</i> infection in organic oranges compared to untreated fruit	121
<b>Figure 7.04:</b> Effects of chitosan and pectin coatings of different concentrations plus volatile compounds on the weight/water loss of organic oranges inoculated with <i>P. digitatum</i> and <i>P. italicum</i> compared to untreated fruit	122
<b>Figure 7.05:</b> Mass spectrum of inulin produced via MALDI-TOF-MS	123
<b>Figure 7.06:</b> Mass spectrum of inulin trimer produced by MALDI-TOF-MS.	124
<b>Figure 7.07:</b> Mass spectrum of inulin tetramer produced by MALDI-TOF-MS.	124
<b>Figure 7.08:</b> Mass spectrum of commercial chitosan obtained from Sigma (U.K) not subjected to hydrolysis	125
<b>Figure 7.09:</b> Mass spectrum of OT52 sample produced by acid hydrolysis method a., illustrating oligomers of DP3 to DP7.	127
<b>Figure 7.10:</b> Mass spectrum of OT53 1st fraction sample illustrating oligomers of DP3 to DP7. All assigned peaks are M + Na+	128
<b>Figure 7.11:</b> Mass spectrum of OT53 2nd fraction sample illustrating oligomers of DP3 to DP8. All assigned peaks are M + Na+	128
<b>Figure 7.12:</b> Mass spectrum of OT52 produced by acid hydrolysis method a., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer	129
<b>Figure 7.13:</b> Mass spectrum of OT53 1st fraction produced by acid hydrolysis method b., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer	130
<b>Figure 7.14:</b> Mass spectrum of OT53 2nd fraction produced by acid hydrolysis method b., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer	130
<b>Figure 7.15:</b> Mass spectrum of OT52 produced by acid hydrolysis method b., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer	132

- Figure 7.16:** Mass spectrum of OT53 1st fraction produced by acid hydrolysis method b., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer 132
- Figure 7.17:** Mass spectrum of OT53 2nd fraction produced by acid hydrolysis method b., highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer 133
- Figure 7.18:** Mass spectrum of OT54 produced by enzyme hydrolysis with Pepsin, illustrating oligomers of DP1 to DP3 134
- Figure 7.19:** Mass spectrum of OT55 produced by enzyme hydrolysis with Amano Lipase A, illustrating oligomers of DP2 to DP8 134
- Figure 7.20:** Mass spectrum of OT56 1st fraction produced by enzyme hydrolysis with Laminarinase, illustrating oligomers of DP3 to DP8 135
- Figure 7.21:** Mass spectrum of OT56 2nd fraction produced by enzyme hydrolysis with Laminarinase, illustrating oligomers of DP3 to DP9. 135
- Figure 7.22:** Mass spectrum of OT55 produced by enzyme hydrolysis with Amano Lipase A, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer. 137
- Figure 7.23:** Mass spectrum of OT56 1st fraction produced by enzyme hydrolysis with Laminarinase, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer. 138
- Figure 7.24:** Mass spectrum of OT56 2nd fraction produced by enzyme hydrolysis with Laminarinase, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan tetramer. 138
- Figure 7.25:** Mass spectrum of OT55 produced by enzyme hydrolysis with Amano Lipase A, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer 139
- Figure 7.26:** Mass spectrum of OT56 1st fraction produced by enzyme hydrolysis with Laminarinase, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer 140
- Figure 7.27:** Mass spectrum of OT56 2nd fraction produced by enzyme hydrolysis with Laminarinase, highlighting the different combination of glucosamine (GlcN) and acetylated glucosamine (GlcNAc) units of the chitosan trimer 140

## **Appendix**

<b>Figure 7.1.1:</b> Mass List of Inulin	177
<b>Figure 7.1.2:</b> Mass List of Commercial Chitosan	179
<b>Figure 7.1.3:</b> Mass List of OT52	181
<b>Figure 7.1.4:</b> Mass List of OT53 First Fraction	182
<b>Figure 7.1.5:</b> Mass List of OT53 Second Fraction	183
<b>Figure 7.1.6:</b> Mass List of OT54	184
<b>Figure 7.1.7:</b> Mass List of OT55	186
<b>Figure 7.1.8:</b> Mass List of OT56 First Fraction	187
<b>Figure 7.1.9:</b> Mass List of OT56 Second Fraction	189

## **List of tables**

<b>Table 2.01:</b> Treatments and RH values obtained with dilute NaCl solutions	22
<b>Table 2.02:</b> Saturated salt solutions – expected RH values	22
<b>Table 2.03:</b> Saturated salt solutions in beakers – expected RH values (Greenspan, 1977) versus measured Values	23
<b>Table 2.04:</b> Saturated salt solutions in beakers combined with the air circulation system – measured RH values	24
<b>Table 2.05:</b> Treatments used on one batch of oranges, showing the development of the techniques to regulate RH	25
<b>Table 2.06:</b> Saturated salt solutions covering base of boxes – measured RH values	25
<b>Table 2.07:</b> Cumulative weekly mean percentage weight loss of oranges incubated at 5 & 20°C with RH maintained by NaCl solutions (unstirred)	27
<b>Table 2.08:</b> Cumulative weekly mean percentage weight/water loss of oranges at 5 & 20°C with RH maintained by the saturated salt solutions	29
<b>Table 3.01:</b> List of volatile chemical compounds used throughout research	42
<b>Table 8.01:</b> Summary of the effects of volatile compounds on <i>Penicillium sp.</i> <i>in vitro</i> and <i>in vivo</i> , plus water/weight loss in oranges and mandarins.	148
<b>Table 8.02:</b> Summary of the effects of volatile compounds on <i>B. cinerea</i> <i>in vitro</i> and <i>in vivo</i> , plus water/weight loss in strawberries.	152

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## Abbreviations

ANOVA	Analysis of variance
C	Carbon
CI	Chilling injury
CO <sub>2</sub>	Carbon dioxide
COS	Chitooligosaccharides
DA	Degree of acetylation
DP	Degree of polymerization
FLU	Fludioxonil
FSA	Food Standards Agency
GlcN	Glucosamine
GlcNAC	N-acetylglucosamine
H <sub>2</sub> O	Water
HCl	Hydrogen chloride
HMW	High molecular weight
IMZ	Imazalil
K	Potassium
K <sub>2</sub> SO <sub>4</sub>	Potassium sulfate
KC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	Potassium acetate
KC	Potassium chloride
LMW	Low molecular weight
MeJ	Methyl jasmonate
MeS	Methyl salicylate
MgCl <sub>2</sub>	Magnesium chloride
MIC	Minimum inhibitory concentration
m/z	Mass-to-charge ratio
NaCl	Sodium chloride
NaOH	Sodium hydroxide
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	Ammonium sulfate
O <sub>2</sub>	Oxygen
P	Phosphorous
<i>P. italicum</i> /digitatum	Penicillium.....
PD	Potato dextrose agar
PP	Polypropylene
RH	Relative humidity
TBZ	Thiabendazole
VPD	Vapour pressure deficit

