

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**SURFACE COATING AND STORAGE EFFECTS ON  
MANDARIN (*Citrus unshiu* Marc.)  
FRUIT QUALITY**

A thesis presented in partial fulfilment of the requirements  
for the degree of  
Master of Applied Science at  
Massey University

**Latchmi Prasad**

April 1996

634.3168  
Pra

2020

## ABSTRACT

Satsuma mandarin grown in the marginal climate of New Zealand has a niche market in Japan and properly managed this trade has good prospects for expanding. The internal quality of satsuma usually do not reach the minimum requirement of a total soluble solids (TSS) to titratable acid ratio of 10:1 during the harvest season with conventional management, thus lowering the export quantity. Two cultivars of mandarin fruit from Kerikeri, Gisborne and Bay of Plenty were picked on 4-5 dates to record the pattern of quality change and to investigate the effect of storage temperature, storage period and surface coatings on the keeping quality and acceptability of mandarin.

The TSS and colour of fruit remained mostly similar while the titratable acidity showed a downward trend as the harvest season progressed in the three districts. The TSS:acid ratio increased due to the progressive decrease in juice acidity. At no harvest did mandarin fruit reached the desired TSS:acid ratio of 10:1. 'Silverhill' had higher a TSS:acid ratio than 'Miyagawa' during the harvest season in all districts. Fruit from Gisborne had the highest ratio while Bay of Plenty had the lowest.

The juice TSS remained similar during storage except in late harvested 'Miyagawa' fruit it increased after 3 weeks cold storage storage at 6°C plus one week at 20°C. Titratable acidity always decreased as the storage period progressed. Provided fruit of both cultivars is not harvested too early it can be improved to meet Japanese market internal quality standards by about 1 month in cold storage. This results from a 20-30% decline in juice titratable acidity.

Fruit dipped in one of the three coatings carnauba, 'Citrusseal' (polyethylene) and 'Citrus Gleam' (shellac) had similar TSS, titratable acid, TSS:acid ratio and colour during 6 weeks cold storage at 6°C and one week at 20°C. During this period the coated fruit accumulated high levels of acetaldehyde, ethanol and carbon dioxide and low levels of oxygen, especially when coated with carnauba or shellac. The resultant off-flavours made the juice unpalatable within as little as 3 weeks at 6°C. Holding

fruit at 20°C accelerated these undesirable changes. Fruit dipped in shellac had higher levels of off-flavours present compared to sprayed fruit. Increasing the shellac coating by a double dip accentuated its effect on fruit oxygen and carbon dioxide in storage.

Coated fruit consistently had a lower level of weight loss compared to uncoated during cold storage (6°C) and at 20°C. Fruit stored at 60% relative humidity had >5% weight loss which is commercial unacceptable.

## ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and sincere thanks to my supervisor Dr G.S. Lawes, senior lecturer in the Plant Science Department of Massey University for his patient guidance, encouragement throughout the course of this study. His advice was most helpful and friendly.

I greatly appreciate the help from C.Yearsley and Sue Jolly for their kind assistance in laboratory work of the experiments and to the staff and student of the Plant Science Department for their valuable assistance in many ways.

I wish to thank Dr Woolley, Dr D.E.J. Wood, A. Currie, M. Currie, P. Fleming, L. Pulupol of Plant Science Department, Mrs M. Hoseason of Works and Services Department and Mrs R. Neill of Marketing Department for participating in the sensory evaluation. I am gratefully indebted to Ms C.B.M. Groenendijk of Food Technology for her expert advice on the procedure of sensory evaluation.

I would also like to thank the following growers for supplying experimental fruit: R. Davies, J. Willets from Kerikeri, D. Smith, R. Jefferson from Bay of Plenty and C. Lewis from Gisborne.

I gratefully acknowledge the New Zealand Ministry of Foreign affairs and Trade for awarding me the scholarship and the Fiji Government for approving my study leave to undertake this study.

To my family, wife Pravin and children Shalesma and Shalvin for their love, moral support, encouragement and understanding during the course of my study.

And finally to almighty God through whose blessing I was able to complete my study.

	v
<b>TABLE OF CONTENTS</b> .....	<b>v</b>
<b>ABSTRACT</b> .....	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>iv</b>
<b>TABLE OF CONTENTS</b> .....	<b>v</b>
<b>LIST OF FIGURES</b> .....	<b>x</b>
<b>LIST OF TABLES</b> .....	<b>xi</b>
<b>CHAPTER 1 GENERAL INTRODUCTION</b> .....	<b>1</b>
<b>CHAPTER 2 LITERATURE REVIEW</b> .....	<b>4</b>
2.1 Fruit Composition .....	4
2.1.1 Total soluble solids .....	6
2.1.2 Acidity .....	6
2.1.3 Volatiles .....	8
2.2 Factors affecting fruit composition .....	9
2.2.1 Maturation .....	11
2.2.2 Climate .....	12
2.1.3 Cultivars .....	14
2.1.4 Rootstock .....	14
2.1.5 Nutrient status of the tree .....	15
2.1.6 Chemical sprays / growth regulators .....	16
2.1.7 Storage conditions .....	16
2.3 Surface coating .....	17
2.3.1 Types of coatings .....	18
2.4 Types of coatings .....	19
2.4.1 Weight loss .....	20
2.4.2 Modified atmosphere .....	20

2.4.3	Respiration	21
2.4.4	Off flavours	24
2.4.5	Appearance	24
2.5	Thickness of coating	24
<b>CHAPTER 3 MATERIALS AND METHODS</b>		<b>26</b>
3.1	Cultivars	26
3.2	District	26
3.3	Fruit harvesting	27
3.4	Fruit analysis at harvest	27
3.4.1	Fruit weight	28
3.4.2	Colour	28
3.4.3	Acidity	28
3.4.4	Total soluble solids	28
3.5	Effect of skin coating during cold storage	29
3.6	Sensory evaluation	30
3.7	1995 Experiments	
3.7.1	Effects of waxes on fruit quality through the cool storage period	31
3.7.2	Effects of wax application methods on mandarin internal atmosphere and eating quality	33
3.7.3	Comparison of spray and dip application of 'Citrus Gleam' on 'Silverhill' mandarin	34
3.8	Statistical analysis	35
<b>CHAPTER 4 RESULTS</b>		<b>36</b>
4.1	Maturation of mandarin cultivars grown in the three main citrus growing districts	36
4.2	Maturation of cultivars in Kerikeri	36
4.2.1	TSS	36
4.2.2	Titrateable acidity	36
4.2.3	TSS : acid ratio	38
4.2.4	Fruit weight and colour	38



4.3	Fruit maturation in the Bay of Plenty .....	38
4.3.1	TSS .....	38
4.3.2	Titrateable acidity .....	38
4.3.3	TSS: acid ratio .....	39
4.3.4	Fruit weight and colour .....	39
4.4	Maturation of mandarin cultivar at Gisborne .....	40
4.4.1	TSS .....	40
4.4.2	Titrateable acidity .....	42
4.4.3	TSS:acid ratio .....	42
4.4.5	Fruit weight and colour .....	42
4.5	Effect of 'Citrus Gleam' coating and storage duration on fruit quality of early harvested Kerikeri mandarin (1994) .....	44
4.5.1	TSS .....	44
4.5.2	Titrateable acidity .....	45
4.5.3	TSS : acid ratio .....	46
4.5.5	Fruit weight loss .....	46
4.5.6	Internal gas composition .....	48
4.6	Effect of storage period, temperature and coating on internal quality of variety 'Silverhill' from late harvest (Kerikeri) in 1994 .....	50
4.6.1	TSS .....	50
4.6.2	Titrateable acidity (TA) .....	51
4.6.3	TSS:acid ratio .....	51
4.6.4	Weight loss .....	52
4.6.5	Colour .....	54
4.7	Effect of temperature, storage period and polyethylene coating on quality of Gisborne 'Miyagawa' fruit harvested on 20 July 1994 .....	54
4.7.1	TSS .....	54
4.7.2	Titrateable acidity .....	55
4.7.3	TSS : acid ratio .....	55
4.7.4	Weight loss .....	56

4.7.5	Colour .....	57
4.8	Sensory evaluation .....	58
4.9	1995 Experiments .....	60
4.9.1	Calibration of vials attached to mandarin fruit .....	60
4.9.2	Changes in the sub-epidermal internal atmosphere during cool storage of coated 'Silverhill' satsuma mandarin in 1995 .....	63
4.9.3	Weight Loss in coated 'Silverhill' fruit during cool storage in 1995 .....	63
4.9.4	Internal composition changes in coated 'Silverhill' satsuma fruit during cool storage (1995) .....	64
4.9.5	Effect of picking date and coating on volatile production in 'Silverhill' mandarin during storage .....	66
4.10	Effects of application methods of coatings on stored mandarin .....	70
4.10.1	Internal gas composition .....	70
4.10.2	Effect of application methods on volatile production in 'Silverhill' mandarin during storage .....	72
4.10.3	Changes in internal quality of 'Silverhill' satsuma mandarin with different methods of coating application (1995) .....	75
4.10.4	Effect of methods of application of coatings on weight loss in 'Silverhill' fruit (1995) .....	76
4.10.5	Effects of spray vs dipping of 'Citrus Gleam' on internal gases of 'Silverhill' fruit during storage (1995) .....	77
4.10.6	Effect of 'Citrus Gleam' application methods on internal quality of cv Silverhill mandarin during storage ..	78
<b>CHAPTER 5 DISCUSSION .....</b>		<b>80</b>
5.1	The seasonal pattern of mandarin fruit maturation .....	80
5.2	Influence of storage conditions on mandarin quality .....	82
5.3	Use of surface coatings to maintain mandarin quality in storage .....	86

<b>CHAPTER 6 CONCLUSION</b> .....	ix
	90
<b>REFERENCES</b> .....	92
<b>APPENDIX</b> .....	102

# LIST OF FIGURES

Figure 1	A proposed major pathway of citric acid synthesis in citrus fruit vesicles. ....	7
Figure 2	Pathways of anaerobic metabolism .....	23
Figure 3	Seasonal changes in internal characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' mandarin (B) at Kerikeri in 1994 ..	37
Figure 4	Seasonal changes in internal characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' mandarin (B) at Bay of Plenty in 1994 .....	41
Figure 5	Seasonal changes in internal characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' mandarin (B) at Gisborne in 1994 .....	43
Figure 6	Changes in vial oxygen concentration during storage at 6°C of 'Silverhill' mandarin fruit. ....	61
Figure 7	Changes in vial carbon dioxide concentration during storage at 6°C of 'Silverhill' mandarin fruit. ....	62
Figure 8	The effect of pick date and treatment on the level of acetaldehyde during storage and shelf-life of 'Silverhill' mandarin fruit. ....	67
Figure 9	The effect of pick date and treatment on the level of ethyl acetate during storage and shelf-life of 'Silverhill' mandarin fruit. ....	68
Figure 10	The effect of pick date and treatment on the level of head space ethanol during storage and shelf-life of 'Silverhill' mandarin fruit. ....	69
Figure 11	The effect of two methods of wax application on the level of juice acetaldehyde after 14 days storage at 6°C and 7 days shelf-life (20°C). ....	73
Figure 12	The effect of two methods of wax application on the level of juice ethanol after 14 days storage at 6°C and 7 days shelf-life (20°C) .....	74

# LIST OF TABLES

Table 1. Citrus harvest dates (day and month) by cultivar, district and grower (1994) .....	5
Table 2. Composition of California 'Valencia' oranges. The values in the first half of the table are expressed in g (100g <sup>-1</sup> ) while those in the second half are expressed in mg (100g) <sup>-1</sup> .....	10
Table 3. Components important to citrus juice flavour. ....	27
Table 4. Physical characteristics of mandarin cultivars at Kerikeri during the 1994 harvest. ....	39
Table 5. Physical characteristics of cvs Miyagawa and Silverhill at Bay of Plenty in 1994. ....	40
Table 6. Physical characteristics of cvs Miyagawa and Silverhill at Gisborne in 1994. ....	44
Table 7a: Effect of storage period and 'Citrus Gleam' coating on internal quality of early harvested Kerikeri 'Miyagawa' mandarin (1994). ....	45
Table 7b: Effect of storage period and 'Citrus Gleam' coating on quality of early harvested Kerikeri 'Silverhill' mandarin (1994). ....	46
Table 8. Effect of 'Citrus Gleam' coating and storage duration (6 weeks at 6°C and 1 week at 20°C) on weight loss in early harvested Kerikeri 'Miyagawa' mandarin (1994). ....	47
Table 9. Effect of 'Citrus Gleam' coating and storage duration (6 weeks at 6°C and 1 week at 20°C) on weight loss in early harvested Kerikeri 'Silverhill' mandarin (1994). ....	48
Table 10a: Effect of 'Citrus Gleam' on internal (core) gas atmosphere composition of mandarin fruit after 42 days cool storage at 6°C. ....	49
Table 10b: Effect of polyethylene coating on internal gas atmosphere composition of mandarin fruit after 42 days cool storage at 6°C. ....	50
Table 11. Effect of storage period, temperature and polyethylene coating on internal quality of late harvest Kerikeri 'Silverhill' (1994). ....	52
Table 12. Effect of temperature, storage period and polyethylene coating on percentage weight loss in cv Silverhill from late harvest in Kerikeri in 1994. ....	53

Table 13. Effect of coating, temperature and storage duration on the skin colour of 'Silverhill' mandarin from Kerikeri in 1994. ....	54
Table 14. Effect of storage period, temperature and polyethylene coating on internal quality of late harvest Gisborne 'Miyagawa' (1994). ....	56
Table 15. Effect of temperature, storage period and coating on percentage weight loss in cv Miyagawa from late harvest in Gisborne in 1994. ....	57
Table 16. Effect of polyethylene coating, temperature and storage duration on the skin colour of 'Miyagawa' mandarin from Gisborne in 1994. ....	58
Table 17. The mean scoring of acidity, sweetness and mandarin flavour characteristics at various storage period of 'Miyagawa' (harvest 21 April and 20 July) and 'Silverhill' (28 April and 20 July) in 1994. ....	59
Table 18. Effect of coatings on sub-epidermal gases ( $O_2$ and $CO_2$ ) in 'Silverhill' mandarin during 42 days storage at 6°C followed by 7 days at 20°C in 1995. ....	65
Table 19. Effect of waxes on percentage weight loss in satsuma mandarin during storage at 6°C (42 days) followed by 1 week at 20°C (1995). ....	66
Table 20. Effect of coatings on internal quality of 'Silverhill' satsuma mandarin during storage in 1995. ....	66
Table 21. Effect of method of wax application on sub-epidermal internal atmosphere of 'Silverhill' fruit after 6°C cool storage and 1 week at 20°C in 1995. ....	71
Table 22. Effect of application methods of surface coating on the internal quality of 'Silverhill' satsuma mandarin (Harvest 22 May, 1995). ....	72
Table 23. Effect of methods of coating application on weight loss in cv Silverhill satsuma mandarin in 1995. ....	77
Table 24. Effects of spray and dip application of 'Citrus Gleam' (C.Gleam) on internal (KPa) gases in the core of 'Silverhill' mandarin during storage (1995). ....	78
Table 25. Effect of 'Citrus Gleam' application methods on internal quality of 'Silverhill' mandarin in 1995. ....	79