

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.

**ETHYLENE SYNTHESIS INHIBITOR AFFECTS
POSTHARVEST KIWIFRUIT QUALITY**

A thesis presented in partial fulfilment
of the requirements for the degree of

Master of Applied Science

at

Massey University

Palmerston North

New Zealand

Jose Roberto Marques

1998

to

Anna Luisa,

my precious little 'kiwi' girl,

and her mother, great little woman,

Cris

ABSTRACT

Firmness is a key quality criteria of kiwifruit and changes significantly during fruit ripening, with premature softening being a serious commercial problem for the industry. Ethylene is involved in regulation of fruit ripening and influences a number of processes, including ethylene production, respiration rate and changes in firmness. Kiwifruit is very sensitive to ethylene, which increases fruit softening rate and reduces storage potential. Aminoethoxyvinylglycine (AVG), an inhibitor of ACC synthase, a key enzyme in the pathway for ethylene biosynthesis, has been applied to horticultural crops, especially apples, in an attempt to regulate ethylene synthesis and its mediated processes, with a number of positive effects including reduced fruit ethylene production, reduced respiration rate, and slower softening rate.

The effects of AVG (500 and 1000 mg.l⁻¹ a.i., or 200 and 400 g.acre⁻¹ a.i.) applied to 'Hayward' kiwifruit vines (6 and 4 weeks before commercial harvest) on ethylene production, respiration rate, firmness and soluble solids content of fruit at harvest and after coolstorage were investigated. Kiwifruit treated with either 500 or 1000 mg.l⁻¹ AVG 4 weeks before commercial harvest and maintained at 20 °C over 15 days, had a lower respiration rate, reduced ethylene production, a slower softening rate, and lower SSC than control fruit immediately after harvest and following 14 days at 0 °C, with the differences generally becoming significant after 6 days at 20 °C. These attributes are generally stimulated by ethylene, indicating that the endogenously produced ethylene was inhibited by the applied AVG, resulting in a slower fruit ripening rate at 20 °C.

However, AVG effects were transitory. There were generally no differences in the above fruit variables between AVG-treated and control fruit at 20 °C up to 20 days following 30, 52, and 80 days at 0 °C. After 110 and 180 days at 0 °C, kiwifruit treated with either 500 or 1000 mg.l⁻¹ AVG 4 weeks before commercial harvest and maintained at 20 °C up to 10 days, had a higher respiration rate, increased ethylene production, and accelerated softening compared with control fruit. There were basically no differences in any of the

above fruit variables between the treatments 500-AVG-6 and control, either immediately after harvest or following storage at 0 °C up to 180 days.

The short term effect of AVG in kiwifruit during and after coolstorage and the questionable efficiency of AVG uptake in kiwifruit are issues to be further addressed before any practical application can be recommended.

ACKNOWLEDGEMENTS

This project has been possible only through the support of many people. I am extremely grateful to my supervisor Prof. Errol Hewett for his valuable support and challenge throughout the course of my studies. His input in many aspects of this project is highly appreciated and recognised. Special thanks to Dr. Bruce MacKay for his precious statistical advice. Thanks to Mr. Shane Max, manager of the Fruit Crops Unit, for his positive help with field activities. I extend my gratitude to all the staff in the Department of Plant Science at Massey University, particularly Anna Kingsley, Hera Kennedy, Lois Mather, Lorraine Davis, Matt Alexander, Pamela Howell, Peter Jeffery, and Ray Johnstone, for providing a helpful and friendly work environment. Very special thanks for the support of the staff from the International Students' Office, particularly Mr. Charles Chua, Mrs. Margareth Smillier, and Ms. Dianne Reilly.

My studies in New Zealand, including my living expenses and those of my family, were supported by the New Zealand Ministry of Foreign Affairs and Trade, for which I am immensely grateful. I also thank Nufarm Ltd., Auckland, and Massey University Research Fund, which partially funded this research project.

I gratefully acknowledge the special contribution in various ways of my colleague Hyun Ok Kim, who shared with me many hours of hard labour in the Bioassay Room and the Postharvest Laboratory. Thanks also to several colleagues at Massey University, for their companionship and help throughout my time in New Zealand, particularly Anna, Beatriz and Cesar, Cassandro, Jason, Jonathan, Khanita, Mary and Danilo, Lilian and Steve, Luciana and Karl, Renata and Luiz, Suzie, and Wendy. In addition, my gratitude to many Christians in Palmerston North, for their caring help and support, particularly Aguirre, Bev and David, Carla, Denise and David, Donna, Gerald, Janet, Joy and Garry, Joyce and Arthur, Karen and Peter, Kerry, Lorena, Marina and Toni, Nolla and Gordon, Silvia and Cristian, and Wendy and Geoff.

It is hard to find appropriate words to express my special appreciation to my wife Cris. Her constant love, wisdom, strength, support, and deep friendship have been an essential source of inspiration and encouragement through all times.

My gratitude also goes to several relatives and friends in Brazil, for their care and support through phone calls, letters, E-mails, and gifts, particularly my father Jose, my mother-in-law Osoria, my dear sister Silvana, my sister-in-law Cintia, my brother Sergio, and my special friend Horacio, who came to New Zealand to visit us.

Above all, I am deeply grateful to the Heavenly Father, who has given me the strength and ability to cope with the challenges of my life in general, and this project in particular. My personal relationship with Him, through a living faith in Jesus Christ, and in the Holy Spirit, has been making life a wonderful experience.

TABLE OF CONTENTS

ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	x
LIST OF FIGURES.....	xii
LIST OF PLATES.....	xiv
1 INTRODUCTION.....	1
1.1 Economic Importance of Kiwifruit.....	1
1.2 Preharvest Factors Affecting Postharvest Fruit Quality	2
1.4.1 Crop Genetics	2
1.2.2 Climate	3
1.2.3 Nutrient and Water Management	4
1.2.4 Cultural Management	5
1.2.5 Diseases	7
1.2.6 Bioregulators	7
1.2.7 Maturity (Time of Harvest)	8
1.3 Postharvest Factors Affecting Fruit Quality	10
1.3.1 Physical Damage	10
1.3.2 Storage Conditions	10
1.3.3 Postharvest Diseases.....	11
1.3.4 Postharvest Losses.....	12

1.4	Fruit Development and Physiology of Kiwifruit	14
1.4.1	Composition and Morphology.....	14
1.4.2	Maturation and Ripening.....	15
1.4.3	Softening.....	16
1.5	Ethylene.....	22
1.5.1	Biosynthesis in Higher Plants.....	22
1.5.2	Role in Fruit Ripening.....	24
1.5.3	Ethylene and Kiwifruit	26
1.6	AVG	28
1.6.1	Action in Plant Tissues.....	28
1.6.2	Application in Horticultural Crops.....	29
1.7	Objective.....	32
2	MATERIAL AND METHODS.....	33
2.1	Field Activities	33
2.1.1	Treatment Application.....	33
2.1.2	Harvesting.....	34
2.1.3	Postharvest Operations	34
2.1.4	Cool Storage	35
2.2	Laboratory Activities	35
2.2.1	Carbon Dioxide Production.....	36
2.2.2	Fruit Ethylene Production.....	37
2.2.3	Fruit Firmness.....	38
2.2.4	Fruit Total Soluble Solids Content.....	39
2.3	Statistical Analysis	39

3	RESULTS.....	43
3.1	Fruit Respiration (CO ₂ Production).....	43
3.2	Fruit Ethylene Production.....	48
3.3	Fruit Firmness.....	53
3.1	Destructive Firmness Measurement ('Texture Analyser')	53
3.2	Non-destructive Firmness Measurement ('Kiwifirm').....	58
3.4	Fruit Total Soluble Solids Content.....	61
4	DISCUSSION.....	65
4.1	General Results.....	66
4.2	Low Temperature Effects in Fruit Physiology.....	69
4.3	Fruit Ethylene Production and Softening	71
4.4	Use of AVG in Kiwifruit and Suggested Future Research.....	72
5	REFERENCES.....	75
	APPENDIX I.....	94
	APPENDIX II.....	95
	APPENDIX III.....	96

LIST OF TABLES

Table 1.1 - Flesh firmness and SSC of 'Hayward' kiwifruit grown in 2 locations (A and B) at harvest and after 6 months at 0 °C (Mitchell <i>et al.</i> 1992).....	9
Table 1.2 - Postharvest losses of kiwifruit in New Zealand (Source: Anonymous 1997b).	13
Table 1.3 - Inhibition of ethylene synthesis (%) in apple plugs by AVG (0.1 mM) in relation to temperature (°C) (Mattoo <i>et al.</i> 1977).	29
Table 1.4 – Pre and postharvest effects of AVG on apple cultivars.....	31
Table 2.1 – Measurement time (days) of fruit variables at 20 °C, after successive removals from 0 °C.	36
Table 3.1 – CO ₂ production (nmol.kg ⁻¹ .s ⁻¹) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means of 15 fruit per treatment per removal time.	44
Table 3.2 – CO ₂ production (nmol.kg ⁻¹ .s ⁻¹) of kiwifruit. Average values of 4 to 5 measurements at 20 °C following storage for up to 180 days at 0 °C. Means of 60 to 75 fruit per treatment per removal time (pooled data).....	46
Table 3.3 – Ethylene production (pmol.kg ⁻¹ .s ⁻¹) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means of 15 fruit per treatment per removal time.	50
Table 3.4 - Ethylene production (pmol.kg ⁻¹ .s ⁻¹) of kiwifruit. Average values of 4 to 5 measurements at 20 °C following storage for up to 180 days at 0 °C. Means of 60 to 75 fruit per treatment per removal time (pooled data):.....	51
Table 3.5 – Loss of firmness (%) of kiwifruit on removal to 20 °C following storage for up to 180 at 0 °C. Means of 60 fruit per removal time from all treatments. Different letters indicate significant difference between removal times.	55

Table 3.6 – Firmness (N) of kiwifruit. Average values of 4 to 5 measurements at 20 °C following storage for up to 180 days at 0 °C. Means of 60 to 75 fruit per treatment per removal time (pooled data).....	56
Table 3.7 – Firmness (‘Kiwifirm’ unit) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means of 15 fruit per treatment per removal time.	59
Table 3.8 – Firmness (‘Kiwifirm’ unit) of kiwifruit. Average values of 4 to 5 measurements at 20 °C following storage for up to 180 days at 0 °C. Means of 60 to 75 fruit per treatment per removal time (pooled data).....	60
Table 3.9 – Soluble solids content (%) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means of 15 fruit per treatment per removal time.	62
Table 3.10 – Soluble solids content (%) of kiwifruit. Average values of 4 to 5 measurements at 20 °C following storage for up to 180 days at 0 °C. Means of 60 to 75 fruit per treatment per removal time (pooled data).....	64

LIST OF FIGURES

- Figure 1.1 - Schematic representation of postharvest softening of kiwifruit in relation to the timing of key events in the process (MacRae & Redgwell 1992).....18
- Figure 1.2 - The major pathway of ethylene biosynthesis in higher plants and the enzymes involved (Fluhr & Mattoo 1996).....23
- Figure 3.1 – CO₂ production (nmol.kg⁻¹.s⁻¹) of kiwifruit during 13 days at 20 °C immediately after harvest. Means of 15 fruit per treatment per sampling time. Bar represents overall LSD (least significant difference).....43
- Figure 3.2 – CO₂ production (nmol.kg⁻¹.s⁻¹) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means from all treatments of 60 fruit per removal time. Bar represents overall LSD (least significant difference). Means with the same letter are not significantly different.....45
- Figure 3.3 - CO₂ production (nmol.kg⁻¹.s⁻¹) of kiwifruit at 20 °C for up to 15 days, after 14 and 180 days at 0 °C. Means of 15 fruit per treatment per sampling time. Bars represent overall LSD (least significant difference).47
- Figure 3.4 – Ethylene production (pmol.kg⁻¹.s⁻¹) of kiwifruit during 13 days at 20 °C immediately after harvest. Means of 15 fruit per treatment per sampling time. Values plotted on logarithmic scale. Bar represents overall LSD (least significant difference).....48
- Figure 3.5 – Number of fruit that exceeded 0.1 µl.l⁻¹ ethylene production per sampling time during 13 days at 20 °C immediately after harvest. Total of 15 fruit per treatment per sampling time.49
- Figure 3.6 – Percent of fruit from each time of removal from 0 °C that exceeded 4.5 pmol.kg⁻¹.s⁻¹ (about 0.1 µl.l⁻¹) ethylene production of kiwifruit at 20 °C for up to 20 days (4 to 5 measurements), following storage for up to 180 at 0 °C. Total of 60 to 75 fruit per treatment per removal time.52

-
- Figure 3.7 – Firmness (N) of kiwifruit during 13 days at 20 °C immediately after harvest. Means of 15 fruit per treatment per sampling time. Bar represents overall LSD (least significant difference).....53
- Figure 3.8 – Firmness (N) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means of 15 fruit per treatment per removal time. Bars represent LSD (least significant difference) at each removal time.....54
- Figure 3.9 – Firmness (N) of kiwifruit at 20 °C for up to 20 days at harvest (A) or following storage at 0 °C for 14 (B), 30 (C), and 52 (D) days. Bar indicates overall LSD (least significant difference).....57
- Figure 3.10 – Firmness ('Kiwifirm' unit) of kiwifruit during 13 days at 20 °C immediately after harvest. Means of 15 fruit per treatment per sampling time. Bar represents overall LSD (least significant difference).....58
- Figure 3.11 – Firmness ('Kiwifirm' unit) of kiwifruit during 15 days at 20 °C after 14 days storage at 0 °C. Means of 15 fruit per treatment per sampling time.....60
- Figure 3.12 - Soluble solids content (%) of kiwifruit during 13 days at 20 °C immediately after harvest. Means of 15 fruit per treatment per sampling time. Bar represents overall LSD (least significant difference).....61
- Figure 3.13 – SSC (%) of kiwifruit on removal to 20 °C following storage for up to 180 days at 0 °C. Means from all treatments of 60 fruit per removal time. Bar represents overall LSD (least significant difference). Means with the same letter are not significantly different.....63

LIST OF PLATES

- Plate 2.1 – The ‘Texture Analyser’ fitted with a 7.9 mm diameter probe, material testing machine used for measuring fruit firmness destructively.41
- Plate 2.2 – The ‘Kiwifirm’, device used for measuring fruit firmness non-destructively.42