

STUDIES ON INCREASING STORABILITY AND MARKETABILITY OF POMEGRANATE FRUITS.

By

ISMAIL AHMED IBRAHIM EMAM

B. Sc. Agric. Sci. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2003.

M. Sc. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2011.

THESIS

**Submitted in Partial Fulfillment of the
Requirements for the Degree of**

DOCTOR OF PHILOSOPHY

In

**Agricultural Sciences
(Pomology)**

**Department of Pomology
Faculty of Agriculture
Cairo University
EGYPT**

2018

APPROVAL SHEET

**STUDIES ON INCREASING STORABILITY AND
MARKETABILITY OF POMEGRANATE FRUITS.**

**Ph. D. Thesis
In
Agric. Sci. (Pomology)**

By

ISMAIL AHMED IBRAHIM EMAM
B. Sc. Agric. Sci. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2003
M. Sc. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2011

Approval Committee

Dr. AHMED MOHAMED KAMAL ABD EL-AAL
Professor of Pomology, Fac. Agric., Menia University

Dr. MOHAMED HELMY ABD EL-ZAHER
Professor of Pomology, Fac. Agric., Cairo University

Dr. ALI ASSEM ZAKI FOUAD
Professor of Economic, Fac. Agric., Cairo University

Dr. SAHAR MOHAMED ABD EL-WAHAB
Professor of Pomology, Fac. Agric., Cairo University

Date: / / 2018

SUPERVISION SHEET

**STUDIES ON INCREASING STORABILITY AND
MARKETABILITY OF POMEGRANATE FRUITS.**

**Ph. D. Thesis
In
Agric. Sci. (Pomology)**

By

ISMAIL AHMED IBRAHIM EMAM
B. Sc. Agric. Sci. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2003
M. Sc. (Pomology), Fac. Agric., Cairo Univ., Egypt, 2011

SUPERVISION COMMITTEE

Dr. SAHAR MOHAMED ABD EL-WAHAB
Professor of Pomology, Faculty of Agriculture, Cairo University

Dr. ALI ASSEM ZAKI FOUAD
Professor of Economic, Fac. Agric., Cairo Uni.

Dr. ABD EL-RAHMAN ABD EL-GAFFAR ABE EL-HAFEEZ
Head Researcher of Handling Fruit Department Horticulture Research
Institute, ARC, Giza

Name of Candidate: Ismail Ahmed Ibrahim Emam	Degree: Ph. D.
Title of Thesis: Studies on Increasing Storability and Marketability of Pomegranate Fruits.	
Supervisors: Dr. Sahar Mohamed Abd El-Wahab Dr. Ali Assem Zaki Fouad Dr. Abd El-Rahman Abd El-Gaffar Abe El-Hafeez	
Department: Horticulture	
Branch: Pomology	Approval: / / 2018

ABSTRACT

The current study was carried out during three successive seasons (2013:2016) to study the effect of pre-harvest treatments (CaCl_2 4%, Chitosan 1%, Combination between CaCl_2 4% and Chitosan), curing (30 °C in durations of 24; 48 and 72 hours and 80-85 RH) and modified atmosphere packaging (MAP) on fruit quality of "Wonderful" pomegranate cultivar during cold storage. Beside, enhance arils (fresh cut) quality attributes during marketability life and evaluation of value chain development in EU market.

The results obtained in this work indicated that chitosan alone or in combination with calcium chloride as pre-harvest treatments, is effective methods for extending the storage life of "Wonderful" pomegranate fruits. The most effective treatment in maintaining fruit quality was CaCl_2 4% + chitosan 1 % during cold storage period at 7 °C.

The weight loss and decay of the fruits progressively increased with storage time. Comparing with control fruit, the, compared with control fruit, the weight loss and decay of packaged pomegranates was significantly reduced. In the control group, visual quality was strongly affected by weight loss, which leads to shriveling and browning of the skin. Indeed, The storage of 'Wonderful' pomegranate fruit in MAP using commercial Xtend® and Lifespan™ sheets effectively reduced weight loss, and maintained fruit quality for at least 5 months after harvest.

Exposure to MAP and cold storage in "Wonderful" pomegranate fruit may modify the activity of SOD, CAT and POD. The combination of MAP and cold storage maintained the antioxidant activity in a high level for long time, which increased the antioxidation ability against oxidation damage.

The highest price for pomegranate in Wholesale market price during 3 months extended by MAP used, from February to March and April (885.4, 1006.9, and 1222.9 \$), extending Egyptian market window to week 18 competitive with South African. The new market window for Egyptian pomegranate to be from week 30 till week 18 in the next year (from July to end of April). By this new window pomegranate off season were May and June only.

Key words: Pomegranate, Wonderful, CaCl_2 , Chitosan, Curing, Fresh cut, Cold storage, MAP, Antioxidant activity and Value chain.

ACKNOWLEDGEMENT

My high praise and gratitude are addressed to Allah, the almighty. Who enabled me to choose the right path and work diligently to achieve my goals.

My high recognition and specific appreciation are also dedicated to Dr. Sahar Mohamed Abd El-Wahab Assistant Professor of Pomology, Faculty of Agriculture, Cairo University for her valuable guidance and supervision through the course of the investigation, supporting the whole work, useful help and encouragement along the progress of this thesis.

I am deeply grateful to the valuable assistance of Dr. Ali Assem Zaki Fouad Professor of Economic, Faculty of Agriculture, Cairo University who allocated a lot of her time and worthy effort for my sake and my interest, during my study toward the acquisition of this degree.

I am also pleased to mention my sincere thanks and high regards for Dr. Abd El-Rahman Abd El-Gaffar Abe El-Hafeez Head researcher of Handling fruit Department Horticulture Research Institute for his valuable guidance in the experimental work, writing the manuscript, continues encouragement, kind advice and support to complete the study.

I would like to state clearly my great appreciation and respect to all the staff members of the Vegetable Handling Research Department Horticulture Research Institute.

CONTENTS

	Page
INTRODUCTION.....	1
REVIEW OF LITERATURE	5
A. Effect of Pre-Harvest Treatments (Calcium chloride and Chitosan) on Physical and Chemical Fruits Characteristics.	
1. Physical characteristics.....	5
2. Chemical characteristics.....	5
B. Effect of Preconditioning (Curing), Modified Atmosphere Packaging (MAP) on Physical and Chemical Fruits Characteristics Under Cold Storage Condition.....	19
1. Physical characteristics.....	24
2. Chemical characteristics.....	25
C. Influence of Modified Atmosphere Packaging (MAP), curing and cold storage on Antioxidants Activity.....	52
D. Minimally processed (Fresh Cut) study.....	54
1. Physical characteristics.....	54
2. Chemical characteristics.....	56
3. Microbial (Bacterial and Fungi) count.....	59
MATERIALS AND METHODS.....	62
RESULTS AND DISCUSSION	75
First: Some Basic Factors and Important Tools to Improve the Keeping Quality of 'Wonderful' Pomegranate Fruits.....	75
A. Effect of Pre-Harvest Treatments (Calcium chloride and Chitosan) on Physical and Chemical Fruits Characteristics.....	75
1. Physical characteristics.....	75
2. Chemical characteristics.....	82
B. Effect of Preconditioning (Curing) Treatments on Quality attributes of "Wonderful" Pomegranate.....	91
C. Effect of Preconditioning (Curing), Modified Atmosphere Packaging (MAP) on Physical and Chemical Fruits Characteristics Under Cold Storage Condition.....	93
1. Physical characteristics.....	93
2. Chemical characteristics.....	125
D. Influence of Modified Atmosphere Packaging (MAP), curing and cold storage on Antioxidants Activity.....	136
1. In case of Catalase (CAT) Enzyme Activity.....	136
2. In case of Peroxidase (POD) Enzyme Activity.....	138
3. In case of Superoxide dismutase (SOD) Enzyme Activity.....	138
E. Minimally processed (Fresh Cut) study.....	142

1. Physical characteristics.....	142
2. Chemical characteristics.....	151
3. Microbial (Bacterial and Fungi) count.....	161
Second: Evaluation of Pomegranate Value Chain Development in EU Market.....	168
1. Samples.....	171
2. Production outlook on Economic indicators of Pomegranate...	171
3. Economic estimate value chain of pomegranate crop in Egypt.	178
4. Factors Affecting Marketing Costs.....	184
5. Pomegranate Value Chain Flow.....	186
6. Estimated pomegranate losses during supply chain in Egypt...	187
7. Exports of pomegranate.....	190
8. Market window of pomegranate.....	195
SUMMARY.....	200
REFERENCES.....	215

LIST OF TABLES

No.	Title	Page
1	Score of visual quality evaluations.....	69
2	Effect of preconditioning (Curing) duration (hour) at 30°C and 80-85 % relative humidity on Quality attributes of "Wonderful" Pomegranate during 2013-2014 and 2014-2015 seasons.....	92
3	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Weight loss % of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	94
4	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Weight loss % of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	95
5	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Decay % of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	98
6	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Decay % of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	99
7	Effect of pre-harvest and preconditioning (Curing) treatments on fruit texture (g/cm ²) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	104
8	Effect of pre-harvest and preconditioning (Curing) treatments on fruit texture (g/cm ²) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	105

LIST OF TABLES

No.	Title	Page
9	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Lightness (L*) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	107
10	Effect of pre-harvest and preconditioning (Curing) treatments on fruit Lightness (L*) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	108
11	Effect of pre-harvest and preconditioning (Curing) treatments on fruit hue angle (h°) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	110
12	Effect of pre-harvest and preconditioning (Curing) treatments on fruit hue angle (h°) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	111
13	Effect of pre-harvest and preconditioning (Curing) treatments on fruit general appearance (score) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	113
14	Effect of pre-harvest and preconditioning (Curing) treatments on fruit general appearance (score) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	114
15	Effect of pre-harvest and preconditioning (Curing) treatments on fruit chilling injury (score) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	117
16	Effect of pre-harvest and preconditioning (Curing) treatments on fruit chilling injury (score) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	118

LIST OF TABLES

No.	Title	Page
17	Effect of pre-harvest and preconditioning (Curing) treatments on headspace gas analysis (O ₂ %) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	120
18	Effect of pre-harvest and preconditioning (Curing) treatments on headspace gas analysis (O ₂ %) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	121
19	Effect of pre-harvest and preconditioning (Curing) treatments on headspace gas analysis (CO ₂ %) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	122
20	Effect of pre-harvest and preconditioning (Curing) treatments on headspace gas analysis (CO ₂ %) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	123
21	Effect of pre-harvest and preconditioning (Curing) treatments on fruit TSS percentage of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	126
22	Effect of pre-harvest and preconditioning (Curing) treatments on fruit TSS percentage of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	127
23	Effect of pre-harvest and preconditioning (Curing) treatments on fruit total acidity percentage of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	130

LIST OF TABLES

No.	Title	Page
24	Effect of pre-harvest and preconditioning (Curing) treatments on fruit total acidity percentage of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	131
25	Effect of pre-harvest and preconditioning (Curing) treatments on fruit anthocyanin contents (mg/ 100 ml juice) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2014-2015 season.....	134
26	Effect of pre-harvest and preconditioning (Curing) treatments on fruit anthocyanin contents (mg/ 100 ml juice) of pomegranate cv. "Wonderful" during storage in modified atmosphere packaging (MAP) at 5 °C and 85-90 % RH in 2015-2016 season.....	135
27	Effect of chemical treatments on arils lightness (L*) value of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	143
28	Effect of natural ingredient treatments on arils lightness (L*) value of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	144
29	Effect of chemical treatments on arils hue angle (h°) value of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	145
30	Effect of natural ingredient treatments on arils hue angle (h°) value of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	146
31	Effect of chemical treatments on arils texture (g/ cm ²) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	149

LIST OF TABLES

No.	Title	Page
32	Effect of natural ingredient treatments on arils texture (g/cm ²) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	150
33	Effect of chemical treatments on arils total soluble solids (TSS) percentage of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	152
34	Effect of natural ingredient treatments on arils total soluble solids (TSS) percentage of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	153
35	Effect of chemical treatments on arils total acidity (TA) percentage of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	155
36	Effect of natural ingredient treatments on arils total acidity (TA) percentage of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	156
37	Effect of chemical treatments on arils anthocyanin of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	159
38	Effect of natural ingredient treatments on arils anthocyanin of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	160
39	Effect of chemical treatments on arils microbial count (Bacteria* 10 ⁻² CFU/ml) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	162
40	Effect of natural ingredient treatments on arils microbial count (Bacteria* 10 ⁻² CFU/ml) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	163

LIST OF TABLES

No.	Title	Page
41	Effect of chemical treatments on arils microbial count (Fungi* 10^{-1} CFU/ml) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	164
42	Effect of natural ingredient treatments on arils microbial count (Fungi* 10^{-1} CFU/ml) of minimally processed (Fresh Cut) pomegranate cv. "Wonderful" during storage at 5 °C and 85-90 % RH in 2014-2015 and 2015-2016 seasons.....	165
43	Distribution of study sample for pomegranate in Egypt...	172
44	The relative importance of pomegranate crop area of fruit crops in the Arab Republic of Egypt during the period (2008-2013).....	175
45	Development of Area, Production and Productivity of Pomegranate Crop at the Republic Level during the Period (1990-2013).....	176
46	Estimate the production cost of pomegranate per ton and fed 2014 season.....	178
47	Estimate the net margin for Pomegranate per ton and fed 2014 season.....	180
48	Split of consumer price per ton of pomegranate in local market.....	185
49	Estimate Pomegranate agro logistic losses during supply chain in Egypt.....	188
50	The trend of exports pomegranates (Ton) during the period (2010-2013).....	193
51	Estimate monthly cost % of value chain per US\$/ton refer to EU market price season 2014.....	194
52	Split of consumer pounds per ton of pomegranate in EU market.....	197
53	Estimate Market windows in EU Market.....	198
54	Estimate Market windows in EU Market after Used MAP Treatments.....	199

LIST OF FIGURES

No.	Title	Page
1	Hue angle diagram and the geometrical arrangement of color attributes.....	69
2	DualTrak model 902D gas analyzer; Quantek Instruments, USA.....	70
3	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Weight loss % of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	76
4	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Decay % of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	77
5	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit texture (g/cm ²) of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	79
6	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Lightness % of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	81
7	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Hue angle (h°) of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	83
8	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit TSS % of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	84
9	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Acidity % of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.....	86
10	Effect of pre-harvest treatments (A) and storage temperatures (B) on fruit Anthocyanin (mg/100 ml) of "Wonderful" pomegranate through cold storage periods (week) during 2013-2014 and 2014-2015 seasons.	89
11	Influence of Modified Atmosphere Packaging (MAP) and curing treatment on Catalase (CAT) Enzyme Activity (u min ⁻¹ g ⁻¹ F.W.) of "Wonderful" pomegranate fruit during storage at 5°C and 85-90 % RH in 2015-2016 season.....	137

LIST OF FIGURES

No.	Title	Page
12	Influence of Modified Atmosphere Packaging (MAP) and curing treatment on Peroxidase (POD) Enzyme Activity ($\mu \text{ min}^{-1} \text{ g}^{-1} \text{ F.W.}$) of "Wonderful" pomegranate fruit during storage at 5°C and 85-90 % RH in 2015-2016 season.....	139
13	Influence of Modified Atmosphere Packaging (MAP) and curing treatment on Superoxide dismutase (SOD) Enzyme Activity ($\mu \text{ min}^{-1} \text{ g}^{-1} \text{ F.W.}$) of "Wonderful" pomegranate fruit during storage at 5°C and 85-90 % RH in 2015-2016 season.....	140
14	Pomegranate planted area in Egypt.....	173
15	Relative status of pomegranate area among fruit crops in the Arab Republic of Egypt as average for the period (2008-2013).....	175
16	Evolution of Pomegranate Area in the Arab Republic of Egypt.....	177
17	The development of pomegranate production in the Arab Republic of Egypt.....	177
18	Evolution of pomegranate production in the Arab Republic of Egypt.....	177
19	Estimate the production cost of Pomegranate per Fed.....	179
20	Estimate the production cost of Pomegranate per Ton.....	179
21	Estimate the cost items percentage of Pomegranate.....	180
22	Estimate the farmer revenue % of Pomegranate.....	181
23	Estimate the farmer share % of Pomegranate consumer price.....	186
24	Pomegranate value chain in Egypt.....	187
25	Pomegranate estimated losses % during supply chain in Egypt.....	188
26	Pomegranate causes losses % during supply chain in Egypt.....	189
27	Estimate Pomegranate agro logistic losses during supply chain in Egypt.....	190
28	Development of Egyptian pomegranate exports during the period 2008-2013.....	192