UNIVERSITI PUTRA MALAYSIA

POSTHARVEST QUALITIES AND METABOLIC RESPONSES OF HYDRO-COOLED ROCKMELON (Cucumis melo L. reticulatus cv Glamour) AFTER DIFFERENTIAL STORAGE DURATIONS

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By

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May 2018

Chairman : Associate Professor Phebe Ding, PhD
Faculty : Agriculture

Harvested rockmelon often accumulates a considerable amount of heat from the high field temperature which accelerates the respiration, metabolic changes and thus shortens the market life of the fruit. The beneficial effects of hydro-cooling to rapidly reduce the core temperature in order to maintain fruit quality during postharvest storage has been reported on various fruits. Therefore, the main objective of this study was to evaluate the cooling time (CT) which characterize the performance of hydro-cooled rockmelon during cold storage. Three experiments were conducted to determine (i) quality and postharvest performances of hydro-cooled rockmelon (ii) antioxidant enzymes activity and histological structure of hydro-cooled rockmelon and (iii) phytochemical content, *in vitro* antioxidant activities and metabolite composition of hydro-cooled rockmelon. To achieve the best cooling time, rockmelon fruit (25.5 °C initial temperature) was hydro-cooled to 14.8 and 9.4 °C to attain 1/2 and 3/4 CT, respectively prior to storage at 13 °C cold room of 85% relative humidity along with non-hydro-cooled fruit (0 CT) as control. Results showed that 1/2 CT was effective in slowing down weight loss and increment of soluble solids concentration, preserving higher chroma intensity of pulp colour and turgor pressure of rind and pulp firmness, and maintaining the citric acid content as compared to the others treatment during rockmelon storage. The significant weight loss in the control and 3/4 CT hydro-cooled rockmelon had influenced cell rigidity as dehydration caused the impact in a loss of cell turgor. During storage, the ascorbate peroxidase, peroxidase and superoxide dismutase enzymes activity were higher for 1/2 CT rockmelon. The significant induction of these antioxidative enzymes activity corresponded to lower lipid peroxidation as measured by malondialdehyde content. The less induction of antioxidative enzyme activity in 3/4 CT and control rockmelon pulp exposed the fruits to deleterious effect of free radicals. The severity of cell membranes disorder in structural characteristics was in line with higher malondialdehyde content due to less tolerance to oxidative stress in 3/4 CT and control rockmelon. To better understand the metabolic changes, untargeted metabolite properties were studied through Nuclear Magnetic Resonance (NMR)-based metabolomics approach to visualize variations in metabolic profile of hydro-cooled rockmelon during cold storage. Overall, sugars and amino acids were appreciably affected by hydro-cooling application. The high intensity of phenylalanine, tryptophan and tyrosine appear to be associated with biosynthesis of secondary metabolites and cold tolerance since their present were altered in 1/2 CT rockmelon, relative to the control and 3/4 CT hydro-cooled rockmelon. Noticeably, less accumulation of sucrose during advanced cold storage in control and 1/2 CT hydro-cooled rockmelon rind might reduce the cell metabolism and fruit resistibility in response to cold storage since it influences the cell structural support and protection against reactive oxygen species (ROS). In short, the 1/2 CT of hydro-cooling application could be considered as the optimum CT level for rockmelon fruit in preserving physico-chemical quality and thus, extending the storage life of rockmelon fruit.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KUALITI LEPAS TUAI DAN TINDAK BALAS METABOLIK RENDAMAN AIR SEJUK ROCKMELON (*Cucumis melo* L. *reticulatus* cv Glamor) SELEPAS TEMPOH PENYIMPANAN BERBEZA

Oleh

BOKHARY BIN ZAINAL

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Pengerusi : Profesor Madya Phebe Ding, PhD
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Rockmelon yang dituai kerap mengumpul banyak haba dari suhu persekitaran yang tinggi di mana meningkatkan respirasi, perubahan metabolik dan seterusnya memendekkan tempoh pasaran buah. Kebaikan kesan rendaman air sejuk dengan cepat dapat merendahkan suhu teras supaya mengekalkan kualiti buah semasa penyimpanan lepas tuai telah dilaporkan pada pelbagai buah-buahan. Oleh itu, objektif kajian ini adalah untuk menilai masa penyejukan (CT) yang menunjukkan prestasi rockmelon rendaman air sejuk semasa penyimpanan sejuk. Tiga eksperimen telah dijalankan untuk menentukan (i) kualiti dan prestasi lepas tuai rockmelon rendaman air sejuk (ii) aktiviti enzim antioksidan dan struktur histologi rockmelon rendaman air sejuk dan (iii) kandungan fitokimia, aktiviti antioksidan *in vitro* dan komposisi metabolit rockmelon rendaman air sejuk. Untuk mencapai masa penyejukan terbaik, buah rockmelon (suhu awal 25.5 °C) telah direndam air sejuk hingga ke suhu 14.8 dan 9.4 °C untuk mencapai 1/2 dan 3/4 CT, sebelum penyimpanan pada 13 °C bilik sejuk 85% kelembapan relatif bersama dengan buah tidak direndam air sejuk (0 CT) sebagai kawalan. Keputusan menunjukkan bahawa 1/2 CT adalah berkesan dalam memperlahankan penurunan berat dan peningkatan kepekatan pepejal larut, mengekalkan ketinggian keamatan kroma bagi warna isi dan tekanan turgor kulit dan isi yang kuat, dan mengekalkan kandungan asid sitrik berbanding dengan rawatan yang lain semasa penyimpanan rockmelon. Kehilangan berat yang signifikan pada buah kawalan dan 3/4 CT rockmelon rendaman air sejuk telah mempengaruhi kesegahan sel apabila dehidrasi menyebabkan impak dalam kehilangan sel turgor. Semasa penyimpanan, aktiviti enzim ascorbate peroxidase, peroxidase dan superoxide dismutase adalah tinggi bagi 1/2 CT rockmelon. Peningkatan signifikan aktiviti enzim antioksidan ini sepadan dengan peroksidasi lipid yang rendah seperti yang diukur oleh kandungan malondialdehid. Pengurangan peningkatan aktiviti enzim antioksidan dalam isi

3/4 CT dan rockmelon kawalan mendedahkan buah-buahan kepada kesan buruk terhadap radikal bebas. Kerosakan membran sel dalam pencirian struktur adalah selari dengan kandungan malondialdehid yang tinggi kerana kurang toleransi dengan tekanan oksidatif pada 3/4 CT dan rockmelon kawalan. Untuk lebih memahami perubahan metabolik, kandungan metabolit yang tidak disasarkan dikaji melalui pendekatan metabolomik berasaskan Magnetik Nuklear Resonans (NMR) untuk menggambarkan variasi dalam profil metabolik rockmelon yang telah direndam air sejuk semasa penyimpanan sejuk. Secara keseluruhannya, gula dan asid amino dipengaruhi oleh aplikasi rendaman air sejuk. Intensiti yang tinggi bagi fenilalanina, triptofan dan tirosina dikaitkan dengan biosinteis metabolit sekunder dan toleransi sejuk di mana kehadirannya telah berubah dalam 1/2 CT rockmelon berbanding dengan yang rockmelon kawalan dan direndam air sejuk pada 3/4 CT. Sukrosa kurang terkumpul semasa lanjutan penyimpanan sejuk dalam kulit rockmelon kawalan dan 1/2 CT rendaman air sejuk mungkin mengurangkan metabolism sel dan daya tahan buah sebagai tindak balas terhadap penyimpanan sejuk kerana ia mempengaruhi sruktur sokongan sel dan perlindungan terhadap spesies oksigen reaktif (ROS). Ringkasnya, aplikasi 1/2 CT rendaman air sejuk boleh dianggap sebagai tahap CT optimum untuk buah rockmelon bagi mengekalkan kualiti fiziko-kimia dan sekaligus memanjangkan tempoh penyimpanan buah rockmelon.

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I certify that a Thesis Examination Committee has met on 2018 to conduct the final examination of Bokhary bin Zainal on his thesis entitled "Postharvest Qualities and Metabolism Responses of Hydro-cooled Rockmelon (*Cucumis melo* L. *reticulatus* cv Glamour) After Differential Storage Durations" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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^{1}H NMR	Proton nuclear magnetic resonance
AAA	Aromatic amino acid
ANOVA	Analysis of variance
APX	Ascorbic peroxidase
CD_3OD	Methanol-*d*4
CT	Cooling time
CV-ANOVA	Cross validated residuals of variance analysis
D_2O	Deuterium oxide
DDPH	2,2-diphenyl-1-picrylhydrazyl
DMRT	Duncan's multiple range test
EDTA	Ethylenediamine tetraacetic acid
GABA	γ-aminobutyric acid
GAE	Gallic acid equivalents
MVDA	Multivariate data analysis
NO	Nitric oxide
PC	Principal component
PCA	Principal component analysis
POD	Peroxidase
PVP	Polyvinylpyrrolidone
QE	Quercetin equivalents
RH	Relative humidity
SOD	Superoxide dismutase
TBA	Thiobarbituric acid

TCA	Trichloroacetic acid
TFC	Total flavonoids content
TPC	Total phenolic content
VIP	Variables influence on projection
WS	Week of storage

CHAPTER 1

INTRODUCTION

Melon is one of the most important fruits in the world. It is the fourth world's major production after orange, banana and grape (Aguayo et al., 2004). The most common melon variety consumed as fresh fruit is cantaloupe or also known as muskmelon or rockmelon (*Cucumis melo* L. *reticulatus*). Rockmelon production in all tropical and subtropical regions of the world at present is mainly as a source of food or commodity produce. The rockmelon fruits are usually consumed directly as a fresh cut fruit, salad or as a dessert with ice cream or custard. Presently, China is the largest rockmelon-producing country with estimated production of over 31 million tonnes (Yahia, 2011). Turkey, Iran, the United States, Spain, India, Egypt, Morocco, Mexico and Italy are the next largest rockmelon-producing countries in the world (FAO, 2014).

In Malaysia, rockmelon is one of the fast growing popular fruits and has gained very high demand. The production of this crop has been tremendously increased in between 2011 to 2015 from 311 to 5,118 metric tons, respectively (Department of Agriculture, 2015). The popular variety of rockmelon type cultivated in Malaysia is 'Glamour' or locally known as 'Golden Langkawi'. Rockmelon fruits are preferably consumed during hot weather and widely accepted among consumers because of their sweet pulp, lusciously rich in flavor and pleasant aroma (Villanueva et al., 2004). In addition to their high appreciation by consumers, rockmelon fruits are extremely nutritious fruit choice as they are rich in ascorbic acid, β-carotene, flavonoids, folic acid, and potassium (Lester and Crosby, 2002; Koubala et al., 2016) as well as a number of other human health-bioactive compounds (Lester, 1997).

However, besides being highly appreciated by consumers, rockmelon fruits have a drawback of lower shelf life due to its high perishability. The substantial loss of its marketability commonly occurs within two weeks during recommended storage conditions at 7 °C with 95% RH (Zheng and Wolff, 2000; Shellie and Lester, 2004). The major factor limiting rockmelon keeping quality and short storage life is desiccation (Mayberry and Hartz, 1992). Desiccation during storage is mainly due to water loss and the amount of water loss may result in a significant loss in fresh weight. This limitation severely limits the wide commercial acceptance of rockmelon fruit as water loss can cause a subtle quality changes in colour, texture, firmness and nutritional value, then limits the possibility of extending the storage life even under current commercial handling techniques (Mayberry and Hartz, 1992).

The relative postharvest life and quality of horticultural crops is significantly affected by temperature. Quality loss after harvest and throughout storage occurs as a result of physiological and biological processes as the rates are influenced primarily by product temperature. For example, crop with high product temperature utilizes the reserves carbohydrates faster due to increase in respiration rate and becoming more perishable than those with lower respiration rates (Fonseca et al., 2002). During respiration, harvested produce gives off vital heat couple with a considerable amount of field heat which is reflected as increase in respiration rate and metabolic activities associated with its decomposition (Aroucha et al., 2016). Indeed, Nunes et al. (1995a) concluded that within six hours of harvest at 30 °C of ambient temperature, 'Chandler', 'Oso Grande' and 'Sweet Charlie' strawberries had greater water loss, low tissue firmness value and prone to browning during postharvest storage.

For the maintenance of market quality, it is necessary not only to cool the product but must be rapidly cooled after harvest to the optimal storage temperature in order to arrest the deteriorative and senescence process to maintain a high level of quality that ensures customer satisfaction (Senthilkumar et al., 2015). In practice, this means that direct cold storage is not recommended as it is slow cooling and delays the core temperature to decrease over hours to cause high metabolic activity and shorten the expected storage life in most perishable crops. Therefore, prompt pre-cooling is critical for produce to remove field heat from freshly harvested crops rapidly so it can minimize postharvest losses and meet consumer demands for high quality fresh produce. Practically, cooling time (CT) is required to establish the relationship between temperature and amount of time produce is exposed to cooling medium (Chakraverty and Singh, 2014).

There are a variety of pre-cooling techniques available for use in the horticultural industry, among them are air-cooling, hydro-cooling, cryogenic cooling and vacuum cooling (Garrido et al., 2015). These pre-cooling methods differed from each other according to the medium used as a heat transfer in lowering the commodity temperature, such as cold water, refrigerated air or ice. Among these, hydro-cooling is a practically popular pre-cooling method because of its simplicity, low cost and effectiveness to lower the temperature. Water has high thermal conductivity (Liang et al., 2013) and utilization of water as cooling medium offers faster and uniform contact with the surface of produce causing the temperature to lower quickly. Unlike air-pre-cooling, hydro-cooling does not dehydrate the produce but it may even revive slightly fruits and vegetables (Henry and Bennett, 1973). Some workers found that hydro-cooling was an effective pre-cooling treatment in preserving fruit quality of apple (Brackman and Balz, 2000), delaying senescence and prolonging postharvest life during distribution of sweet cherry (Manganaris et al., 2007), rambutan (Nampan et al., 2006) and dates (Elansari, 2008).

Therefore, the general objective of this work was to evaluate the CT which characterize the performance of hydro-cooled rockmelon. The performance of hydro-cooled product requires extensive evaluation concerning quality and storability attributes of fruit throughout storage period. Hence, three studies were conducted with the aims:

1. To evaluate the effects of different CT of hydro-cooling treatment in conjunction with cold storage on the physico-chemical quality of rockmelon fruit;

2. To determine the activity profile of antioxidative scavenging enzymes (superoxide dismutase, ascorbate peroxidase and peroxidase), postharvest structural analysis and malondialdehyde content which is end product of lipid peroxidation in cells represent oxidative damage of the hydro-cooled 'Glamour' melon fruit during cold storage; and

3. To profile the phytochemical content, *in vitro* antioxidant activities and major trend in metabolite composition of hydro-cooled rockmelon fruit during storage.

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