EFFECT OF HOT WATER TREATMENT AND DURATION OF SUBMERGENCE ON THE PHYSICAL AND CHEMICAL QUALITY OF PINEAPPLE

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ABSTRACT

This study was conducted to determined the effect of hot water temperature, time of submerge and storage duration on pineapple (*Ananas comosus*). Freshly harvested pineapples were treated with hot water temperature at 35, 45 and 60°C and time of submerge at 15, 30 and 60 minutes for 0, 5, 10 and 15 storage days (28±3°C). Control pineapple was only washed with distilled water (26±1°C) before stored. Pineapple uniform size (800-1100 g) was selected for this experiment. The experiment design used in this experiment was complete randomized design with a factorial of treatments with four replicates. The result showed that the hot water temperature significantly affected the soluble solid concentration (SSC) and pH value. The SSC was high for fruit treated with hot water temperature at 60°C irrespective time of submerge with 12.55°Brix. Control and pineapple treated with hot water 60°C have high pH value with 3.88 and 3.79 respectively. The combination of hot water temperature and time of submerge significantly affected the weight loss of the fruit. Pineapple treated with hot water at 60°C and time of submerge 60 minutes had high weight loss at 9.17%. Meanwhile, pineapple treated with hot water 60°C and time of submerge for 15 minutes had low weight loss at 5.16%. The combination of hot water temperature and storage duration significantly affected the pH value of the fruit. Control and pineapple treated with hot water temperature 60°C after 15 days of storage had high pH value with 4.35 and 4.25 respectively. However, pineapple treated with hot water temperature 35 and 45°C after 15 days of storage had low pH value with 3.55 and 3.19 respectively. Combination of hot water temperature of 60°C and time of submerge at 15 minutes effectively reduce the weight loss of the pineapple. This result can be used to make decision on hot water temperature and time of submerge to treat pineapple fruits.

ABSTRAK

Kajian ini dijalankan untuk menentukan kesan air panas, tempoh masa rendaman dan tempoh masa simpanan terhadap nanas (*Ananas comosus)*.Buah nanas yang baru dipetik dirawat menggunakan kaedah rendaman air panas pada suhu 35, 45 dan 60°C, selama 15, 30, dan 60 minit dan akhirnya disimpan dalam bilik simpanan selama 0, 5, 10, dan 15 hari (28±3°C). Kawalan dibuat dengan merendamkan buah nanas segar dalam air suling (26±1°C) sebelum disimpan di dalam bilik simpanan selama 0, 5, 10, dan 15 hari (28±3°C). Buah nanas segar dengan saiz dan berat sekata (800-1100 g) dipilih secara rawak untuk kajian ini. Kaedah kajian untuk eksperimen ini adalah rekabentuk rawak penuh dengan rawatan disusun secara faktorial iaitu empat replikasi. Keputusan menunjukkan bahawa rendaman dalam air panas memberi kesan signifikan terhadap jumlah pepejal terlarut (SSC) dan pH buah nanas. Nilai SSC didapati tinggi pada nanas yang direndam dalam air panas pada suhu 60°C 12.55°Brix. Kawalan dan nanas dalam rendaman 60°C air panas mempunyai nilai pH yang tinggi, masing-masing pH 3.88 dan pH 3.79. Kombinasi rawatan air panas dan tempoh masa rendaman memberi kesan yang signifikan terhadap kehilangan berat buah nanas. Nanas yang dirawat dalam air panas pada suhu 60°C selama 60 minit menyeabkan kehilanan berat sebanyak 9.17%. Sementara itu, buah nanas yang direndam dalam air panas pada suhu 60°C selama 15 minit menyebabkan kehilangan berat sebanyak 5.16%. Kombinasi rawatan air panas dan masa simpanan memberi kesan signifikan terhadap nilai pH buah nanas. Kawalan dan buah nanas yang dirawat pada suhu 60°C selepas 15 hari penyimpanan masing-masing mempunyai nilai pH 4.32 dan pH 4.25. Buah nanas yang dirawat pada suhu 35°C dan 45°C yang disimpan selama 15 hari pula mempunyai nilai pH rendah, masing-masing pH 3.55 dan pH 3.19. Ini menunjukkan bahawa kombinasi rawatan air panas pada suhu 60°C dan tempoh penyimpanan selama 15 minit memberi kesan yang besar terhadap kehilangan berat buah nanas. Keputusan eksperimen ini membolehkan suhu rawatan air panas dan tempoh masa rendaman ditentukan untuk merawat buah nanas.

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LIST OF ABBREVIATIONS

%	Percentage
RM	Ringgit Malaysia
°C	Degree Celsius
RH	Relative Humidity
PPO	Polyphenol Oxidase
POD	Peroxides
PAL	Phenylalanine Ammonia-lyase
g	Gram
kCal	Kilocalorie
mg	Milligram
SSC	Soluble Solid Concentration
H^+	Hydrogen ion
cm	Centimetre
Nm	Nanometre
kg^{-1}	Per kilogram
CO_2	Carbon Dioxide
CI	Chilling Injury
-	Hyphen
SST	School of Science and Technology
V	Volume
π	Pi
$kg.cm^{-2}$	Kilogram per centimetre square

CHAPTER 1

INTRODUCTION

1.1 Introduction

Pineapple (*Ananas* comosus) is one of the important plants from the family of Bromeliaceae. The origin of the pineapple is South America and now pineapples are grown in many parts of the world including Malaysia.

Pineapple is a non-climacteric fruit and the demand for this fruit is high. It is the third important tropical fruit after banana and citrus (Rohrbach *et al*., 2003). In Malaysia, pineapple is the oldest industrial crop. It is widely planted in the state of Johor, Selangor and Kelantan.

Malaysia not only markets the fruits locally, they are also exported to other countries such as Singapore and Japan. Malaysia is ranked 17^{th} in the world for exporting pineapples, contributing about 1.6 percent to the world market with an export value of about RM 9.6 million in 2003 (FAMA, 2003). Pineapples are exported fresh or sometimes canned, depending on the demand in the market. Seventy percent of the world's pineapples are exported fresh.

Fruits and vegetables production is lower than grain production. However, they contribute important nutrients to the diet, including vitamins A and C, folic acid, potassium and dietary fibre. Consumers tend to prefer fresh fruits rather than processed or canned food and postharvest losses of fresh fruits are one of the major problems of the fresh food industry.

Handling of pineapple for local markets is easy. However, handling for export purpose needs more attention and have to go through few processes like proper harvesting, grading, packaging, storing and transporting. For long distance distribution of this fruit, ships and airplanes are needed. To ensure the fruits reach the destination in good condition, storage is important during distribution and transport action.. To make sure the quality of the pineapple is maintained at standard grade, good methods of storage through a combination of appropriate storage temperature, atmosphere and relative humidity, control of the production of ethylene gas and control of disease in the storage room (Rohrbach *et al.*, 2003).

The quality of pineapple fruits is a very important property. Under low temperature 10°C and 85-90% RH, storage develops internal browning symptoms (Teisson *et al.*, 1979). Fruits acidity, polyphenol oxidase (PPO) and peroxides (POD) enzyme activities increase sharply and phenylalanine ammonia-lyase (PAL) activity increase slightly during low temperature storage, concurrent with the development of internal browning during prolonged low temperature storage (Dull *et al.*, 1971). Harvesting the fruits early in the morning reduces both incidence and severity of internal browning.

Post harvest heat treatment, in the form of a hot water dip, induces pineapple fruit tolerance to cold injury which, in turn, reduces internal browning during prolonged low temperature storage. However, lots of heat treatments on pineapples have been done and research shows that differences in submergence time give different results. According to Wijeratnam *et al.* (2005), treatment for three minutes resulted in the pineapples lasting for three weeks. Paull and Chen (2000) showed that a longer treatment for 24 hours before and after storage in low temperature resulted in pineapples lasting for two weeks. According to Porat *et al.* (2000), the heat treatment process is still under thorough investigation.

1.2 Objective

The objective of this study is to study the effect of different heat treatment and submergence time on the physical and chemical quality (colour, texture, soluble solids concentration and acidity) of Babagon pineapple during storage.

CHAPTER 2

LITERATURE REVIEW

2.1 Pineapple

The pineapple was first discovered by Europeans when Columbus and his men landed on the island of Guadalupe during the second voyage in 1493 (Rohrbach *et al.*, 2003). They called the fruit 'pina' because of its resemblance to the pine cone. Early explorations by botanists in South America indicated the area of origin to be South-Eastern Brazil, Paraguay and Northern Argentina, because of the abundance of the wild species. Based on materials collected in South America, an area further north was proposed. This general area include North-western and Eastern Brazil, all of Colombia and Guyana and most of Venezuela (Rohrbach *et al.*, 2003). In the 16th Century, the Spaniards brought the pineapple to the Philippines and Peninsular Malaysia and possibly Indonesia. The crop is now widely grown throughout the tropics and the subtropics.

The pineapples are also known as pain de *sucre* (French), *pina* (Spanish), *nanas* (Malaysia), *sapparot* (Thailand) and *Mahkut* (Laos) (Rohrbach *et al*., 2003). The pineapple is best eaten fresh, although it can be cooked in a number of dishes. The fruits were canned as early as the end of the 19th Century in Hawaii and Singapore and to date the bulk of the crop is grown for canning and exported all over the world.

The botanical key to the genera and species and the major characteristics of five 'Cayenne' clones for selection of appropriate parents was developed. A later taxonomic key identified 18 commercial clones with vernacular names and descriptions (Rohrbach *et al*., 2003). This includes a new group 'Maipure', composed of smooth-leaved clones. 'Cayenne' and 'Maipure' smooth-leaved groups differ, in that leaves of the former group exhibit a few spines near the leaf tip while the latter group shows leaf piping with a greyish streak due to folding over of the lower epidermis on to the upper leaf surface (Rohrbach *et al*., 2003).

2.2 Pineapple Quality

The quality of a product encompasses sensory properties (appearance, texture and aroma), nutritive value, chemical constituents, mechanical properties, functional properties and defects (Shewfelt, 1999). He pointed out that quality is often defined based on the perspective. Products orientation perspective considers quality as a bundle of attributes that are inherent in a product and can be readily quantified through handling and distribution. Consumer orientation perspective defines quality in terms of consumer satisfaction. Product orientation perspective is best at assessing the effectiveness of changes in a handling system, such as cultivars selection, harvesting or postharvest techniques.

The component attribute of quality varies with context. The choice of what to measure, how to measure it and what values are acceptable are determined by the person or institution requiring the parameters and according to the available technology, economics and tradition (Abbott, 1999). For grades and standards of a product, the definition of quality is formalized and institutionalised so that it has the same meaning for everyone using it. Shewfelt (1999) suggested that the combination of characteristics of the product itself be termed quality and that the consumer's perception and response to those characteristics be referred to as acceptability.

Pineapple fruit quality is at its best only if the fruit matures on the plant. They do not become sweeter if harvested earlier since there are no starch reserves to be converted to sugar. The sugar content must come from the rest of the plant.

2.2.1 Nutritional Value

Pineapple is the king of tropical fruits, featuring an intense perfume and unique taste. It contains high levels of vitamins, proteins, lipids, amino acids and minerals as shown in Table 2.1.

Table 2.1 Nutritional Value of *Ananas comosus* per 100g edible portion

Nutrient	Quantity
Energy	45 kCal
Water	87.8 g
Protein	0.5 g
Fat	0.1 g
Fibre	10.6 g
Ash	0.6 g
Calcium	0.4 g
Phosphorus	24 mg
Iron	6.0 mg
Sodium	1.4 mg
Potassium	31.0 mg
Vitamin A	40.0 mg
Vitamin B1	270.0 mg
Vitamin B2	0.17 mg
Niacin	0.1 mg
Vitamin C	15.2 mg

Source: FAMA (2003)

2.2.2 Texture

Food texture is defined as: 'all the theological and structural (geometrical and surface) attributes of food product perceptible by means of mechanical, tactile and where appropriate, visual and auditory receptors' (Jowitt, 1974). Terms such as crispness, juiciness, hardness and mealiness are few of a broad spectrum of attributes that define the feel of fruits in the mouth. They are experienced during mastication, which causes the breakdown of the tissue. In many fruits this tissue is made up of parenchyma cells. Although these cells contain a variety of inclusions such as starch, it is the presence and structural integrity of the cell wall that plays a major role in the perception of texture.

2.2.3 Soluble Solid Concentration (SSC)

Sweetness is one of the important criteria that affect the quality of a fruit. It has been extensively evaluated as soluble solid concentration (SSC) in fruit crops because it can easily be determined using a refractometer and the sugar content accounts for the majority of SSC (Iwanami *et al*., 2002). Therefore, SSC is a major characteristic used for assessing fruit crop quality (Ventura *et al*., 1998). Fruits including pineapple contain many compounds that are soluble in water; e.g. sugar, ascorbic acids, amino acids and some pectins.

Dull (1971) reported that SSC in pineapple are low during 70 days before the fruit harvest and rapidly increases during 30 days prior to fruit harvest. Soluble solids levels in fruits may respond to soil or foliar treatments of nutrients such as potassium and nitrogen, although not consistently. High nitrogen status has been associated with lower soluble solids levels in pears (Raese, 1977) and apple (Dris *et al.*, 1999). Soluble solids concentration increased in tomatoes with increasing fertilizer nitrogen levels.

2.2.4 pH Value

pH value in fruits mean the measurement of the acidity or alkalinity in the fruit. The value of the pH is obtained from the free H^+ ions (Wills *et al.*, 1989). During the maturity of the fruits, the pH value of the fruit normally increases. This will cause the organic acids to decrease during the metabolic process. The decrease of the organic acids will decrease the free H^+ ions and consequently increase the pH value. During prolong storage, pH declines because the acids are respired or converted to sugar (Wills *et al.*, 1989).

2.2.5 Titratable Acidity

Titratable acidity gives the amount of acid present in the fruits that contribute to the taste of the fruit. They are produced from the fermentation of carbohydrate, specifically di- and oligo-saccharides, starch, sugar alcohols and non-starch polysaccharides (Hove *et al.*, 1998). The acidity of unripe fruit is lesser than the acidity of ripe fruit. Acids are important for the taste of the fruit because, taste is mainly a balance between sugar and acid content.

2.2.6 Fruit Firmness

Fruit firmness is a prime indicator of fruit quality, being a ripening index in fruits such as apple, kiwifruit and avocado. Much postharvest research effort is dedicated to ways of maintaining fruit firmness during postharvest storage and shelf life. Greater flesh firmness (slower rate of softening), in fruits such as apples, pears, and kiwifruit has been associated with higher flesh calcium concentrations (Poovaiah *et al*., 1988).

2.3 Factors Influencing Quality during Storage

2.3.1 Bruising

Fruit bruising is a major problem during harvesting and packaging. Bruising can be caused by impact damage, with a 30 cm drop causing significant damage (Wills *et al*., 1989). This injury is normally confined to the impact side of the fruit. The damaged flesh appears slightly straw-coloured. The bruised area leads to leakage of cell contents and provides openings for saprophytes and disease causing organisms. Mechanical injury to translucent fruits can lead to loss of fruit-cell content and loss of marketable fruit (Cappellini *et al*., 1988).

Bruising has been reported in 14% of inspected shipments arriving in New York (Cappellini *et al*., 1988). Translucent fruits are highly susceptible to bruising, and leaking of ruptured cellular contents is common in bruised translucent fruit. A bruising test based on absorption spectral changes in carotenoid extracted in alcohol has been developed, though it is not used commercially. The changes in caroteinods are associated with isomerization of the carotenoids at 466 and 425 nm, caused by the release of acids from bruised cells.

2.3.2 Respiration

Pineapple is a non-climacteric fruit and produces around 22 ml kg^{-1} h^{-1} of CO_2 at 23°C, with no dramatic respiratory change during ripening (Rohrbach *et al*., 2003). Ethylene production increase during ripening, but has no pronounced peak. Exogenous ethylene application stimulates only respiration rate when there is some chlorophyll remaining in the shell, and may also open the crown leaf stomata (Rohrbach *et al*., 2003). The absence of a peak in ethylene production and lack of a relationship of respiration with pronounced biochemical ripening changes support the conclusion of a non-climacteric pattern of development.

2.3.3 Postharvest degreening of shell

Treating mature green pineapple fruit with ethylene postharvest leads to shell degreening occurring in 40% of the time required if fruits are left on the plant. Postharvest use of ethephon has been tested in Australia (Smith and Fry, 1991). Treated fruits show uniform skin degreening, however, shelf life is shortened.

REFERENCES

Abbott, A. J. 1999. Quality measurement of fruit and vegetables. *Postharvest. Biol. Technol.* **15**, 207-225.

Akamine, E. K., Goo, T., Steepy, T., Greidanus, T. and Iwaoka, N. 1975. Control of endogenous brown spot of fresh pineapple in postharvest handling. *J. Amer. Soc. Hort. Sci.* **100**, 60-65.

APHIS, 1993. *Plant Protection and Quarantine Treatment Manual*. United States Department of Agriculture. Animal and Plant Health Inspection Service.

Biggs, M. S., Woodson, W. R. and Handa, A. K. 1988. Biochemical basis of high-temperature inhibition of ethylene biosynthesis in ripening tomato fruits. *Physiologia Plantarum*. **72**, 572-578.

Cappellini, R. A., Ceponis, M. J. and Lightner. G. W. 1988. Disorders in avocado, mango and pineapple shipments to New York Market, 1972-1985. *Plant Disease*, **72**, 270-273.

Couey H. M. 1989. Heat treatment for control of postharvest diseases and insect pests of fruits. *Hort Science* **24**(2), 198-202.

Dris, R., Niskanen, R. and Fallahi, E. 1999. Relationship between leaf and fruit minerals and fruit quality attributes of apples grown under northern conditions. *Journal of Plant Nutrition* **22**, 1839-1851.

Dull, G. G. 1971. The Pineapple: General. In: Holme, A. C. (pynt), *The Biochemistry of Fruits and Their Products*, Academic Press, London. 2, 303-324.

Federal Agriculture Marketing Authority (FAMA). 2003. *Menuju ke arah kualiti 'Malaysia's Best' nanas bagi nanas*. Lembaga pemasaran pertanian persekutuan Selangor.

Hallman, G.J. 1990. Vapour-heat treatment of carambolas infested with Caribbean fruit fly (Diptera:Tephritidae). *J. Econ. Entomol.*, **83**(6), 2340-2342.

Hove, H. 1998. Den. Med. Bull. 45:15. Cited from Ewaschuk, J. B., Zello, G. A., Naylor, J. M. and Brocks, D. R. 2002. Metabolic acidosis: Separation methods and biological relevance of organic acids and lactic acid enantiomers. *J. Chromotography Bul.*, **781**, 39-56

Iwanami, H., Yamada, M. and Sato, A. 2002. A great increase of soluble solids concentration by shallow concentric skin in Japanese persimmon. *Science Hort.*, **94**, 251-256.

Jowitt, R. 1974. The terminology of food texture. *Journal of Texture Studies*, **5**, 351-358.

Klien, J. D., Abbott, J. A., Basker, D., Conway, W. S., Fallik, E. and Lurie, S. 1998. Sensory evaluation of heated and calcium-treated fruits. *Acta Horticulturae*, **464**, 467-471.

Lurie, S. 1998 Postharvest heat treatments. *Postharvest Biology and Technology*, **14**, 257-269.

Lurie, S., Handros, A., Fallek, E. and Shapira, R. 1996. Reversible inhibition of tomato fruit gene expression at high temperature. *Plant Physiology*, **100**, 1207-1214.

Martinez-Tellez, M. A. and Lafuente, M. T. 1997. Effect of high temperature conditioning on ethylene, phenylalanine ammonia-lyase, peroxidase and polyphenol oxidase activities in flavedo of chilled 'Fortune' mandarin fruit. *Journal of Plant Physiology*, **150**, 674-678.

Pantastico, E. B., Chattpopadhyay, T. K and Subramanyam, H. 1995. Penyimpanan dan Operasi Penyimpanan Secara Komersial. Dalam: Pantastico, E. B., *Fisiologi Lepas Tuai: Pengendalian dan Pengunaan Buah-Buahan dan Sayur-Sayuran Tropika dan Subtropika*, DBP, Selangor, 316-342.

Paull, R. E. and Chen, N. J. 2000. Heat treatment and fruit ripening. *Postharvest Biology and Technology*, **21**, 21-37.

Poovaiah, B. W., Glenn, G. M. and Reddy, A. S. N. 1988. Calcium and fruit softening: physiology and biochemistry. *Horticultural Reviews*, **10**, 107-152.

Porat, R., Pavoncello, D., Peretz, J., Ben-Yehoshua, and Lurie, S. 2000. Effect of various heat treatment on the induction of cold tolerance and on the postharvest qualities of 'Star Ruby' grapefruit. *Postharvest Biology and Technology*, **18**, 159-166.

Raese, J. T. 1977. Response of young 'd' Anjou' pear trees to triazine and triazole herbicides and nitrogen. *Journal of the American Society for Horticulture Science*, **102**, 215-218.

Renato, M. P., William, N. and José, A. A. 2005. Liming and quality of guava fruit cultivated in Brazil. *Journal of Scientia Horticulturae*, **106**, 91-102.

Rohrbach, K. G., Leal, F. and d'Eeckenbrugge, G. C., 2003. History, distribution and World Productoin. In : Bartholomew, D. B., Paull, R. E., and Rohrbach, K. G. *The Pineapple : Botany, Production and Uses*. CABI Publishing, UK, 1-23.

Sharp, J.L., Gaffney, J.J, Moss, J.I., and Gould, W.P. 1991. Hot-air treatment device for quarantine research. *J. Econ. Entomol*. **84**(2), 520-527.

Shewfelt, R. L. 1999. What is quality? *Postharvest Biol. Technol*. **15**, 197-200.

Smith, R. C. and Fry, S. C. 1991. Endotransglycosylation of xyloglucans in plant cell suspension cultures. *Biochemical Journal*, **279**, 529-536.

Smock, R. M. 1977. Nomenclatur for internal storage disorders of apple. *HortScience*. **12**:306-308.

Teisson, C., Cobres, J. C., Martin-Prevel, P. and Marchal, J. 1979. Inernal browning of pineapples: III-Symptoms, IV – Biochemical approach. *Fruits* **33**(1), 315-338.

Ventura, A., DeJager, A., DePutter, H. and Roelofs, F. P. M. M. 1998. Non-destructive determination of soluble solids in apple fruit by near infrared spectroscopy (NIRS). *Postharv. Biol. Technol.*, **14**, 21-27.

Wijeratnam, R. S. W. and Hewajulige, I. G. N., 2005. Postharvest Hot Water Treatment for the Control of *Thieoviopsis* Black Rot of Pineapple. *Postharvest Biology and Technology*, **21**(1),1-6.

Wills. R. B., Lee, T. H., Graham, D., McGalsson, W. B. and Hall, E. G. 1989. Postharvest. *An introduction to the physiology and handling of fruits and vegetables*. Australia: N. S. W. University Press.

UNEP. 1994. *Montreal Protocol on substances that deplete the ozone layer*. United Nations Environment Programme. 1994. Report of the Methyl Bromide Technical Options Committee. 1995 Assessment. EPA 430/K94/029.