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Postharvest Handling of Jackfruit

Sutrisno[1], Ismi M. Edris[2] and Sugiyono[2]

ABSTRACT

Researches on jackfruit postharvest handling are not widely conducted, but there are several studies on storage condition, postharvest handling and packaging based on consumer's preference particularly on seeded or non-seeded jackfruit forms. Due to the objectives and the utilization of jackfruit, the fruit can be harvested at 3–8 months after juvenile. The storage of fresh jackfruit at 12–16°C can extend self life up to 4–6 weeks than storage at room temperature (25–27°C) with 4–5 days storage life. Coating with commercial soybean protein isolates at non-seeded fruit obtains higher sensory acceptance value than that seeded fruit either in normal gas composition storage or with stretch film packaging at the end of storage. Pre modified atmosphere packaging treatments including dipping the fruits in $CaCl_2$, ascorbic acid, citric acid, and sodium benzoate can prevent chilling injury. Vacuum drying at 60°C and 75°C in three different stages of maturity showed no visual differences in color which close to fresh jackfruit.

***Key words*:** Jackfruit, Postharvest, Fresh cut, Coating, Modified atmosphere packaging

1. INTRODUCTION

Harvested fruits are living entities since they still continue their performance of metabolic functions in the post harvest state. Quality deterioration of harvested fruits is the result of a combination of physiological, mechanical, microbiological and environmental factors and conditions (Palipane *et al.*, 2008). Improper packaging, rough handling and overloading of vehicles during transportation from production to consumption areas, account for approximately 20% of losses within the post-production chain (Palipane *et al.*, 2008). Postharvest handling researches of jackfruit are widely focusing on storage of fresh cut product with coating and Modified Atmosphere Packaging (MAP) treatments.

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Fruits and vegetables products can be served and consumed fresh, minimally processed or even cooked. Jackfruit is commonly sold to consumers as a fresh cut product because of the weight and size. Nowadays, many packaged minimally processed fruits have been produced whose packaging is not only to maintain fruit quality but also to improve the added value. Besides, in these recent years in Indonesia, fruits and vegetables crackers have became popular including jackfruit cracker. Saxena *et al.* (2008) said that jackfruit is commonly used as a starchy vegetable for curry preparation in unripe stage and as a dessert fruit when it is ripe.

2. HARVESTING

Harvested fruits and vegetables sustain metabolic processes which occurred before harvest to maintain physiological systems. The main factors which influence the development of deterioration of fresh fruits and vegetables are respiration, transpiration and ethylene production. In general, there is an inverse relationship between respiration rates and the postharvest life of fresh horticultural commodities (DeEll *et al.*, 2003). The quality of a crop at harvest can have a major effect on its postharvest life. The issues that influence product quality include obvious things such as harvest maturity, cultivar or variety, climate and soil in which it was grown, chemicals which have been applied to the crop and its water status. These numerous factors involved frequently interact (Thompson, 2003).

Harvest maturity is judged to be when the last leaf of the fruit stalk turns yellow; the spines become spaced and flattened; peel segments widen; the rind yields to moderate pressure when pressed with a finger; develops an aromatic odor and produces a hollow sound when tapped (Pantastico, 1975; Selvaraj *et al.*, 1989 *in* Thompson, 2003; Palipane *et al.*, 2008). Jackfruits can reach very large size (as much as 90 cm long, 50 cm wide, and 25 kg in weight) depending on the cultivar, production area, and the fruit load on the tree. Optimum harvest for long-distance transport is when the fruit changes color from green to yellowish-green and also harvested with a portion of the stalk attached to be used in its handling (Kader, 2009).

Determination of harvest maturity is closely associated with the objectives of harvesting and utilization. As a fresh fruit, it is harvested at ripe stage reaching physiologic maturity approximately 8 months (125–160 days), while a small jackfruit variety only takes 4–5 months (Suprapti, 2004). For use as vegetable, fruit is harvested at unripe stage approximately 3 months. Physiological characteristics at this stage are the bulb and the seed remain white in color. For making crackers, fruit used is over 80% with physiological maturity approximately 7–7.5 months but remain firm and develop stronger aromatic odor.

Harvesting must be conducted by careful handling to prevent fruit damage. Fruit should be harvested by cutting from the stalk using sharp knife. In a situation where the fruit is high up in the tree, a sack should be tied around the fruit with a rope, the stalk should be cut and the fruit should be gently lowered to the ground (Palipane *et al.*, 2008). After harvesting, in order to remove dirt, latex and any field contamination the fruits are washed using chlorinated water in 100 ppm (ICUC, 2004). Latex remaining on the skin can cause discoloration of the skin.

3. STORAGE AND RIPENING

Postharvest handling of jackfruit can be conducted in two forms, both in fresh and fresh cut which are conditioned at different temperature and relative humidity according to physiological changes. Kader (1992) *in* Sugema (2002) and Selvaraj *et al.* (1989) *in* Thompson (2003) stated that jackfruit is classified into climacteric fruit with CO_2 production rate at 5°C is 10–20 $mg.kg^{-1}.h^{-1}$. Kader (2009) defined pre climacteric phase is 20-25 ml $CO_2.kg^{-1}.h^{-1}$ and climacteric peak is 50–55 ml CO_2 $kg^{-1}.h^{-1}$ at 20°C storage temperature.

Freshly harvested ripe fruits can be stored for 4 to 5 days at 23–35°C; 2 to 6 weeks at 11–13°C with relative humidity of 85–95%. Jackfruits stored at temperature below 12°C before transfer to higher temperature exhibit chilling injury symptoms including dark-brown discoloration of the skin, pulp browning, and deterioration in flavor and increase susceptibility to decay (ICUC, 2004). Kader (2009) also stated that optimum temperature for jackfruit storage is at 12–14°C with potential postharvest life is 2 to 4 weeks. In fresh cut form, jackfruit bulbs are packed in polythene bags which are heat-sealed or in polypropylene containers with lids that can be kept at 2°C for 3 weeks. But when in pre-processed pulp form, it can be kept for more than one year when stored at –20 to –22°C using polythene bags packing or in plastic containers (ICUC, 2004). In order to avoid deterioration during distribution process of packed jackfruit bulbs, fruits are maintained at chilled temperature (2°C).

Prior to the pre- or minimal processing, jackfruits should be ripened fully to achieve optimum aroma, sweetness, taste and eating quality. Mature jackfruits stored at 24–27°C will ripen in 3 to 4 days. However, uneven ripening is a major problem in the natural ripening process, especially for large sized fruits. Exposing fruits to 50 ppm ethylene for 24 h at 25°C and followed by ripening for 3 to 4 days yields more uniform ripened fruits (ICUC, 2004). Kader (2009) stated that exposing fruits to 100 ppm ethylene for 24 h accelerates ripening of mature-green jackfruits at 20–25°C. During ripening, the starch is converted into sugars, the pulp color changes from pale white or light yellow to golden yellow, and the fruit aroma becomes intense.

Traditionally, storage and ripening method for optimum maturity can be conducted by stabbing the fruit base up to the pith using sharp bamboo or wood. During storage, fruits are arranged vertically with stabbed side facing above until the optimum maturity is obtained. Fruits which are close to maturity do not need to be stabbed; it will ripen within 1–2 days. Proper use of Modified Atmosphere (MA) can retard senescence (ripening), slowing down respiration and ethylene production rates, softening and compositional changes (Kader *et al.*, 2003). Modified Atmosphere Packaging (MAP) can maintain reduction of water loss; improve sanitation of the commodity and possible exclusion of light. The term of MA refers to atmospheres in which the gas composition surrounding the commodity is different from air (*i.e.*, 78.08% N_2, 20.95% O_2, 0.93% argon and 0.03% CO_2).

4. COATING

Coating treatment is to improve fruit appearance such as gloss, delay deterioration, control weight loss and to carry postharvest fungicides with the end effect is to extend storage life of the fruit (Thompson, 2003). Utilization of edible coating increases as increasing number of people become aware of food hygiene and food safety. Edible coating is defined as a thin layer of edible material form as a film on the surface of the fruits and vegetables that can restrict loss of water, oxygen and other soluble material of food (Ghasemzadeh *et al.*, 2008). The application of edible coating to extend shelf-life and maintain food safety is widely used in fresh cut apple, kiwi, pear, avocado, melon, apricot and garlic.

Components of edible films and coating can be divided into three categories: hydrocolloids, lipids and composites. Hydrocolloids include proteins and polysaccharides, such as starch, alginate, cellulose derivatives, chitosan and agar. Lipids include waxes, acylglycerols, and fatty acids (Min & Krochta 2005 *in* McHugh *et al.*, 2009). Composites contain combinations of both hydrocolloid components and lipids. The choice of formulation for edible film or coating is largely dependant on its desired function-such as biodegradability, edibility, aesthetic appearance and good barrier properties against oxygen- which varies based on the composition of the film (Cha & Chinnan 2004 *in* McHugh *et al.*, 2009).

5. MINIMAL PROCESSING

In general, fruits and vegetables should be processed so as to make it easier for utilization, storage and distribution. Jackfruit being a large fruit requires wide space in containers and therefore the economic value is affected if it has to be transported. Lee *et al.* (2003) and Saxena *et al.* (2008) stated that jackfruit bulbs in pre-cut form can provide convenience for consumers and an appropriate post-harvest technology for shelf-life extension may facilitate its transportation from production site to remote location in a fresh-like state.

Fresh-cut produce remains at the top of the list of products meeting the needs of today's busy consumers among the growth of new products and changing trends in today's food marketplace (Garrett, 2002). Fresh- cut produce sales have increased spectacularly during the last decade in Europe and USA, mainly due to changes in consumer demand but also to improvements in the cool chain and processing technology, including Modified Atmosphere Packaging (MAP) (Gil *et al.*, 2001).

Minimal processing includes cleaning, cutting, grading, washing, sorting, peeling, slicing, chopping, packaging or processing by any means short of denaturing the fruit tissues (Lee *et al.*, 2003; Techawongstien, 2006). In particular fruits, the removal of seed or not is based on consumer's preference and the technology availability to maintain fruit quality.

6. JACKFRUIT POSTHARVEST RESEARCH

Researches on jackfruit postharvest handling are not widely conducted, but there are several studies on storage condition, postharvest handling and packaging based on consumer's preference particularly on seeded or non-seeded jackfruit forms. Sudiari (1997) and Sugema (2002) studied quality changes experiment on seeded and non-seeded jackfruit using MAP at the 5°C, 10°C and ambient temperature and also in normal gas composition. Frozen storage at –30°C and –5°C was carried out to study quality changes of minimally processed jackfruits (Pikni *et al.*, 2004).

Application of edible coating on jackfruit storage uses protein and starch as coating solution base. Commercial soybean protein isolates (Sugema, 2002) and commercial casein calcium is used as protein base while commercial alginate sodium is used as a starch base (Pikni *et al.*, 2004). This chapter will also report dipping treatment into $CaCl_2$, ascorbic acid, citric acid and sodium benzoate solution followed by MAP (Daryanti, 2003; Setyaningsih, 2003; Saxena *et al.*, 2008; Partha *et al.*, 2009). Research on jackfruit processing is carried out by applying vacuum drying technology (Taqi, 1994).

6.1. Storage in Normal Gas Composition

6.1.1. *The Effect of Minimal Processing and Coating to Respiration Rate during Storage*

The average production rate of CO_2 of non-seeded coated fruit is 1.3-fold, 0.9-fold and 0.7-fold higher than that seeded non-coated fruit at 5°C, 10°C and ambient temperature, respectively (Fig. 19.1). Fig. 19.2 shows the production rate of CO_2 of non-seeded coated fruits. Climacteric peak at 10°C storage occurred at h 150th. The jackfruit bulbs after separation from the fruit immediately showed an enhanced respiration and further size reduction after pitting caused further acceleration in the respiration to an extent of 70 ± 1.5 mg CO_2.kg^{-1}.h^{-1} at 6°C in control samples (Saxena *et al.*, 2008).

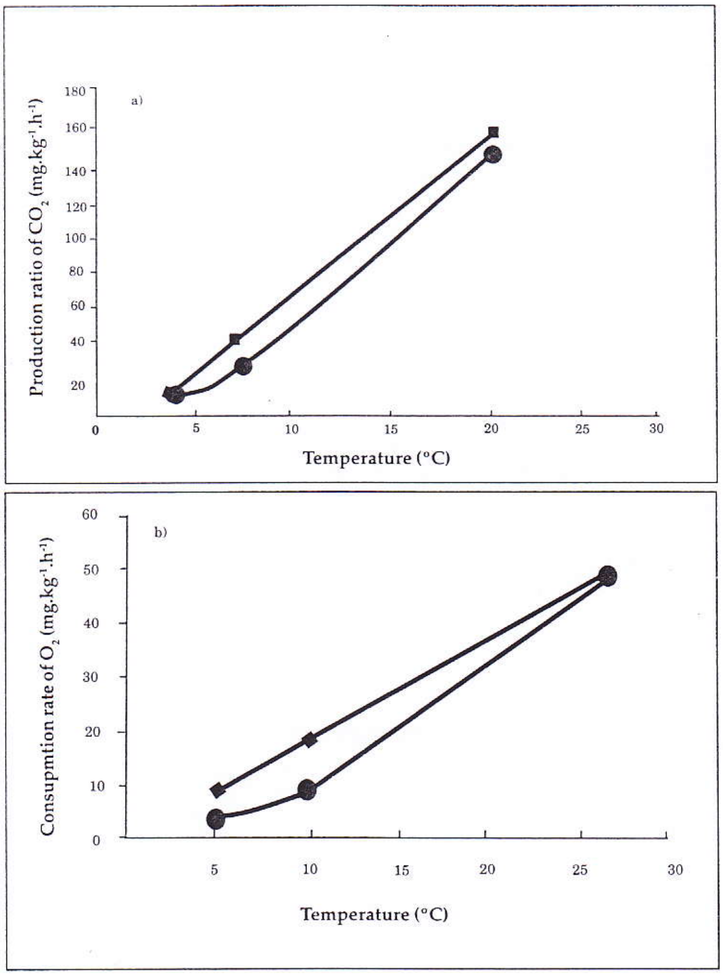

Fig. 19.1: Average respiration rate of fresh cut jackfruit bulbs (Sudiari, 1997; Sugema, 2002); (a) production of CO_2 symbols show (•) seeded non-coated fruits; (♦) non-seeded coated fruits. (b) consumption of O_2, symbols show (•) seeded non-coated fruits; (♦) non-seeded coated fruits

For non-seeded coated fruits, the average consumption of O_2 at ambient temperature, 10°C and 5°C are 48.15 mg. $kg^{-1}.h^{-1}$, 18.23 mg. $kg^{-1}.h^{-1}$ and 9.27 mg. $kg^{-1}.h^{-1}$ while the average production of CO_2 are 161.01 mg. $kg^{-1}.h^{-1}$, 45.91 mg. $kg^{-1}.h^{-1}$ and 15.37 mg.$kg^{-1}.h^{-1}$, respectively, with Respiration Quotient (RQ) was higher than 1 (Sugema, 2002). The climacteric peak wasn't identified until the last day of storage since the production rate of CO_2 increased constantly. The last day of storage at 5°C and 10°C temperature is at h 315th and 123th respectively.

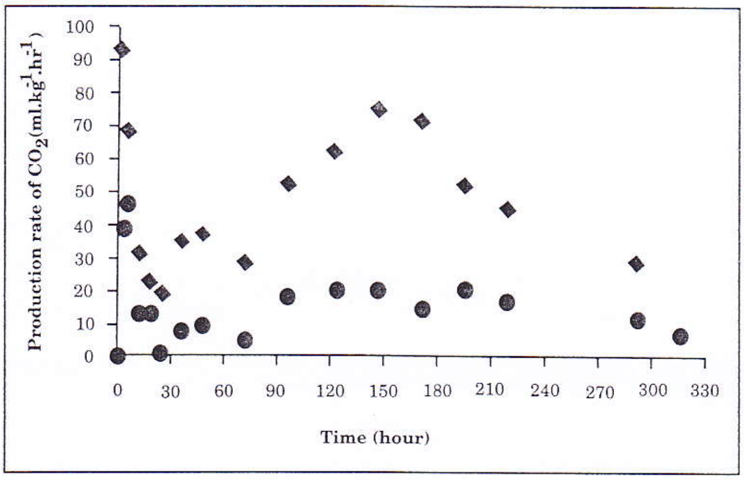

Fig. 19.2: The production rate of CO_2 of non-seeded coated fruit during storage (Sugema, 2002). Symbols show (•) at 5°C storage temperature; (♦) at 10°C storage temperature

Treatment of seeded non-coated fruits produced the average production of CO_2 is 12.035 mg.$kg^{-1}.h^{-1}$, 30.398 mg.$kg^{-1}.h^{-1}$, 149.604 mg.$kg^{-1}.h^{-1}$ with RQ 0.26, 1.09 and 2.83 for each 5°C, 10°C and ambient temperature storage, respectively (Sudiari, 1997). It also said that the presence of mold and senescence induced after 190 h and 45 h at 10°C and ambient storage temperature, respectively. While at 5°C, shelf-life extended up to 216 h. Based on the initial time of visually senescence occurrence, it was obtained that seeded non-coated fruits had 4 folds shelf life longer than non-seeded coated fruits at 10°C storage.

6.1.2. *The Effect of Coating to Quality Changes during Storage*

The changes of firmness, L value, b* value and weight loss at non-seeded coated fruits showed higher than that at seeded non-coated fruit during storage at 5°C and 10°C in normal gas composition. The changes of non-seeded coated fruits is 4.35-fold, 1.07-fold, 1.11-fold and 2.23% at 5°C on day 6th, while at 10°C on day 4th is 2.7-fold, 1.12-fold, 1.23-fold and 1.7%, respectively. The value of each quality properties in the end of storage is 0.31 kg.mm^{-1}, 72.93, 34.52 and 2.23% at 5°C while at 10°C is 0.5 kg.mm^{-1}, 69.57, 31.43 and 2.61%.

For seeded non-coated fruits, the changes is 1.37-fold, 1.06-fold, 1.04-fold and 1.17% at 5°C on day 4th, while at 10°C on day 4th is 1.92-fold, 1.19-fold, 1-fold and 2.61%. The value of each quality properties in the end of storage is 10.64 N.cm^{-2}, 64.43, 31.38 and 1.17% at 5°C and 6.33 N.cm^{-2}, 57.89, 32.86 and 2.61% at 10°C. Those showed that higher changes also appeared at higher storage temperature. High differences occurred in L value of color properties of both processed product forms at two storage temperatures.

Lee *et al.* (2003) stated that the application of edible coating effectively retarded enzymatic browning on minimally processed apples during storage at 3°C for 2 weeks relative to non-coated apples. Whey active protein coating treatments followed by ascorbic acid as anti browning agent are effective on maintenance of firmness. Jackfruit minimally processed storage with coating material using calcium caseinat, sodium alginate and non-coating produced weight loss 12%; 11.9% and 15.9% at 4°C on day 30. While at –5°C and 10°C, weight loss is 6.4% and 5.6%; 6.3% and 4.2%; 10.2% and 8.6% (Pikni *et al.*, 2004).

A consumers subjectivity of the initial acceptance of fruit quality with acceptance scale 1–5 (dislike–like) showed that panelists prefer seeded non-coated fruits than non-seeded coated fruits (Fig. 19.3). At the end of storage (day 6th), the acceptance score of non-seeded coated fruits is higher than seeded non-coated fruit but both are no longer liked by panelists. Lee *et al.* (2003) reported that the application of carrageenan and whey protein concentrate

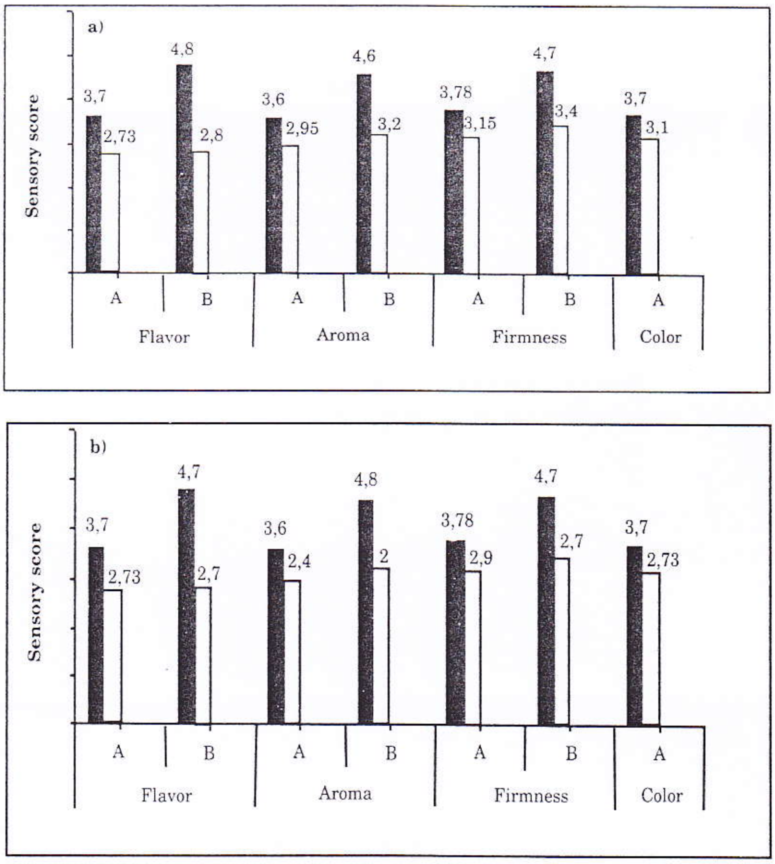

Fig. 19.3: Panelists acceptance value of sensory attributes of minimally processed jackfruit at different storage temperature (Sudiari, 1997; Sugema, 2002). a) at 5°C storage temperature, symbols show (A) non-seeded coated fruits; (B) seeded non-coated fruits; (■) day 0; (□) day 6th and (b) at 10°C storage temperature, symbols show (A) non-seeded coated fruits; (B) seeded non-coated fruits; (■) day 0; (□) day 4th

powder together with anti-browning agent treatment resulted in higher sensory score than non-coated apples for all quality factors tested.

Based on ethylene production observation showed that dipping treatment of non-seeded coated fruits into $CaCl_2$ for 15 min at 50°C followed by white *koro* (*Phaseolus lunatus*, L.) edible coating treatment at 4°C for 3 d could inhibit chilling injury (Partha *et al.*, 2009). Without dipping treatment into $CaCl_2$ and coating, ethylene production and texture are 8-11 $nl.kg^{-1}.h^{-1}$ and 5.9 $N.m^{-2}$. The lowest ethylene production occurred at coated fruits with dipping into $CaCl_2$ 1.5%; $CaCl_2$ 2% and $CaCl_2$ 1%. The value is 2–0.2 $nl.kg^{-1}.h^{-1}$, 4–0.2 $nl.kg^{-1}.h^{-1}$, 6–4 $nl.kg^{-1}.h^{-1}$, respectively. Dipping treatment followed by coating could also maintain texture at highest level, total acid at the lowest level and proportion of sugar reduction better than fruit quality with non-dipping and non-coating treatment. The lowest level of texture and sugar reduction was obtained by $CaCl_2$ dipping treatment at 2%, 1.5% and 1%, respectively, with coating (Partha *et al.*, 2009).

Positive response to $CaCl_2$ is caused by cross bond between ions Ca with pectin compound arising more in peeled jackfruit. Thus makes more resistant to degradation or hydrolysis leading to bulb softening. Cell texture becomes more solid as Ion Ca has capability to bond with pectin to form calcium pectate on cell wall and middle lamella (Guzman *et al.*, 2000 in Partha *et al.*, 2009). While heating at 50°C–70°C could trigger pectin methyl esterase (PME) enzyme activity to demethylate pectin compound so that more provided carboxyl to bond with ion calcium (Daryanti *et al.*, 2004 *in* Partha *et al.*, 2009). An addition of calcium chloride to an acidic dipping solution could minimize the softening of apple slices (Lee *et al.*, 2003).

Soaking in 1.5% of $CaCl_2$ for 15 min resulted in the best textural retention of thawed jackfruit. The increase of Calcium concentration in soaking medium increases absorption and bonds Calcium in the fruit. Although the increase of Calcium improves thawed fruit texture of the quick frozen fruits, it is not the case in slow freezing treatments (Setyaningsih, 2003).

The PME activity was optimum at 60°C. On the other hand, the optimum temperature of calcium treatment for jackfruit was 50°C since the decrease in metoxyl groups of jackfruit mostly occurred at this temperature; and the firmness, concentration of total calcium and bound calcium were maximum. The treatment of jackfruit with 1% $CaCl_2$ dipped at 40 and 50°C for 10 min resulted in an inhibition of the decrease in firmness and quality of ready-to-eat jackfruit. There were no significant differences in color, taste and odor after calcium treatment. Texture and the acceptability of jackfruit treated with calcium dip and mild heat were better than control (Daryanti, 2003).

6.2. Modified Atmosphere Packaging

Sudiari (1997) and Sugema (2002) reported that optimum gas composition at 5°C storage for non-seeded coated and seeded non-coated jackfruit is 6–8% O_2; 8–10% CO_2 and 4–7% O_2; 10–12% CO_2, respectively. Differences in susceptibility to elevated CO_2 and/or reduced O_2 levels among commodities, or among cultivars of a given commodity, may be due to structural (anatomical) differences rather than metabolic differences. Natural barriers in the commodity may affect the diffusion coefficients of CO_2 or O_2 (*e.g.*, cuticula resistance, number of stomata and lenticels). Gas diffusion across these barriers and tissue respiration combine to significantly alter gas composition within commodities (Kader *et al.*, 2003).

Gas composition at 6–8% O_2 and 8–10% CO_2 at 5°C for non-seeded coated fruit produced the lowest of weight loss 0.87%, the highest of average firmness 0.73 kg.mm^{-1}, the lowest deterioration of lightness from 77.88 to 74.56, the lowest of average yellow color value 33.50, the highest of average Total Soluble Solid (TSS) 32.29%, the highest of vitamin C 27.35 mg. 100g^{-1} and the highest of color value acceptance 3.29 among others gas composition and storage temperatures. Gas composition at 4–7% O_2 and 10–12% CO_2 at 5°C for seeded non-coated fruit produced the lowest of weight loss by 2.03% and could maintain firmness of samples from 14.61 N.cm^{-2} to 5.12 N.cm^{-2} on day 16th which still was accepted by panelist on day 10th among others gas compositions and storage temperatures.

Application of Stretch Film (SF) and White Stretch Film (WSF) packaging materials upon non-seeded coated fruits and seeded non-coated fruits showed that condition of optimum MA was not obtained (Fig. 19.4). Sudiari (1997) and Zagory (1990) *in* Sugema (2002) stated that packaged product quantity affects equilibrium gas concentration, but produced O_2 and CO_2 concentration cannot always be predicted from permeability data and product respiration rate. There is linearity between packaged product weight with O_2 and CO_2 concentration inside package, whereas heavier of product weight produce higher CO_2 concentration, while O_2 concentration decreases proportionally.

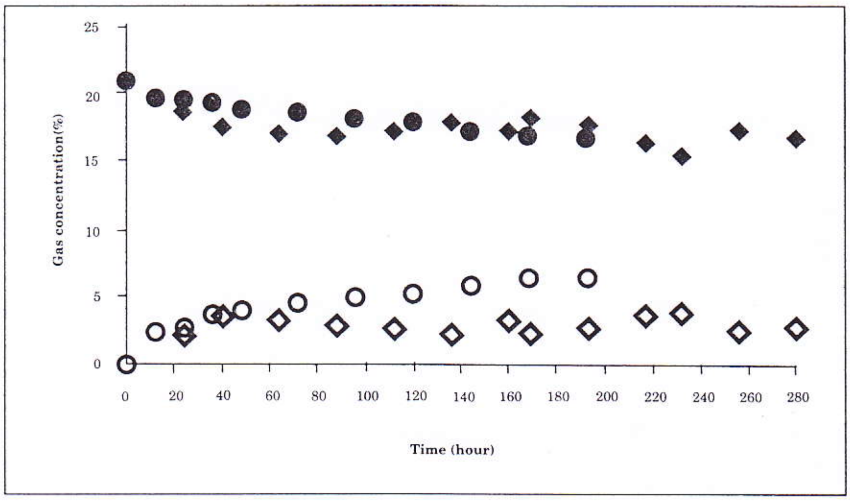

Fig. 19.4: Gas concentration of minimally processed jackfruit with stretch film packaging (Sudiari, 1997; Sugema, 2002). Full symbols show O_2 concentration at (♦) non-seeded coated fruits; (•) seeded non-coated fruits. Empty symbols show CO_2 concentration at (◇) non-seeded coated fruits; (O) seeded non-coated fruits

The 5°C storage, the weight loss of non-seeded coated fruits with SF packaging is higher than seeded non-coated fruits with 3.34% on day 12th and 3.21% on day 11th, respectively. Higher percentage of weight loss occurred on WSF packaging with 3.41% and 4.11%, respectively. The firmness on seeded non-coated fruit decreased 65.8% and 72.7% to 4.81

$N.cm^{-2}$ and 3.84 $N.cm^{-2}$ on day 11th for SF and WSF packaging, respectively. While on non-seeded coated fruits on day 12th, the firmness decreased 51.9% and 63.9% to 3.34 $kg.mm^{-1}$ and 3.91 $kg.mm^{-1}$ respectively.

Color observation using Chromamometre on non-seeded coated fruits showed that L and b* value on SF packaging are lower than WSF packaging, those are 63.53 and 28.03; 68.30 and 29.82 for each packaging material, respectively. The non-seeded coated fruits with SF packaging, SSC and vitamin C measurement at the last day of storage (day 12th) are 23.83% and 21.78% whereas each quality properties above increased 1.6-fold and decreased 1.6-fold also from the quality value prior to storage treatments. For WSF packaging on day 12th, the SSC increased 1.5-fold to 22.40% while vitamin C decreased 1.05-fold to 21.06%. The Duncan test 5% showed that weight loss and SSC in different packaging material showed significant difference. While firmness, L value; b* value and vitamin C resulted non different effect between both packaging materials. Pikni *et al.* (2004) reported that application of coating material using sodium alginate and calcium casein on minimally processed jackfruit result non different effect.

Panelist preference regarding non-seeded coated and seeded coated fresh cut forms was determined using sensory testing including flavor, aroma, firmness and color with range from 1 to 5 (dislike - like; 3 is neutral). In the early storage, seeded non-coated fruits showed higher sensory acceptance than non-seeded coated fruits in terms of flavor, aroma and firmness. While in the last day of storage, seeded non-coated fruits were no longer liked on day 11th in terms of flavor, aroma and firmness. On the other hand, at the same day, non-seeded coated fruits were still on neutral acceptance in terms of aroma, firmness and color (Fig. 19.5).

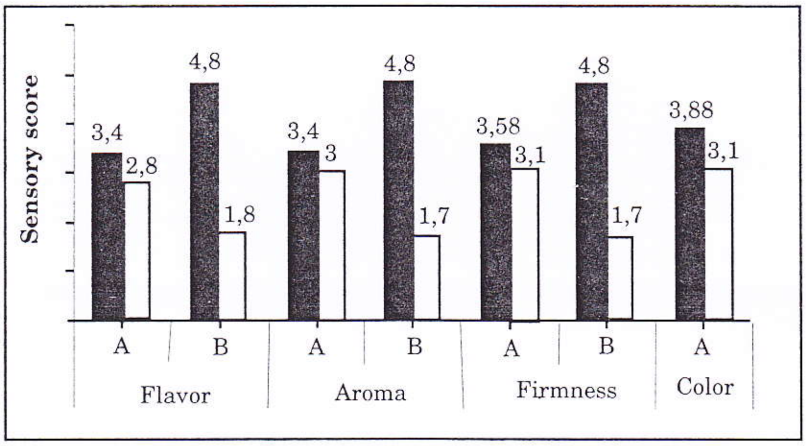

Fig. 19.5: The quality acceptance value on minimally processed jackfruit with Stretch Film packaging (Sudiari, 1997; Sugema, 2002). Full symbol show (■) day 0th for (A) non-seeded coated fruits and for (B) seeded non-coated fruits. Empty symbol show (□) day 12th for (A) non-seeded coated fruits and day 11th for (B) seeded non-coated fruits

Saxena *et al.*, (2008) reported that gas composition adjustment 3 kPa O_2 + 5 kPa CO_2 (with balance of N_2) mixed with dip pre-treatment consisted $CaCl_2$ (1% w/v); ascorbic acid (0.02% w/v); citric acid (1% w/v) and sodium benzoate (0.45% w/v) along with different MAP was found effective in establishing optimum O_2 and CO_2 concentrations, reducing the respiration rate, ethylene production and electrolyte leakage, restricting changes in TSS/titrable acid (TA) ratio and maintaining sensory attributes of the samples compared to control (non-dip) samples kept under same MAP conditions at 6°C. Dip pretreated sample packed in 3 kPa O_2 + 5 kPa CO_2 gas mixture flushed polyethylene (PE) bags was found to preserve the initial firmness value of the jackfruit bulbs (about 44 N) with a minor loss of around 7% after 35 d compared to significantly higher loss in the control samples packaged in the same MAP. Dipped samples also maintained a significantly higher lightness (L value) and color intensity (chrome) of jackfruit bulb surface compared to the control fruit. Polyethylene Terephthalate (PET) jar with silicon membrane window was also found to be capable of achieving equilibrate atmosphere more efficiently than PE bags which in turns maintained more stable gas composition and minimized physiological and quality changes. On the basis of sensory quality attributes, the shelf-life of pre-treated jackfruit bulbs packaged in gas mixture flushed PE bags, in PET jars with silicon membrane window and in PE bag were 35, 31 and 27 days, respectively.

6.3. Vacuum Drying of Jackfruit

Vacuum drying at 60°C and 75°C in three different stages of maturity showed no visual differences in color which close to fresh jackfruit. Browning symptoms only appeared on some samples in chocolate thin line along the bulb edge. Obvious difference was on the fruit weight dried at 60°C which smaller and looked more compact. Drying at the 75°C and 60°C needed about 10 h and 18 h to get product reaching constant weight. Final water content is 0.6% db and 1.1% db with average drying rate is 0.7 g water. 100 g^{-1} dry weight.min and 0.4 g water. 100 g^{-1} dry weight. min, respectively (Taqi, 1994) (Fig. 19.6).

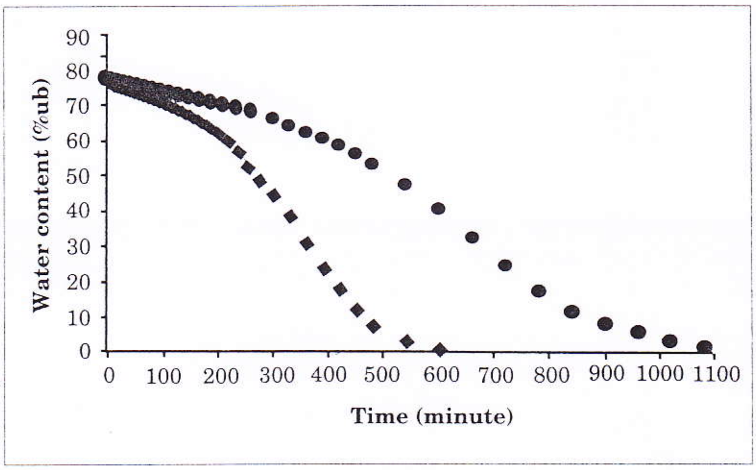

Fig. 19.6: The changes of water content during drying of minimally processed jackfruit (Taqi, 1994). Symbols show (♦) 70°C drying temperature and (•) 60°C drying temperature

A smaller size obtained from 60°C drying was because of the occurrence of constant drying rate when fruit was still soft and wet and then caused loss of turgor of cell wall where the presence of internal pressure will release water. Water release causes net wrinkling. Drying temperature affects the amount of driving force of evaporation and diffusion coefficient number (Brooker *et al.*, 1974; Thahir, 1986; Priyanto, 1991 *in* Taqi, 1994). At higher temperature, temperature driving force; pressure driving force and diffusion coefficient number increased that lead to increasing of evaporation volume and increasing of drying rate as well.

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