

Influence of Sealing Film Lid on the Quality of Packaged Fresh-cut Mangosteen

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ABSTRACT

Three types of film lid (OPP/LLDPE, PET and LDPE) were used to seal rigid trays containing fresh-cut mangosteen to examine the influence of the films on the gas composition of the headspace and the quality of the product during storage. LDPE film, which has the highest OTR and CTR (2,795 and 10,500 cm³/m² day, respectively) (analyzed by the Department of Science Service), showed the highest O₂, C₂H₄, ethanol and acetaldehyde accumulation and lowest residual CO₂ in the package. Furthermore, firmness and weight losses were higher than those of OPP/LLDPE and PET films. Film type did not affect the microbial growth of fresh-cut mangosteen during storage. Overall visual quality (OVQ) was influenced by type of films. Samples packed in PP trays sealed with OPP/LLDPE and PET films maintained higher sensory quality than those packaged in LDPE film under the same storage conditions.

Keywords: Fresh-cut mangosteen, Sealing film, Quality changes, In-package atmospheric changes

INTRODUCTION

Mangosteen is considered one of the finest tasting tropical fruits and generally known as “the queen of fruit”. It has a relatively short shelf life, limited to 5-7 days at 25-35°C. The rapid loss in quality (hardening of the rind and white flesh becoming light brown) occurs during storage at high temperature and low relative humidity (Diczbalis, 2009). Hence, to facilitate distribution in markets with strong demand, the producer may prepare in fresh-cut form and pack in modified atmosphere packaging (MAP). MAP of fresh produce relies on the modification of the atmosphere inside the package achieved by the natural interplay between two processes, the respiration of the commodity and the permeability of the sealing films (Mangaraj et al., 2009). The right package with sealing film

can create conditions in the package that can delay maturation and aging of the commodity. It is therefore possible to improve the shelf life and quality of fresh-cut produce.

Respiration of the fresh-cut fruit depends on the gas composition in the package. At low oxygen concentrations, respiration is usually slower than at high oxygen concentrations, slowing the aging process and extending the shelf life. However, if the O₂ drops below critical levels, respiration ceases, resulting in biochemical changes that lessen quality. Sealing film for fruit and vegetables are never impervious to oxygen, carbon dioxide and water vapor. Even though the packaging film is welded quite tight, these gasses can transfer through the film. The rate of water or gas transmission depends on the type, thickness and surface area of the film and the temperature/pressure differences of the gasses on each side of film (Al-Ati and Hotchkiss, 2003). Selection of a suitable film requires careful consideration of the gas transmission rate. For rapid respiring products, such as fresh-cut mangosteen, it is necessary to select films that ensure oxygen is not depleted inside the package to avoid changes in quality.

Although the consumption of fresh-cut mangosteen has increased, very little information exists on its quality retention in packaged, fresh-cut form. The objective of this research was to evaluate the influence of various sealing film lids on package atmosphere and the quality and shelf life of fresh-cut mangosteen.

MATERIALS AND METHODS

Sample preparation

Mangosteen fruits (*Garcinia mangostana*, L.) at stage 3 (reddish pink) according to the scale of Palapol et al. (2008) with a mean weight of 120±5 g were obtained from a local orchard. Damaged or diseased fruits were discarded. The fruits were treated with 40 ppm 1-MCP (1-methylcyclopropane) for 12 h at 25°C, and then transported to the laboratory. The fruits were processed into fresh-cut form in an isolated and cleaned minimal-processing room at 30°C. The entire white arils were removed and immediately placed in cold water (10°C). After 5 min, the arils were dried with a handheld blower, approximately 200 g were packed in polypropylene (PP) trays (11.5×17.5×4.5 cm) and the trays were sealed with either specified OPP/LLDPE (laminated film of oriented polypropylene and linear low density polyethylene), PET (polyethylene terephthalate) or LDPE (low density polyethylene) films with a silicone sealant. The water, O₂ and CO₂ transmission rates of the films (analyzed by Department of Science Service in 2010) are 0.29, 0.94 and 8.60 (g/m² day), 1,160, 116 and 2,795 (cm³/m² day) and 3,150, 375 and 10,500 (cm³/m² day) for OPP/LLDPE, PET and LDPE films, respectively. The trays were stored at 5°C with 85% RH in a refrigerator. Three replicates, with two trays per replicate, were analyzed at 0, 3, 6, 9 and 12 days of storage.

Measurement of gas concentrations in the packages

Changes in the headspace gases (O₂, CO₂ and C₂H₄) concentrations were measured at 3-day intervals by withdrawing air samples (1 ml) through a septum

using a gas-tight syringe. The sample gas was injected into a gas chromatograph (GC) (AutoSystem XL, The Perkin Elmer Corporation, USA) equipped with a thermal conductivity detector (TCD). The oven and detector temperatures were 60 and 150°C, respectively, with helium as the carrier gas. C₂H₄ production was measured with the same gas chromatograph, but equipped with a flame ionization detector (FID) on the 1 ml gas sample. The oven, injector and detector temperatures were 40, 120 and 180°C, respectively, with helium as the carrier gas. Gas concentrations were expressed as %O₂, %CO₂ and ppm C₂H₄.

Physical changes

Firmness was evaluated by using a TA-XT2i texture analyzer (Stable Micro Systems, England) with a 25 kg load cell, equipped with a 2 mm diameter cylinder stainless steel probe (P/2). The measurements of maximum force (g/mm²) obtained from the penetration of the probe at speed 2.0 mm/s into the fruit 3 mm were recorded as firmness. Weight loss was determined from the difference between the weight of the sample at the beginning and end of the storage period. Color was measured by using a colorimeter (Miniscan 45/0-L, Hunter Associates Laboratory, Inc., USA) with illuminant D/65/10° according to CIE L* (lightness), a* (green to red) and b* (blue to yellow) values. Numerical values of a* and b* were converted into chroma [$C = (a^{*2} + b^{*2})^{1/2}$] and hue values [$^{\circ}H = \tan^{-1} b^{*}/a^{*}$] (Francis, 1980).

Chemical analyses

Acetaldehyde and ethanol contents were measured using the method of Gonzalez-Aguilar et al. (2004). In brief, tissue (5 g) was placed in amber colored bottles with 60 ml capacity and placed in a 65°C water-bath for 15 min. Headspace gas samples of 1 ml were injected into a gas chromatograph (AutoSystem XL, The Perkin Elmer Corporation, USA) equipped with a 60 m × 0.325 mm × 0.25 μm DB-WAX column (J&W Scientific, Folsom, California). The oven, injector and detector temperatures were 60, 250 and 250°C, respectively, with helium as the carrier gas. Retention times and standard curves of acetaldehyde and ethanol in water solutions were used for peak identification and quantification. Acetaldehyde and ethanol contents were expressed as μl/kg fruit.

Microbiological analyses

Microbial determinations were carried out using standard methods (BAM, 2001). Twenty-five grams of sample were diluted in 225 ml of sterile buffered Butterfield's Phosphate and homogenized for 2 min at normal speed using a Stomacher (Model 400 Circulator, Seward, Norfolk, England). Serial dilutions of the suspension were made and analyzed for total viable count (TVC), yeasts and molds and *E. coli* by spread plate methods on plate count agar, Sabouraud's dextrose agar and eosin methylene blue agar, respectively. Another 25 g were diluted in 225 ml of buffered peptone water for the detection of Salmonella. Plates were incubated at 35°C for 24 h for bacteria and at 30°C for 48 h for yeasts and molds.

Sensory evaluation

Twenty semi-trained panelists (who were once trained using the prepared fresh-cut mangosteen with different appearances) were asked to rate the samples for browning, off-odor, texture, wateriness and overall visual quality (OVQ) of treated fresh-cut mangosteen against reference samples using methods described by Gomez-Lopez et al. (2008) with some modifications. The 5-point ratings were assigned as follows: (5) not original, (4) slightly original, (3) moderately original, (2) very original and (1) extremely original. The reference samples were prepared from untreated fresh-cut fruit immediately after cutting as a good sample and from an untreated fresh-cut after 1 day at room temperature as a bad sample. Each treatment consisted of six fresh-cut fruit served on a white plastic plate at room temperature (25°C) and the same samples were evaluated by each panelist within 1 h. Scores greater than 3 were considered undesirable.

Statistical analyses

All data were subjected to analysis of variance (ANOVA) according to the experimental design in CRD and mean differences estimated by Duncan's multiple range test (DMRT) using SPSS Statistics Standard software (IBM Corp, Sommers, NY, USA). Differences at $p < 0.05$ were considered significant.

RESULTS

In-package atmospheric changes

The concentrations of O₂ in PP trays of fresh-cut mangosteen sealed with all three films were 16.8-17.9 % at the beginning of storage and decreased rapidly thereafter (Table 1). O₂ concentrations remained higher in trays sealed with LDPE than PET and OPP/LLDPE film ($p < 0.05$). There was no significant difference in O₂ concentrations in trays sealed with PET and OPP/LLDPE films ($p > 0.05$) after 12 days of storage. The higher O₂ transmission rate of LDPE film (2,795 cm³/m² day) was likely responsible for the difference. CO₂ concentrations increased throughout the storage in PP trays sealed with all films, but gradually peaked at day 9-12 in trays sealed with PET film. This is again due to the lower CO₂ transmission rate of PET film than OPP/LLDPE and LDPE, causing higher CO₂ accumulation in the package.

Table 1. Changes in O₂ and CO₂ concentration* in the headspace of fresh-cut mangosteen in PP trays sealed with three different films during storage.

Gas content (%)	Film type	Time (days)				
		0	3	6	9	12
O ₂	OPP/LLDPE	17.97±0.25ns	14.00±0.92ns	9.40±4.00a	6.53±0.42a	3.77±0.25a
	PET	16.80±0.20ns	13.40±0.26ns	8.40±0.53a	6.30±0.56a	3.67±0.42a
	LDPE	17.63±0.40ns	14.73±0.23ns	11.47±0.35b	9.23±0.55b	6.00±2.00b
CO ₂	OPP/LLDPE	1.90±0.00 ns	6.41±0.52 ns	12.11±0.72ns	14.73±0.44a	17.78±0.48b
	PET	1.54±0.05 ns	7.81±0.21 ns	14.00±1.00ns	16.26±0.22b	17.99±0.19b
	LDPE	1.82±0.00 ns	7.54±0.33 ns	11.53±0.47ns	12.30±0.26a	11.53±0.56a

Note: * mean±SD followed by the same letter within column for each gas are not significantly different ($p>0.05$); ns (non significant, $p>0.05$).

Ethylene inside the package increased during the first 6 days after processing and slowly increased thereafter (Figure 1). Ethylene accumulation was higher in trays sealed with OPP/LLDPE and LDPE than PET film ($p<0.05$).

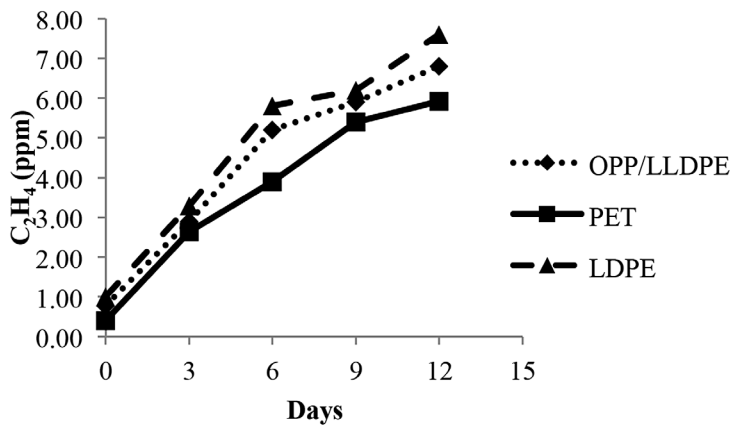


Figure 1. Ethylene concentrations changes in the headspace of fresh-cut mango- steen in rigid trays sealed with three different films.

Changes in physical properties

The firmness of fresh-cut mangosteen decreased continuously during storage, but the extent varied depending upon the film used to seal the trays. The decrease was significantly more pronounced with LDPE than either OPP/LLDPE or PET film ($p<0.05$) (Figure 2). Weight losses increased rapidly during the first 6 days of storage of fresh-cut mangosteen packaged in trays and sealed with different films, then either increased gradually or remained relatively stable, depending on film type. Weight losses of samples packed with sealing OPP/LLDPE and PET were lower than those sealed with LDPE film ($p<0.05$) (Figure 3). Lightness values measured for fresh-cut mangosteen packed in rigid trays sealed with all three films gradually decreased throughout storage (Figure 4A). Chroma values decreased immediately after processing, but remained relatively stable thereafter (Figure 5B).

Hue angle measurements decreased throughout storage (Figure 5C). Statistical analysis revealed that there were no significant differences ($p>0.05$) in lightness, chroma and hue angle value associated with the treatments.

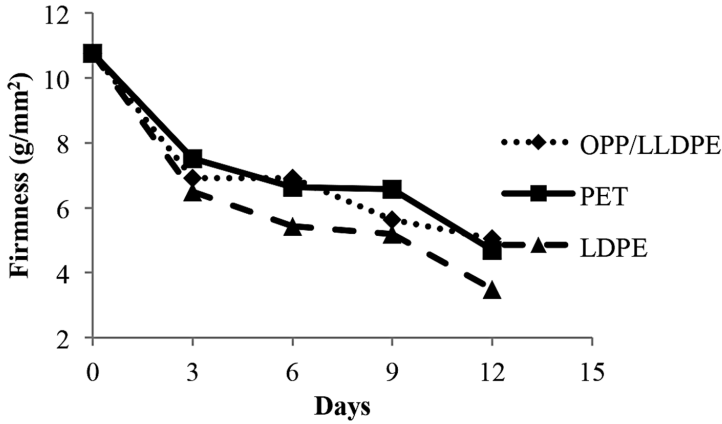


Figure 2. Flesh firmness of fresh-cut mangosteen in rigid trays sealed with three different films.

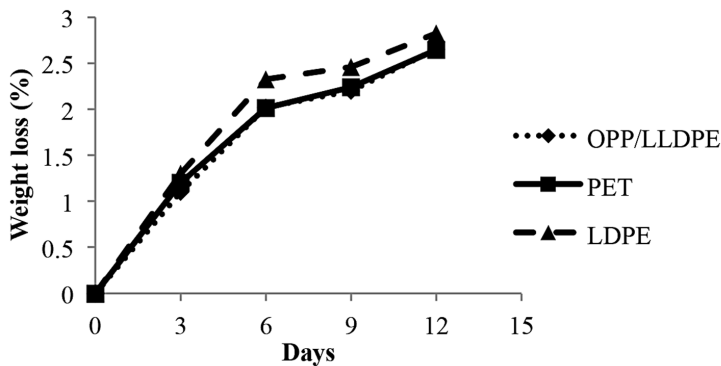


Figure 3. Weight losses of fresh-cut mangosteen in rigid trays sealed with three different films.

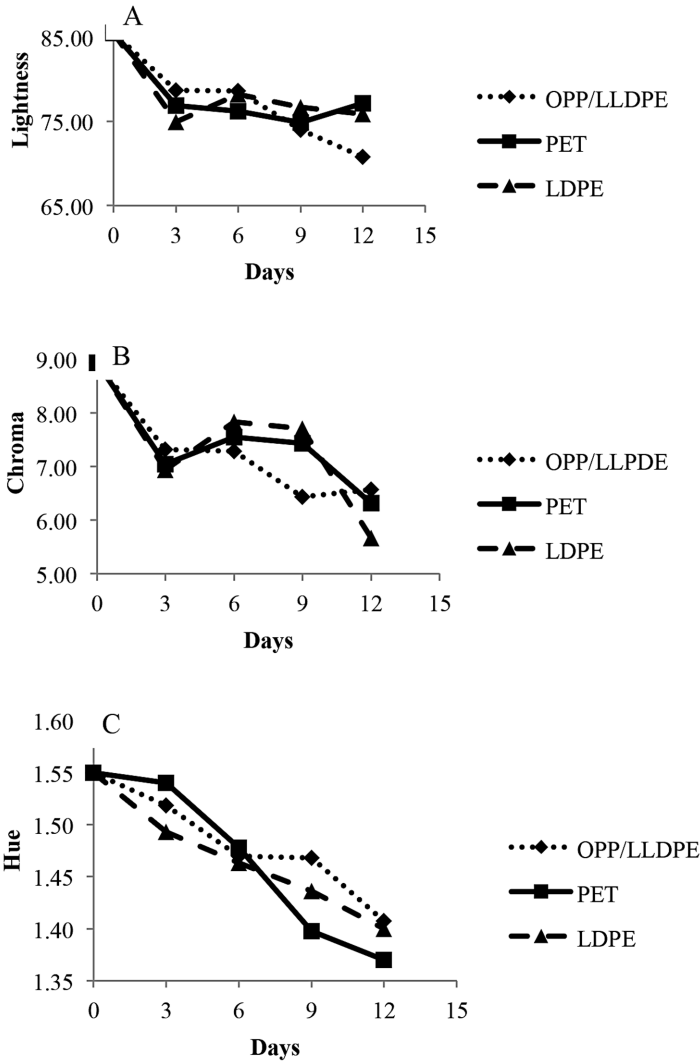


Figure 4. Color changes of fresh-cut mangosteen in rigid trays sealed with three different films A: lightness B: chroma and C: hue angle values.

Chemical changes

In this experiment, acetaldehyde concentrations decreased throughout storage but there were differences associated with film type (Figure 5). Concentrations of acetaldehyde in trays sealed with LDPE film remained higher than in those sealed with OPP/LLDPE and PET films ($p < 0.05$) at the end of storage period.

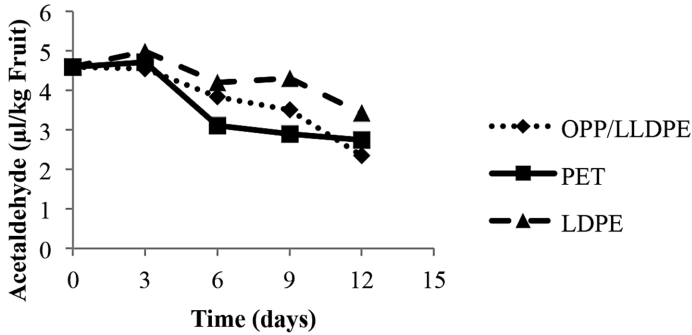


Figure 5. Acetaldehyde content of fresh-cut mangosteen in rigid trays sealed with three different films.

Ethanol concentrations in trays sealed with all sealing films tended to increase throughout storage (Figure 6). The concentrations in trays sealed with LDPE decreased after 6 days, while samples in trays sealed with OPP/LLDPE and PET slightly increased. Low concentrations of ethanol and acetaldehyde may impart floral, fruity or otherwise pleasant odors in fruit (Kim et al., 2005).

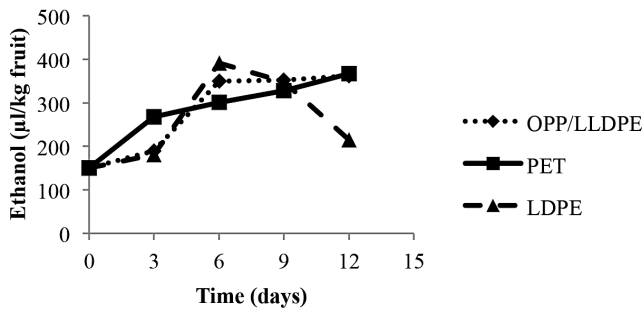


Figure 6. Ethanol content of fresh-cut mangosteen in rigid trays sealed with three different films.

Microbiological changes

Microbiological analysis of fresh-cut mangosteen stored at 5°C in PP trays sealed with all three films revealed no evidence of microbial growth during storage (Table 2). The fresh-cut mangosteen aril remained relatively intact during storage, which limited the release of nutrients for microbial growth.

Table 2. Microbial populations of fresh-cut mangosteen packed in PP trays sealed with three different films during storage at 5°C.

Microorganisms	Day 0	Day 3	Day 6	Day 9	Day 12
-TVC (CFU/g)	<10	10	10	10	20
-Yeast and mold (CFU/g)	<10	<10	<10	<10	<10
- <i>E. coli</i> (MPN/g)	<3	<3	<3	<3	<3
- <i>S. aureus</i> (MPN/g)	<3	<3	<3	<3	<3
- <i>Salmonella</i> sp.	N.D.	N.D.	N.D.	N.D.	N.D.
- <i>L. monocytogenes</i>	N.D.	N.D.	N.D.	N.D.	N.D.

Note: The microbial populations in fresh-cut mangosteen in PP trays sealed with each film are the same values. N.D. (Not detected).

Sensory analysis

The scores of all sensory attributes of fresh-cut mangosteen packed in PP trays and three different films during storage increased over time (Table 3). Scores for browning, firmness, wateriness and overall visual quality changed immediately after processing (the scores were more than 1, which indicated not extremely original). Changes in odor were first observed after 3 days of storage, probably due to the accumulation of ethanol in the trays.

Table 3. Sensory scores* of fresh-cut mangosteen packed in PP trays under three different films during storage.

Attributes	Film type	Time (days)				
		0	3	6	9	12
Browning	OPP/LLDPE	1.55±0.51 ^{ns}	2.63±0.95 ^{ns}	2.43±0.85 ^a	2.67±0.80 ^a	3.02±1.00 ^a
	PET	1.55±0.51 ^{ns}	2.85±1.04 ^{ns}	2.90±0.89 ^b	2.81±0.81 ^{bc}	3.58±1.07 ^b
	LDPE	1.55±0.51 ^{ns}	2.60±0.94 ^{ns}	2.48±0.81 ^a	2.78±0.84 ^c	3.32±0.89 ^b
Off-Odor	OPP/LLDPE	1.00±0.00 ^{ns}	1.65±0.81 ^a	1.76±0.89 ^a	2.67±1.11 ^b	3.17±0.92 ^{ab}
	PET	1.00±0.00 ^{ns}	1.80±0.95 ^a	1.81±0.93 ^a	1.81±0.75 ^a	3.33±1.14 ^b
	LDPE	1.00±0.00 ^{ns}	2.70±1.34 ^b	2.81±1.25 ^b	2.88±1.12 ^b	2.95±1.22 ^a
Firmness	OPP/LLDPE	1.40±0.50 ^{ns}	2.15±1.18 ^{ns}	2.05±0.92 ^a	2.38±1.02 ^{ns}	3.16±0.90 ^a
	PET	1.40±0.50 ^{ns}	2.11±1.10 ^{ns}	1.81±0.98 ^a	2.19±0.86 ^{ns}	3.39±0.76 ^b
	LDPE	1.40±0.50 ^{ns}	2.00±1.26 ^{ns}	2.30±0.75 ^b	2.33±0.98 ^{ns}	3.63±1.04 ^b
Watery	OPP/LLDPE	1.25±0.44 ^{ns}	1.70±0.80 ^a	1.90±0.77 ^{ns}	2.33±0.55 ^a	3.03±0.61 ^a
	PET	1.25±0.44 ^{ns}	1.95±0.83 ^{ab}	2.05±0.59 ^{ns}	2.05±1.02 ^b	3.11±0.99 ^a
	LDPE	1.25±0.44 ^{ns}	2.20±1.20 ^b	2.05±0.67 ^{ns}	3.00±0.73 ^c	3.74±0.88 ^b
OVQ	OPP/LLDPE	1.20±0.52 ^{ns}	2.15±1.18 ^a	2.33±1.11 ^a	3.38±0.97 ^a	3.53±1.26 ^a
	PET	1.20±0.52 ^{ns}	2.65±1.27 ^b	2.85±1.02 ^b	3.67±1.11 ^b	4.37±1.92 ^b
	LDPE	1.20±0.52 ^{ns}	2.80±1.40 ^b	4.19±1.54 ^c	4.52±1.25 ^c	4.68±1.83 ^c

Note: * mean±SD from 20 panelists followed by the same letter within column for each attribute are not significantly different ($p>0.05$); ns (non significant, $p>0.05$).

DISCUSSION

The influence of various sealing film lids on in-package atmosphere, quality and shelf-life of fresh-cut mangosteen in this study showed that the O₂ concentration in all treatments decreased rapidly, while CO₂ concentration gradually increased during storage at 5°C. A similar finding was reported for fresh-cut lettuce stored in trays sealed with different films, with O₂ concentrations greatest with films with the highest OTR (Kim et al., 2005). Mangosteen is a climacteric fruit with a high respiration rate during ripening, producing ethylene up to 1,000 fold the initial rate during this process (Kim et al., 2005). During respiration, O₂ is consumed and carbohydrates are broken down to produce energy to run cellular processes, while water, CO₂, energy and ethylene are released. Consequently, higher levels of ethylene in fruit packaged with OPP/LLDPE and LDPE films were expected due to their higher permeability to O₂ than PET.

The physical changes of fresh-cut mangosteen during storage under three types of sealing film were monitored. The results indicated that the firmness decreased during storage, which could be related to an increase in metabolism associated with higher residual O₂ inside trays sealed with LDPE film. Enhanced enzymatic activity associated with higher metabolic rates is known to result in loss of the firmness of fresh-cut fruit (Gonzalez-Aguilar et al., 2004). Samples lost weight throughout storage, probably due to the higher water transmission rate (WTR) of LDPE film than OPP/LLDPE and PET films, thus permitting greater movement of water from the inside of the tray to the outside. In addition, these studies suggested that flesh color changes during storage were not influenced by the type of film used to seal the trays.

Acetaldehyde and ethanol content, detected in the headspace immediately after processing, were used to monitor the chemical changes of fresh-cut produce. Acetaldehyde, a natural aroma compound, is formed from pyruvate and reacts with CO₂ to form ethanol. High acetaldehyde concentrations in LDPE film could be associated with the stress response when fruit tissues are exposed to high O₂ concentrations. Acetaldehyde may be reduced to ethanol and react further to form ethyl acetate (Jandric et al., 2010). That reaction, together with acetaldehyde permeation through the package material, could explain the decrease of acetaldehyde after 3 days of storage. Production of ethanol is an indicator of anaerobic fermentation and ethanol is responsible for development of un-pleasant off-flavors and odors in fresh-cut fruits. Reasons for this decline are unclear, but could be related to the permeability of the film. Both acetaldehyde and ethanol are generally associated with anaerobic respiration, which is stimulated by very low O₂ and high CO₂ atmospheres. In this study, it is unlikely that O₂ was sufficiently depleted and CO₂ elevated to the point where the fruit would enter into strictly anaerobic metabolism. Thus, the relatively low levels of acetaldehyde and ethanol detected in fresh-cut fruit would probably not detract from the overall quality of the product. Generally, the development of microbial populations in fresh-cut fruit can be retarded by lowering the storage temperature, since higher temperatures can hasten many metabolic processes that stimulate their growth (Gonzalez-Aguilar et al., 2004). Izumi and Watada (1994) found that the increase in microbial population

of carrots was about 100-fold greater at 10°C than at 0°C, due to the faster release of sugars from the plant tissues at the higher temperature. This, in combination with the use of low storage temperature, was likely responsible for the control of microbial growth. Therefore lowering storage temperature was more critical for the control of microbial growth than the type of film used to seal the trays.

Overall visual quality (OVQ) was influenced by type of films. Samples packed in PP trays sealed with LDPE film had the highest OVQ score, likely due to the watery appearance of the samples. Product from this treatment was considered unacceptable after 6 days in storage (score more than 3) while those stored in trays sealed with OPP/LLDPE and PET film maintained acceptable scores until the 9th day of storage. Hence, samples packed trays sealed with OPP/LLDPE and PET films maintained higher sensory quality than those packaged in LDPE film under the same storage conditions.

CONCLUSION

Film properties are crucial in fresh-cut packaging. The OTR and WTR of films used in this research influenced the quality of fresh-cut mangosteen. Fresh-cut mangosteen packed under LDPE film, which has the highest WTR and OTR, retained firmness but exuded more water than product stored under PET and OPP/LLDPE films. The color and microbial population of product were unaffected by film properties. Furthermore, the high OTR of LDPE film led to higher levels of acetaldehyde and sensory analysis suggested that the product packed under LDPE film suffered greater losses in quality. The results of this study indicate that OPP/LLDPE and PET films could be used to maintain the overall visual quality of fresh-cut mangosteen for up to 9 days at 5°C. On the contrary, LDPE film is not recommended due to adverse effects on the sensory shelf life of the product.

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