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Postharvest Characterization and Storage of Fresh Katmon Fruit (*Dillenia philippinensis*)

Leonisa A. Artes[1,*], Amparo M. Wagan[2], Michelle E. Omana[2], and Leonardo L. Tamisin, Jr.[2]

[1]Postharvest Horticulture Training and Research Center, College of Agriculture and Food Science, University of the Philippines Los Baños

[2]Agricultural Systems Institute, College of Agriculture and Food Science, University of the Philippines Los Baños, Laguna, Philippines

*Author for correspondence; Email: laartes@up.edu.ph

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Katmon fruit has great economic potential but little is known about its postharvest behavior. This study characterized the katmon fruit after harvest so that appropriate handling may be recommended to extend its shelf life during storage or market display. Physicochemical characteristics, particularly firmness, pH, total soluble solids (TSS), titratable acids (TA), and TSS:TA ratio were evaluated during storage under room condition (22°C) and at low temperature (15°C). These characteristics were almost constant under 22°C or at 15°C for two weeks, with pH at 2.8, TSS at about 3.40°Brix, TA at 1.1 – 1.5%, and TSS:TA ratio at 3.1 – 2.04. Only moisture loss significantly increased, reaching 29% after the first week, which reduced the fruit's shelf life and quality. Fruit in small quantities (1.5 kg) favorably responded to modified atmosphere packaging (MAP) using sealed polyethylene bags (PEB, 0.02 mm). About 15% O_2 and 0.45% CO_2 were maintained in PEB, which extended the fruit's fresh quality up to two weeks under 22°C. MAP was also able to maintain the firmness of intact fruits for two weeks when stored at 22°C. In contrast, control fruits reached their limit of marketability after one week. Those without peel may also be kept for about two weeks when packed in PEB (300g per pack), especially if stored at 15°C.

Keywords: visual quality, weight loss, firmness, TSS:TA ratio, modified atmosphere packaging

INTRODUCTION

Katmon, also known as elephant apple, is indigenous to the Philippines and is found in forests and low to medium altitude areas. It grows wildly in the slopes and riverbanks of Quezon, Laguna, and Benguet provinces (Barcelo 2015). Its fruit is green in color, round to ovoid globose in shape, and enclosed by 2 – 3 layers of fleshy sepals. Inside are about 10 juicy carpels with the edible pulp and the seeds at the center. The fruit can be harvested between May and December.

Around 110 species of the genus *Dillenia* exist in the tropical and subtropical regions of Madagascar, Southern Asia, Australasia, Fiji, and Indian Ocean islands (Lima et al. 2014; Sabandar et al. 2017). Out of 60 species found in tropical Asia, 5 have been found in the Philippines: *D. philippinensis* (*katmon kulambog*), which has a greenish soft acidic flesh and is endemic in the Philippines; *D. reifferscheidia* (*katmon kalabaw*), found in low-medium altitude areas; *D. megalantha* (*katmon bayani*), which is at least 7 cm in diameter and is found in low-altitude forests of Luzon and Visayas; *D. mindanaense* (*katmon kambog*), which has a very sour fruit and is located in low-altitude areas of Mindanao; and *D. indica*, which has a very large fruit but is considered rare in the Philippines.

In Quezon, katmon trees are commonly found in the towns of Infanta, Real, General Nakar, and Atimonan. The locals commonly use the fruit as a souring agent in cooking, similar to their use of bilimbi (*Averrhoa bilimbi*) or tamarind (*Tamarindus indicus*). However, the fruit is not commonly sold in the local markets.

Postharvest studies have already been conducted on star fruit (*Averrhoa carambola*) and bilimbi. In star fruit, changes in fruit color accurately indicate the stage of ripeness since the two are inversely proportional (Mitcham and McDonald 1991). However, studies of its patterns of respiration and ethylene production have been inconclusive as to it being climacteric, though this was reported earlier (Lam and Wan 1983). Its total soluble solids (TSS) is around 8.13%, with its pH at 3.8, malic acid at 0.43%, and phenolic acids at 93.7% (Tan et al. 2022).

Bilimbi, a climacteric fruit (Guadarrama and Gonzalez 2008), produces about 50 – 2400 nL C_2H_4 g^{-1} h^{-1} 1 d after harvest (Masilungan and Absulio 2012). A higher production was observed when the fruit is injured, making it a good natural ripening agent. Bilimbi's TSS is around 3.9 – 5.1% (De Lima et al. 2001) which is lower than the TSS of star fruit at 8.0% (Neog and Mohan 1991). Its oxalic acid level is quite high at 8.6 – 10.3 mg g^{-1}, and its pH value is extremely low (0.91 – 1.5).

Only about 33 kcal per 100 g is obtained when consuming katmon. The fruit contains about 92 g of water per 100 g of fruit, 0.3 g of protein, 0.2 g of fat, 7.4 g of carbohydrates, 28 mg of calcium, 4 mg of vitamin C, and traces of B-carotene (25 ug) and vitamin A (4 ug).

In a study of edible wild fruits in Benguet, katmon exhibited the highest antioxidant activity among 31 fruit species (Barcelo 2015). It was found to have alkaloids, steroids, flavonoids, tannins, and polyphenols. Total phenolics are considered powerful antioxidants in vitro and are more potent than vitamin C, vitamin E, and carotenoids (Rice-Evans et al. 1997). Studies have also shown that flavonoids and polyphenols are better antioxidants than vitamins (Pietta 2000). Katmon leaves, stems, and bark also contain numerous flavonoids and triterpenoids (Lima et al. 2014). These are also traditionally used for conditions like cancer, diarrhea, and arthritis, and are found to moderately inhibit human lung adenocarcinoma cells (Macahig et al. 2011).

Given the potential benefits of katmon fruit, this study determined the following: a) the physicochemical properties of katmon fruit after harvest, b) the response of intact and peeled katmon fruits during storage, and c) the suitability of modified atmosphere packaging (MAP) in prolonging its shelf life.

MATERIALS AND METHODS

Physicochemical Characterization of Katmon Fruit

Katmon fruits that farmers regarded as mature were light green in color with diameters of about 5 – 6 cm. Fruits were harvested from Dinahican, Infanta, Quezon and brought to the Postharvest Horticulture Training and Research Center, University of the Philippines Los Baños for evaluation. Physicochemical changes were monitored during storage at room condition (22°C, 80% RH) for 2 wk. Quality changes were recorded using visual quality rating (VQR) where 5 is highly acceptable, 4 is moderately acceptable, 3 is satisfactory, 2 is limit of marketability or acceptance, and 1 is unmarketable or unacceptable.

Weight loss was monitored by regularly weighing the same individual samples on a fresh weight basis. For the physicochemical analyses, the pulp and peel weight of each fruit replicate were measured to determine the ratios. Then, 10 g of katmon pulp per fruit was blended with distilled water and filtered with cotton to obtain a clear aliquot. The aliquot's TSS, which mainly measures sugar content, was taken using a refractometer (Atago PR-1). Its pH level was measured using an analog pH Meter (Jenco 603A). The level of total acid concentration (titratable acidity, TA) was determined by titrating the aliquot with 0.100 N NaOH. Five fruit samples, each of regular size, were monitored for the above parameters 1, 8, and 13 d after harvest (DAH).

Modified Atmosphere Packaging (MAP)

MAP of Intact Fruit

Newly harvested katmon fruits were placed in MAP using sealed polyethylene bags (PEB, 0.02 mm thick). Fruits placed in open trays served as control. Fruits were stored under room condition (22°C) and at 15°C for 2 wk. No ethylene adsorbent was used as it was found to be unnecessary based on the results of a preliminary setup. An earlier setup consisted of katmon fruits in MAP with the addition of ethylene adsorbent per pack; however, there was no distinct difference between control and those with adsorbent in terms of visual quality after storage.

Carbon dioxide and oxygen levels in the packs were monitored using a gas analyzer (Checkmate II, PBI Dan Sensor). Weight loss and VQR, as well as the physicochemical changes mentioned earlier, were also monitored. Each treatment consisted of four replicates, with each replicate containing 1.5 kg of intact fruit. One fruit per replicate was analyzed for physicochemical tests. Slope of the line for VQR and weight loss changes over time were also computed using Microsoft Excel.

MAP of Peeled Fruit

The peel of katmon fruit easily gets bruised, resulting in faster visual quality decline. To check if the edible pulp was affected by the slight peel injuries, peeled fruit samples were packed in sealed PEB and in unsealed polystyrene trays with cover (control) for 2 wk under 22°C and 15°C. Weight loss, VQR, and physicochemical changes were monitored for 2 wk. Each treatment consisted of four replicates, with each replicate containing 300 g of peeled fruit. One fruit per replicate was analyzed for physicochemical tests. Slope of the line for VQR and weight loss changes over time were also computed using Microsoft Excel.

Statistical Analyses

The main treatments were either number of days when evaluation was done, or the treatments done on the fruit samples (i.e., packaging or storage temperature). Means were analysed using Tukey's test at 5% level of comparison. Linear regressions of VQR and weight loss were calculated using Microsoft Excel statistical program.

RESULTS AND DISCUSSION

Physicochemical Characterization

Peel drying and browning were the most visible changes observed in katmon under room condition (22°C). The fruit peel remained green until it showed a tinge of browning at the edges, which is possibly due to drying; however, the peel did not turn yellow. As the peel dried up, it became more difficult to peel the fruit. When damages due to bruising, dropping, or cuts are only skin deep, the fruit does not deteriorate easily. However, if the damage reaches the pulp inside causing the juice of the fruit to spread or be squeezed out, faster deterioration is expected.

Weight loss of intact fruit increased with time (29 – 40%) which can be attributed to both peel and pulp weight loss (Table 1). Although not significant, the peel showed a decreasing trend in %weight loss over time, while the pulp showed the opposite. However, the ratio of peel and pulp weight loss decreased over time, reaching 1:1 after 13 d.

Table 1. Changes in weight of katmon days after harvest (DAH) at 22°C[1].

	1 DAH	8 DAH	13 DAH
Fruit weight (g)	96 a	68 b	58 b
Fruit weight loss (%)		29 b	40 a
Peel weight (%)	55	52	50 ns
Pulp weigth (%)	45	48	50 ns
Peel:Pulp weight	1.2:1.0	1.1:1.0	1.0:1.0

[1]Each value is an average from 5 fruits (replicates). Mean comparison for each parameter is by Tukey's test at 5%.

Fig. 1 shows the physicochemical changes at 22°C. The pH level was quite stable and very acidic (pH~2.8) as expected. TSS, which is a measure of water soluble sugars, was quite low and showed a decreasing pattern over time (from 3.5 to 3.1°Brix), but was insignificant. However, TA slightly increased over time (1.1 to 1.5%), thus the TSS:TA ratio decreased from 3.2 to 2.0, 2 wk after fruit harvest.

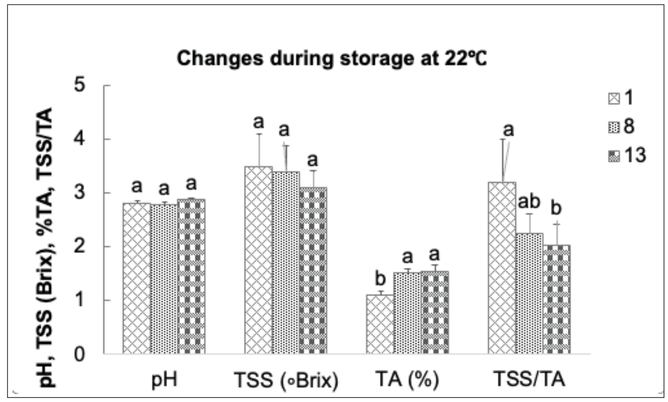

Fig. 1. Physicochemical changes during storage of katmon fruit at 22°C after 1,8, and 13 DAH. Each point is the average of 5 fruit samples. Mean comparison per parameter is by Tukey's test, 5%.

It is important that katmon fruit is properly harvested and handled to lengthen its shelf life. Physical damages on the fruit (i.e., bruises, impacts, or cuts) that reach the pulp inside hasten its deterioration. Weight loss over time (30 – 40%) was also quite high because the fruit is 92% water (FNRI-DOST 1997). There was a 1:1 weight loss between fruit peel and pulp after 2 wk (Table 1).

Physicochemical analyses showed that katmon fruit has acidic pH (2.8), low TSS (3.10 – 3.50°Brix), and TA (1.1 – 1.5%) over time. Its TSS content is quite low compared to starchy fruits like banana (19 – 22°Brix) and mango (13 – 16°Brix) (Artes 1995; Abarra et.al. 2018). On the other hand, its TA values are comparable to those of pineapple (Artes et al. 1999) and star fruit (Tan et al. 2022). With regard to its TSS:TA ratio, a decreasing trend (3.0 – 2.0) was obtained over time.

MAP of Intact Fruit

An almost linear level of gasses (15.18% O_2 and 0.45% CO_2) was maintained inside the packs of katmon fruits during storage at 22°C. No off-odor was noted when the MAP-stored fruit samples were opened after 2 wk—an indication that the gas levels inside the pack were still favorable to the fruit.

The limit of marketability (VQR 2) of control fruits at 22°C was reached at about 11 DAH, while those under MAP

Table 2. Visual quality rating (VQR) of intact katmon fruits at 22°Cand 15°C[1].

Treatment	Days After Harvest (DAH)					Slope (Y)
	1	6	8	11	14	
22°C Control	4.00	2.25	1.75	2.12	1.60	0.66x + 4.56
22°C MAP	4.00	4.00	3.12	2.55	2.00	0.16x + 2.32
15°C Control	4.00	3.87	3.62	3.12	3.00	0.28x + 4.13
15°C MAP	4.00	3.50	3.12	3.50	3.00	0.11x+ 3.56

[1]Each value is an average of 4 replicates with 1.5 kg of fruit per replicate. Comparison within each day is by Tukey's test at 5%. (VQR: 5 = highly acceptable; 4 = moderately acceptable; 3 = satisfactory; 2 = limit of marketability or acceptance; 1= unmarketable or unacceptable).

showed later at 14 DAH (Table 2). On the other hand, both fruit samples (control and MAP) stored under 15°C had better quality (VQR 3) than fruits at 22°C (VQR 2) after 2 wk. They maintained satisfactory visual quality (VQR 3) until 14 DAH.

Computations of their slopes show the differences among the treatments (Table 2). Control fruits at 22°C showed the fastest decline in quality (0.66x + 4.56) followed by those at 15°C (0.28x + 4.13). Fruits under MAP in both temperatures exhibited slower deterioration rates (0.16x + 2.32; 0.11x + 3.56).

The effects of storage temperature and packaging were obviously seen in the weight loss of katmon fruit (Fig. 2). Control fruit samples at 22°C had three times higher weight loss (25 – 30%) than those kept at 15°C (8 – 11%) toward the end of 2 wk. In comparison, those kept in MAP under both temperatures incurred almost negligible weight loss after 14 d. Computing the slope of weight loss shows that fruits at 22°C without packaging (control) had the highest weight loss (2.404x - 3.64). Weight loss was reduced by one-third in fruit samples stored at 15°C (0.85x - 1.44). On the other hand, fruits in MAP under both storage temperatures had nearly no weight loss until end of storage (22°C MAP: 0.06x - 0.17; 15°C MAP: 0.01x - 0.02).

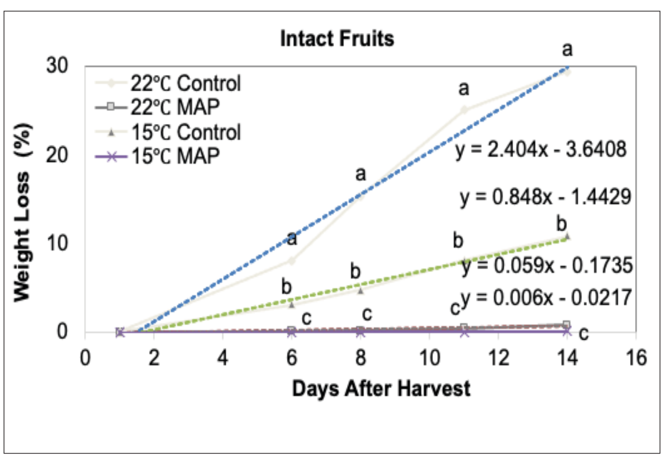

Fig. 2. Weight loss of intact katmon fruits during storage at 22°C and 15°C. Each point is the average of 4 replicates, with 1.5 kg fruit each. Mean comparison per day is by Tukey's test, 5%.

Fig. 3 shows the physicochemical changes of intact fruits during storage at 22°C. Fruit firmness slightly decreased over time (9.2 to 7.6 kg-force) in the control fruits (in open trays or unpacked); but fruit samples in MAP maintained their initial values for 14 d. Katmon fruit is quite acidic (~pH 3), and this level of acidity was maintained when the fruit was stored in MAP for 2 wk. Its TSS showed no distinct pattern of changes (4.4 – 5.4%), while TA was the highest during the initial stages (0.96%) but decreased over time even for fruit kept in MAP (0.81%). The TSS:TA ratio increased over time (4.6 – 6.7) and between control and fruits in MAP. The latter had higher ratios (6.1, 6.7) than the control (5.2, 4.8) after storage. The TSS:TA ratio increased because TSS increased while TA slightly declined over time.

Peel drying, which starts at the edges and is primarily due to weight loss, is the most visible deteriorative change in katmon after harvest. The control fruits at 22°C were observed to be at the limit of marketability around 8 DAH, while those in MAP reached 14 DAH. Keeping katmon under MAP for 2 wk was shown to be favorable in prolonging its shelf life. Moreover, those stored at 15°C still had satisfactory ratings and were acceptable even after 14 d, whether stored in MAP or not. The effects of temperature and packaging on katmon were obvious in its weight loss. Control fruit (unpacked) showed the greatest weight loss at 22°C (30%) and at 15°C (11%), while those in MAP had negligible weight loss (< 0.1%) in both temperatures. Computed slopes of the line show the differences in weight loss of fruits at different temperatures and packaging.

The physicochemical characteristics of intact fruit (pH, TSS, TA) at 22°C slightly changed over 2 wk. Firmness slightly decreased (~9 to 8 kg-force) in fruits when stored unpacked (control), while those under MAP maintained their initial levels. Also, the TSS:TA ratio of intact fruits under MAP (6.1, 6.7) was higher than that of control fruits (5.2, 4.8) after 7 and 14 d.

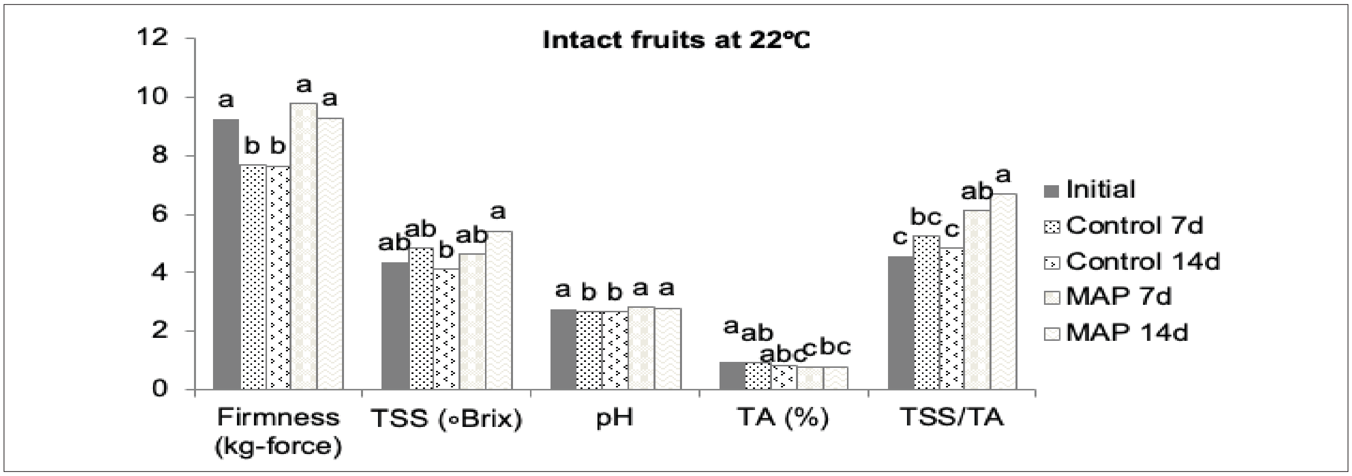

Fig. 3. Physicochemical changes in intact katmon fruit during storage at 22°C. Each value is the average of 4 replicates, consisting of 1 fruit each from 1.5 kg fruit per replicate. Mean separation of treatments per parameter is by Tukey's test at 5%.

The results of this study demonstrate the benefit of storing perishable crops such as katmon under MAP, since weight loss is minimized and physicochemical properties hardly changed for 2 wk. Various subtropical and tropical fruits had also been previously shown to have extended shelf life under modified atmospheres (Kader 1992).

MAP of Peeled Fruit

The edible pulp of control peeled fruit showed the fastest decline, while those stored in MAP looked almost the same even after 2 wk. The VQR values show that the peeled fruit samples at 22°C declined faster than those at 15°C (Fig. 4), whether in MAP or unpacked (control). Slopes of the line distinctly show the differences among treatments. Those at 22°C had faster deterioration rates than at 15°C, with control fruits consistently having a higher rate than those under MAP at the same temperature.

Control peeled fruit had higher weight loss (13.4%, 9.7%) in both storage temperatures than those in MAP (Fig. 5), which had almost negligible weight loss (< 1.0%), thus delaying the latter's quality deterioration. Corresponding slopes of weight loss for each storage condition show the differences among treatments. Fruit samples stored in open trays (control) at 15°C (y = 0.79x + 1.7) had about one-half less rate of weight loss compared to those at 220°C (y = 1.17x - 2.5). On the other hand, those stored in MAP under both storage temperatures had almost negligible weight loss (y = 0.06x - 0.10; 0.01x - 0.01).

Physicochemical analyses (Fig. 6) show that the firmness of peeled fruit samples declined during storage to about the same levels (9 to 6 kg-force) in both control and MAP stored fruits. The pH levels (~2.8) did not vary with time and across treatments, while TSS levels were found to slightly increase in both treatments after 14 d (5.7%, 5.4%). TA levels initially

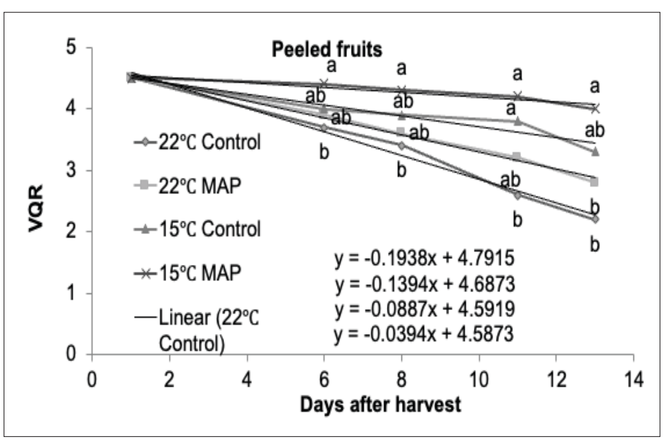

Fig. 4. Visual quality rating (VQR) of peeled katmon fruits stored in the open (control) and in sealed PEB (MAP) at 22°C and 15°C. Each treatment consists of 4 replicates, with 300 g of fruits each. Mean comparison per day is by Tukey's test at 5%.

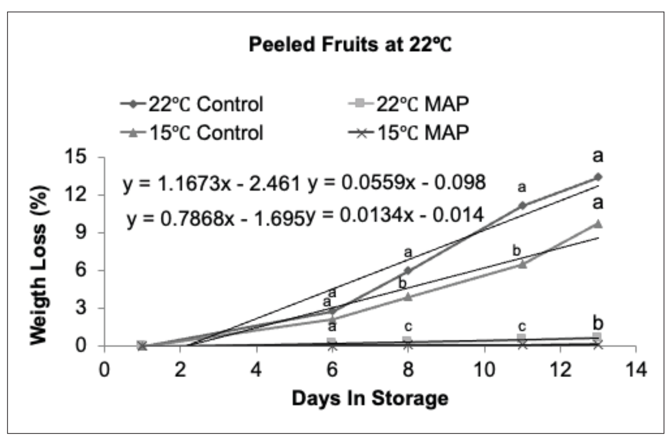

Fig. 5. Weight loss of peeled katmon fruits under room conditions (22°C and 15°C). Peeled fruit was stored in open tray (control) and in sealed PEB (MAP). Each treatment consists of 4 replicates, with 300 g of fruit each. Mean comparison within the day is by Tukey's test, 5%.

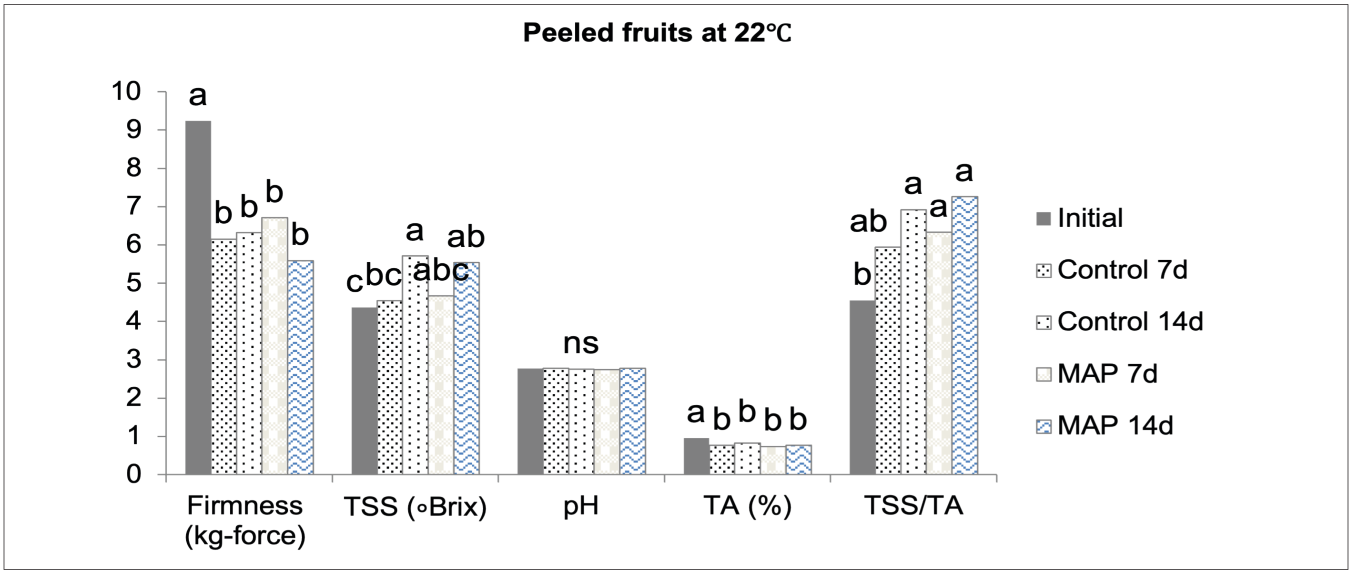

Fig. 6. Physicochemical changes in peeled katmon fruit stored in open trays (control) and in MAP for 7 and 14 days at 22°C. Each value is the average of 4 fruits taken from a pack of 300 g fruit per replicate. Mean comparison within each parameter is by Tukey's test at 5%.

declined (0.96% to 0.77%) but did not change much afterwards. Hence, the TSS:TA ratio slightly increased especially after 14 d of storage for both control and MAP fruits (5.9 to 6.9; 6.3 to 7.3)

Peeled fruit was kept in best quality when sealed in PEB (MAP) at 22°C room condition. It was observed to retain acceptable quality (VQR 3 and 4) after 14 d. Peeled fruit declined in quality more slowly, as indicated by its lower slope values ($y = 0.19x + 4.8$; $y = 0.09x + 4.6$) than when intact ($0.66x + 4.56$; $0.28x + 4.13$), both at 22°C and 15°C. This is possibly due to its waxy pulp covering which remained intact, thus exhibiting slower weight loss. Fruit was only peeled and not cut, so each individual piece of katmon was technically still intact. Hence, it is possible for the fruit to have longer shelf life even without the peel. Normally, freshly cut fruits such as melon and papaya have only 4 d and 3 d shelf life even at 14 – 15°C (Falah et al. 2015).

Weight loss of control fruit samples after about 2 wk at 22°C (13%) was consistently higher than at 15°C (10%), whereas MAP-stored fruit incurred almost negligible weight loss (< 1.0%) throughout storage under both temperature treatments. Hence, keeping the peeled fruits under MAP is the best way to keep them marketable for the longest possible time.

On the other hand, firmness of peeled fruit (~6.0 kg-force) was lower at 7 and 14 d after with or without packaging, compared to intact fruit (7.6 kg-force). Its TSS slightly increased while TA decreased over time, resulting in an increased TSS:TA ratio, especially for those under MAP.

CONCLUSION

The quality of katmon fruit mostly depends on how it was harvested, packed, and transported, as the fruit gets easily injured. Marks on the peel are readily shown through peel browning later. The use of MAP simulating retail marketing was found to be favorable both to intact and peeled katmon. Gas levels inside the fruit pack were maintained at favorable levels for two weeks at 22°C without resulting in any off-odors to the fruit or significant changes in its physicochemical properties. In contrast, the unpacked fruit (control) already exhibited peel drying and browning after only a week. The difference in weight loss of the control and those in MAP made a significant difference in the freshness and marketability of both intact and peeled fruits. Unpacked (control) fruits exhibited higher weight loss whether intact (25 – 30%; 8 – 11%) or peeled (10%, 13%) at 22°C or 15°C, while fruit in MAP whether intact or peeled had negligible weight loss (< 1.0 %) in both temperatures. Almost constant levels of pH, TSS, TA, and TSS:TA ratio were observed under MAP during storage. Hence, when sealed in PEB, katmon fruit (intact or peeled) can be stored or displayed in supermarkets for two weeks without any significant changes in its weight or physicochemical properties. In contrast, unpacked (control) fruits may reach its limit of marketability after only about a week. To ensure food safety for fresh katmon, it is recommended that intact fruits be sorted first, choosing only those with intact peel, washing them in water, letting them dry, then packing them in sealed PEB and storing at a low temperature (< 25°C). For fruits with minor injuries, it is best to keep them peeled and packed under MAP, then stored at lower temperatures.

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