Food Research 7 (6) : 262 - 271 (December 2023)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Effects of seaweed (*Kappaphycus alvarezii*) based edible coating on quality and shelf life of minimally processed mango (*Mangifera indica L. king*)

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Article history:
Received: 1 February 2022
Received in revised form: 31 March 2022
Accepted: 4 October 2022
Available Online: 27 December 2023

Keywords:
Minimally processed mango,
Edible coating,
Physicochemical quality,
Sensorial properties,
Microbiological effect

DOI:
https://doi.org/10.26656/fr.2017.7(6).061

Abstract

Coating of minimally processed mango fruit (*Mangifera indica L. king*) with seaweed paste (SP) and gum Arabic (GA) has been found to increase their overall quality and shelf -life. The main purpose of this study was to find out the effect of seaweed and gum Arabic on the physicochemical properties, microbial analysis and sensory quality of minimally processed mango fruits. Coating minimally processed mangoes with seaweed (*Kappaphycus alvarezii*) enhanced their shelf-life and postharvest quality. Different concentrations of seaweed paste (0, 10%, 20%) and gum Arabic (0, 5%, 10%) were used for the formulation of the edible coating for minimally processed mango cube and stored at 5°C for 14 days. The result of the study showed that coatings with a 10% and 20% (w/w) seaweed paste mixed with 5% and 10% (w/w) gum Arabic had significantly ($P<0.05$) higher sensory quality and reduced microbial load. This combination of 10% seaweed paste, and 5% gum Arabic can be recommended to use as an edible coating for minimally processed mango fruit.

1. Introduction

Mango (*Mangifera indica L. king*) is one of the seasonal fruits, it has high nutritional value, rich in vitamins A (beta-carotene), B6 and C. It also contains sugar, a small amount of protein, fats, fibres, iron, calcium, phosphorus and other nutrients (Shobana and Rajalakshimi, 2010). Mangoes require peeling, taking away flesh from the seed, and cutting before consumption. Very little is identified about the maximum storage life, quality changes, or microbial inhabitants of minimally processed mangoes (Nithiya and Alley, 2000; Nithiya *et al*., 2001). Edible coatings have been used to decrease the damaging effect brought about by minimal processing (Rocculi *et al*., 2009). It is expected to produce a nature-modified atmosphere as a barrier to gases in each coated fruit piece, it can reduce moisture, rates of oxidative reaction, gas exchange, respiration and along with relative humidity and optimum storage temperature to get a longer shelf life in minimally processed products (Rojas-grau *et al*., 2008; Gaspar, 2011).

Kappaphycus alvarezii is a red algae, that is used in the food industry and it has unique colloidal properties (Rajasulochana *et al*., 2010). Gum Arabic is generally considered safe, and it is widely used as a stabiliser, thickening agent and hydrocolloid emulsifier (Almuslet *et al*., 2012). The purpose of this study is to determine the potential of different concentrations of seaweed coatings on physicochemical properties for minimally processed Mango fruit.

2. Materials and methods

2.1 Materials

Fresh mango (*Mangifera indica L. king*) was purchased from Selangor, Malaysia. The maturity stage was decided based on the Malaysian standard by the Federal Agricultural Marketing Authority. Seaweed (*Kappaphycus alvarezii*) was collected from the coastal areas of Sabah in Malaysia. It was thoroughly rinsed and soaked in water for 117 mins and then soaked again in 5% lemon juice overnight to eliminate the fishy odour of seaweed (Xiren and Aminah, 2014). Deodourised wet seaweed and distilled water were mixed in a tank by stirring at 20°C to prepare seaweed paste (Siah *et al*., 2014). Seaweed paste was used in the edible coating as the main ingredient. Gum Arabic was included as an emulsifier for edible coating formulations.

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

2.2 Preparation of coating solution

Seaweed paste (44.97% fresh seaweed and 55.02% water) and gum Arabic were prepared at three different concentrations (0, 10%, 20% and 0, 5%, 10% respectively) were dissolved in 100 mL distilled water by mixed with a homogenizer (ultra Turrax T25, Germany) for 5 min at 24500 rpm and stirred with low heat 40°C for 30 mins using a hot plate magnetic stirrer.

2.3 Application of coating to minimally processed mango

Before the preparation of samples, mangos, all containers, cutting boards, knives and other utensils in contact with mango were washed and sanitized with 0.1% sodium hypochlorite solution (Azarakhsh, 2012). After washing, the mango was peeled manually and cut with a sharp knife into cubes of 2 cm (Nithiya *et al*., 2001). The mango cubes were dipped in the seaweed-based edible coating formulation (seaweed paste +gum arabic) for 2 mins and then the excess coating materials in mango cubes were permitted to drip off. Commercial minimally processed mango was used as a control sample. The polystyrene trays were used for packing the coated mango cubes and then wrapped with PVC film (Azarakhsh, 2012). The packed treated mangos were stored at 5°C (Kader, 2008).

2.4 Physicochemical properties

Analysis on sampling days 0, 7, and 14 for each control and coated Mango samples were evaluated for firmness, PH, Titratable acidity (TA), soluble solids (TSS), colour and moisture loss.

2.5 Firmness

Fruit firmness was measured by compression of individual mango cubes with a Stable Micro System TA-EZ test/AGS-H) Texture analyzer. The procedures for operating the texture analyzer were stated in the Standard Operating Procedure (SOP). This test measured mango firmness based on the resistance of the flesh of an individual mango cube to deformation by the plate. Three replicates of 9 samples were used for each storage time. Results were expressed as (g/f) (AOAC, 1998).

2.6 Titratable acidity

The titratable acidity of mango cubes was determined by titrating 10 g of liquefied minimally processed mangoes with 100 mL of distilled water with 0.1 mol L^{-1} NaOH solution until pH 8.2. All determinations were performed with three replicates.

2.7 Total soluble solids

Total soluble solids (TSS) are an index of soluble solids concentration in the fruit. The total soluble solids were determined by a digital refractometer (ATAGO PR-32, USA Inc. Kirkland, WA, USA). Results were expressed as %.

2.8 pH

The pH of cantaloupe flesh was measured using a digital pH meter (Cole Parmer, Ph 500 series, Model #59003-20, Singapore) previously calibrated with standard solutions, pH 4, 7, and 10. The juice of three cantaloupe cylinders (10 mL) was squeezed to avoid any solids in the sample, and a glass electrode was immersed to record the reading. The experiment was carried out at room temperature and in triplicate for each of the experiments.

2.9 Weight loss

The fresh weights of control and coated mango samples were measured every week and moisture losses were calculated as:

$$Weight\ loss(\%) = \frac{Weight(day0) - weight(dayX)}{Weight\ (day0)}$$

2.10 Microbiological analysis

Analysis on sampling days 0, 7, and 14 for each control and coated Mango sample were evaluated for microbial contamination including total plate count (TPC), coliform, *Escherichia coli*, yeast and mould enumeration. Ten grams of each sample was drawn out and placed into a sterile stomacher bag and added with 90 mL Maximum Recovery Diluent, MRD (1:10) and homogenized for 1 min at normal speed in a Seward Stomachers 400 Laboratory Blender (Seward, UK). An aliquot (1 mL) of the homogenate was removed and serially diluted with 9 mL MRD in an aseptic condition, up to a dilution of 10^9. An aliquot (0.1 mL) of each dilution was aseptically transferred to Plate Count Agar (PCA) for total plate count where the plates were incubated up-side-down at 37°C for 24 hrs, Chromocut Coliform Agar (CCA) for coliform and *E.coli* at 37°C for 24 hrs, Potato Dextrose Agar (PDA) for yeast and mould at 25°C for 48 hrs. Colonies were enumerated after incubation, and the results of the sample were reported as log CFU/g. All determinations were performed with three replicates.

2.11 Sensory analysis

Participants had to have previously passed a test of recognition of basic tastes and a test of visual ranking to ensure that they were suitable for training (Contador *et*

https://doi.org/10.26656/fr.2017.7(6).061

al., 2014). The selected panel included 12 people: 7 females and 5 males. Eleven panels had previous experience in sensory analysis. The participants' ages ranged from 20 and 40 years those involved Malay, Chinese, Indonesian and Arab students from the food science department at the national university of Malaysia. The training process was conducted in 4 sessions of approximately 1.5 hrs each. All of the sessions were conducted in a sensory evaluation room. The attributes chosen by the panel leader were colour, aroma, taste, firmness and overall acceptability. Specific training on mango attributes' intensity evaluation was provided to panellists to ensure panel consistency. The evaluation of the attributes such as color, aroma, taste, firmness and overall acceptance was carried out by trained panelists on days 0, 7 and 14. A Quantitative Descriptive Analysis (QDA) was performed. For the evaluation of the attributes on the first day, the 9 different samples (8 experimental + control); on the 7 and 14 days, the 10 different samples (8 experimental + control + reference) with three-digit codes were presented in plates. Mineral water was used for cleansing the mouth. The panelists were asked to compare each sample with the reference sample and evaluate all samples in terms of each sensory attribute to check the perceived intensity. When the intensity of treated samples was considered higher or lower than the reference sample, they were requested to point out the amount of difference on a standard seven-point scale (Castricini *et al*., 2012). For colour 1: extremely dark colour and 7: light yellow colour; for aroma 1: no mango odour and 7: strong mango odour; for taste 1: no mango taste and 7: strong mango taste; for firmness 1: soft and 7: firm; for overall acceptance 1: extremely dislike and 7: extremely like.

2.12 Statistical analysis

Statistical comparisons of the results were achieved by one-way ANOVA and Duncan using SPSS ver.19. Significant differences (P<0.05) among the concentrations and storage period were analyzed by Duncan triplicates range test (Addai *et al*., 2013).

3. Results and discussion

3.1 Firmness

Firmness is a critical quality attribute influencing consumer acceptability of fresh fruit. It is linked to metabolic changes and the water content of fruit (Nongtaodum and Jangchud, 2009). Table 1 shows the effect of seaweed-based coating on the firmness of minimally processed mango fruits stored at 5°C for different periods of time (0-14 days). All fruit samples remained very firm and there was no significant difference (P < 0.05) at day 0. After 7 days, all fruit samples started to lose firmness, the control sample had the lowest values of firmness during storage time. All coated samples were significantly (P <0.05) firmer (higher force values) in comparison to the control. The 20%SP+5%GA, 10%SP+10%GA and 10%SP+5%GA with the highest force values (486.49, 486.41 and 486.41 g/f respectively), followed by 20%SP+10%GA and 10% GA (486.02 and 485.95g/f respectively), then the 10%SP and 20%SP (485.28 and 485.01 g/f respectively), and lastly 5%GA (484.59 g/f). All coated treatments demonstrated high effectiveness in retaining the mango's original firmness even after 14 days of storage, while the uncoated control sample had a softer and mushy texture after the seventh day of storage. By the last day of storage (day 14), the coated samples showed firmness values ranging from 481.13 to 486.35 g/f. The coated samples with a combination of seaweed and gum Arabic had the highest firmness values than coated samples only with seaweed or gum Arabic. This may be due to the effect of biological treatments (seaweed + gum Arabic) in delaying fruit ripening, increasing preserving higher firmness and resistance to a storage disorder. Seaweed can be proffered as a means of offsetting the ripening of fruit, whilst sustaining levels of antioxidants. Gum

Table 1. The effect of seaweed-based coating on firmness of minimally processed mango fruits.

Sample	Day 0	Day 7	Day 14
S0	487.38±0.03^{Aa}	484.41±0.09^{Bf}	480.13±0.08^{Ch}
S1	487.34±0.07^{Aa}	484.59±0.10^{Be}	481.13±0.10^{Cg}
S2	487.27±0.09^{Aa}	485.95±0.10^{Bb}	485.25±0.10^{Cd}
S3	487.33±0.13^{Aa}	485.28±0.10^{Bc}	482.41±0.10^{Ce}
S4	487.23±0.08^{Aa}	486.41±0.10^{Ba}	486.35±0.10^{Ca}
S5	487.31±0.03^{Aa}	486.41±0.10^{Ba}	486.33±0.10^{Ca}
S6	487.3±0.07^{Aa}	485.01±0.00^{Bd}	481.43±0.10^{Cf}
S7	487.24±0.06^{Aa}	486.49±0.10^{Ba}	486.04±0.10^{Cb}
S8	487.24±0.11^{Aa}	486.02±0.10^{Bb}	485.69±0.10^{Cc}

Values are presented as mean±SD. Values with different uppercase superscripts within the same row are statistically significantly different (P<0.05) while values with different lowercase superscripts within the same column are statistically significantly different (P<0.05). S0: untreated mango cubes, S1: mango cubes were treated with 5% gum Arabic coating, S2: mango cubes were treated with 10% gum Arabic coating, S3: mango cubes were treated with 10% seaweed coating, S4: mango cubes were treated with 10% seaweed coating incorporating 5% gum, S5: mango cubes were treated with 10% seaweed coating incorporating 10% gum, S6: mango cubes were treated with 20% seaweed coating, S7: mango cubes were treated with 20% seaweed coating incorporating 5% gum, S8: mango cubes were treated with 20% seaweed coating incorporating 10% gum.

https://doi.org/10.26656/fr.2017.7(6).061

Arabic is used as a stabilizer due to its water absorption properties. The role of gum Arabic in these coating solutions is to help moisture retention and cause a fine texture. Pectin substances occur during fruit ripening and hydrolysis due to the actions of the enzyme. This is caused to fruit softening, the enzyme's actions may be reduced by a low level of O_2 and higher levels of CO_2 which allows the retention of the firmness during storage (Al-juhaimi *et al*., 2013). These results agreed with Kamel (2014) who mentioned that applying sprays of seaweed extract to Valencia orange fruits during cold storage led to a significant increase in the hardness of fruits, on another hand significantly increased as the storage period prolonged. Also, Al-juhaimi *et al*. (2013) reported that fruits coated with gum Arabic had significantly ($p \leq 0.05$) higher firmness values than the control sample during the storage period.

3.2 Effects of coatings on mango fruit pH, titrable acidity and total soluble solids

All the samples, including the control, showed a slightly increasing trend of pH over time, as it is seen on day 14 (Table 2). Throughout the time of storage, the pH values of coated and uncoated samples were not significantly ($P > 0.05$) different. The concentration of seaweed and gum Arabic in the coating did not ($P > 0.05$) have an impact on the pH of the coated mangoes. This finding was supported by those reported by Abdelgader and Ismail (2011), that there is no significant difference in acidity between the control sample and coated sample which was treated with gum Arabic in the third month.

TA value, which is a measure of organic acids, decreases with the senescence process. Organic acids are used as a respiratory substrate with time after harvest (Ediriweera *et al*., 2014). Referring to Table 2, titratable acidity was markedly decreased with increasing storage period in minimally processed mango cubes which were coated with seaweed-based edible coating. Control sample S0 was 0.23 on day 0 and reached 0.19 at the end of the storage period, while the treated samples 5%GA to 20%SP+10%GA ranged from 0.2 to 0.22 at zero time and 0.16 to 0.2 on day 7, and decreased 0.12 to 0.16 on 14 days. There was no significant ($P< 0.05$) difference between the control sample and treated samples on day 14. These results are in agreement with Abdelgader and Ismail (2011).

Changes in the total soluble solids of minimally processed mangoes over the storage period are shown in Table 2. The total soluble solids of fruit increased with increasing storage time. On 0, 7 and 14 days of storage time, the total soluble solids content of control and treated samples were not significantly different ($p>0.05$). The total soluble solid of the control sample was 9.8 at zero time and reached 10.8 at the end of the storage period. The treated samples 5%GA to 20%SP+10%GA ranged from 9.3 to 10.5 at zero time and reached 10.2 to

Table 2. Effect of seaweed-based coating on PH, TA and TSS of minimally processed mango fruits.

Storage day	Samples	pH	TA (%)	TSS
0	S0	4.28±0.45[a]	0.19±0.04[a]	9.83±0.29[a]
	S1	4.10±0.18[a]	0.22±0.03[a]	9.33±0.76[a]
	S2	4.17±0.23[a]	0.20±0.02[a]	9.50±0.50[a]
	S3	4.13±0.39[a]	0.22±0.03[a]	10.50±1.50[a]
	S4	4.24±0.49[a]	0.23±0.05[a]	9.83±0.29[a]
	S5	4.36±0.54[a]	0.22±0.04[a]	9.17±0.29[a]
	S6	4.21±0.53[a]	0.22±0.04[a]	9.50±0.87[a]
	S7	4.24±0.50[a]	0.22±0.04[a]	9.83±0.76[a]
	S8	4.39±0.69[a]	0.22±0.04[a]	9.83±0.29[a]
7	S0	4.24±0.40[a]	0.12±0.03[a]	10.67±0.29[a]
	S1	4.08±0.08[a]	0.18±0.03[ab]	10.00±1.00[a]
	S2	4.12±0.11[a]	0.16±0.02[ab]	10.00±0.50[a]
	S3	4.08±0.14[a]	0.18±0.04[ab]	10.67±1.26[a]
	S4	4.22±0.37[a]	0.20±0.04[a]	10.33±0.29[a]
	S5	4.36±0.40[a]	0.18±0.03[ab]	9.67±0.29[a]
	S6	4.22±0.31[a]	0.18±0.04[ab]	10.33±1.53[a]
	S7	4.24±0.39[a]	0.19±0.04[a]	10.17±1.04[a]
	S8	4.30±0.45[a]	0.19±0.05[a]	10.33±0.29[a]
14	S0	4.32±0.41[a]	0.07±0.02[b]	10.83±0.58[a]
	S1	4.36±0.29[a]	0.13±0.03[a]	10.17±1.04[a]
	S2	4.39±0.25[a]	0.12±0.10[a]	10.33±0.58[a]
	S3	4.29±0.35[a]	0.13±0.40[a]	10.83±1.04[a]
	S4	4.32±0.37[a]	0.16±0.03[a]	10.83±0.29[a]
	S5	4.36±0.39[a]	0.15±0.01[a]	10.83±0.29[a]
	S6	4.35±0.36[a]	0.14±0.04[a]	10.83±1.89[a]
	S7	4.33±0.41[a]	0.16±0.02[a]	10.83±0.76[a]
	S8	4.36±0.37[a]	0.16±0.02[a]	10.83±0.29[a]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different (P<0.05). S0: untreated mango cubes, S1: mango cubes were treated with 5% gum Arabic coating, S2: mango cubes were treated with 10% gum Arabic coating, S3: mango cubes were treated with 10% seaweed coating, S4: mango cubes were treated with 10% seaweed coating incorporating 5% gum, S5: mango cubes were treated with 10% seaweed coating incorporating 10% gum, S6: mango cubes were treated with 20% seaweed coating, S7: mango cubes were treated with 20% seaweed coating incorporating 5% gum, S8: mango cubes were treated with 20% seaweed coating incorporating 10% gum.

https://doi.org/10.26656/fr.2017.7(6).061

10.8 on 14 days. Kamel (2014) reported that Skelton and Senn (1969) on peach fruits and Povolny (1969) on Cox's orange apple fruits spraying seaweed extract had no significant effect on the soluble solids content of fruits, Burns and Echeverria (1990) disclosed that application of wax had no effect on brix level of stored 'Valencia' fruits.

3.3 Weight loss

Table 3 shows the effect of seaweed-based coating on weight loss of minimally processed mango fruits stored at 5°C for different periods of time (0-14 days). Weight loss of the control fruits significantly (P < 0.05) increased following the storage time increase and reached 2.6 and 3.13 % on days 7 and 14 at 5°C, respectively, this may be due to the high respiration rate of the fruit. Fruits coated with a seaweed-based edible coating which contains Arabic gum had less weight loss during storage than the control sample. The effects of seaweed and gum Arabic were significant (P<0.05) on weight loss. The findings show that the lowest decrease in weight loss was seen in 10%SP+10%GA, 10%SP+5% GA, 20%SP+5%GA and 20%SP+10%GA varied from 1.1 to 1.4 % on 14 days. Weight loss of the control

Table 3. The effect of seaweed-based coating on weight loss of minimally processed mango fruits.

Sample	Day 0	Day 7	Day 14
S0	0^{C}	2.60^{Ba}	3.13^{Aa}
S1	0^{C}	1.37^{Bcd}	1.87^{Acd}
S2	0^{C}	1.13^{Bd}	1.70^{Ade}
S3	0^{C}	1.60^{Bbc}	1.97^{Ac}
S4	0^{C}	0.80^{Be}	1.30^{Af}
S5	0^{C}	0.57^{Be}	1.17^{Af}
S6	0^{C}	1.60^{Bbc}	2.00^{Ac}
S7	0^{C}	1.20^{Bd}	1.60^{Ae}
S8	0^{C}	1.90^{Bb}	2.30^{Ab}

Values are presented as mean±SD. Values with different uppercase superscripts within the same row are statistically significantly different (P<0.05) while values with different lowercase superscripts within the same column are statistically significantly different (P<0.05). S0: untreated mango cubes, S1: mango cubes were treated with 5% gum Arabic coating, S2: mango cubes were treated with 10% gum Arabic coating, S3: mango cubes were treated with 10% seaweed coating, S4: mango cubes were treated with 10% seaweed coating incorporating 5% gum, S5: mango cubes were treated with 10% seaweed coating incorporating 10% gum, S6: mango cubes were treated with 20% seaweed coating, S7: mango cubes were treated with 20% seaweed coating incorporating 5% gum, S8: mango cubes were treated with 20% seaweed coating incorporating 10% gum, SP: seaweed paste, GA: gum Arabic.

sample significantly (p≤0.05) increased with storage time and reached 2.7% on day 14. These results concluded that seaweed-based coatings used on minimally processed mangoes were effective in reducing water loss when gum Arabic was applied in the coating formulation. The basic mechanism of weight loss from fresh fruit is through vapor pressure, although respiration also causes weight loss (Bhowmik and Pan, 1992; Yaman and Bayoindirli, 2002; Al-juhaimi, 2013). The coating has a semi-permeable barrier property against O_2, CO_2, moisture and solute movement and this causes a reduction in respiration rates and weight loss (Baldwin *et al*., 1999; Park, 1994; Al-juhaimi, 2013). Rojas-Grau *et al*. (2008) reported that sodium alginate-based coatings used on minimally processed apples were effective in reducing water loss *(*Ghavidel *et al*., 2013). Azarakhsh *et al*. (2012) reported that hydrophilic nature and high concentrations of alginate, gellan and glycerol led to a reduction in weight loss. Fruits coated with gum Arabic had less weight loss than the control sample during storage, and weight loss increased gradually during the storage period (Al-juhaimi *et al*., 2012). The results obtained indicated that gum significantly (p≤0.05) reduced weight loss and acted as a barrier against water loss. Wyasu and Okereke (2012) concluded that high-quality film was obtained from the gum Arabic solution with 10% of the plasticizers or cross-linking agents.

3.4 Microbiological analysis

The changes in total plate count, yeast and moulds and coliform of mango cubes stored at 5°C are shown in Table 4. The initial TPC of the mango cubes was 0.0×10^{6} CFU/g on day 0. After storage for 7 days, the TPCs of the control sample increased more observably than 5% GA, 10%GA, 10%SP, 20%SP, 10%SP+5%GA, 20% SP+10%GA, 20%SP+5%GA and 20%SP+10%GA. Treatment 10%SP+5%GA, 10%SP+10%GA, 20% SP+5%GA and 20%SP+10%GA had a better effect than 5%GA, 10%GA, 10%SP and 20%SP, although there was significant difference (P < 0.05). Treatment 10%GA and 10%SP had a better effect than 20%SP and 5%GA (P <0.05), but no significant difference between 20%SP and 5%GA. After storage for 14 days, 20%SP had a better effect than 5%GA (P < 0.05). This indicated that gum Arabic incorporated in the seaweed-based coating could strongly inhibit the growth of TPC. This may be the sample antimicrobial effect of seaweed and gum Arabic resulting in a decrease in the number of the colony. It has been reported that seaweed sprays applied to peach trees generally affected in better shelf life of treated fruits. Past 21 days, more than 50% of uncoated peaches were spoiled, compared to less than 20% of the fruit getting seaweed sprays (Skelton and Senn, 1969). Similar results had been found that gum Arabic edible coating (Addai *et*

Table 4. Total plate count, yeast and mould and total coliform for minimally processed mango fruits treated with different concentration and stored at 5°C for 0, 7 and 14 days.

Storage day	S0	S1	S2	S3	S4	S5	S6	S7	S8
Total plate count (CFU/g)									
Day 0	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}
Day 7	2.8×10^{6Ba}	2.6×10^{6Bb}	2.1×10^{6Bc}	2.2×10^{6Bc}	1.1×10^{6Bd}	1.1×10^{6Bd}	2.6×10^{6Bb}	1.1×10^{6Bd}	1.1×10^{6Bd}
Day 14	3.9×10^{6Aa}	3.5×10^{6Ab}	2.9×10^{6Ad}	3.0×10^{6Ad}	1.7×10^{6Ae}	1.6×10^{6Ae}	3.1×10^{6Ac}	1.6×10^{6Ae}	1.6×10^{6Ae}
Yeast and mould (CFU/g)									
Day 0	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}
Day 7	2.3×10^{6Ba}	1.7×10^{6Bb}	1.4×10^{6Bc}	1.4×10^{6Bc}	1.1×10^{6Bd}	1.0×10^{6Bd}	1.5×10^{6Bc}	1.0×10^{6Bd}	1.2×10^{6Bd}
Day 14	3.8×10^{6Aa}	3.1×10^{6Ab}	2.3×10^{6Ac}	2.4×10^{6Ac}	1.9×10^{6Ad}	1.8×10^{6Ad}	2.4×10^{6Abc}	1.8×10^{6Ad}	1.9×10^{6Ad}
Total coliform content (CFU/g)									
Day 0	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}	0.0×10^{6Ca}
Day 7	2.5×10^{6Ba}	2.5×10^{6Ba}	1.9×10^{6Bb}	2.0×10^{6Bb}	1.5×10^{6Bd}	1.5×10^{6Bd}	2.0×10^{6Bb}	1.7×10^{6Bc}	1.7×10^{6c}
Day 14	3.7×10^{6Aa}	3.3×10^{6Ab}	2.8×10^{6Ad}	3.1×10^{6Ac}	2.2×10^{6Aef}	2.1×10^{6Af}	3.1×10^{6Ac}	2.2×10^{6Ae}	2.2×10^{6Ae}

Values are presented as mean±SD, n = 3. Values with different uppercase superscripts within the same column are statistically significantly different (P<0.05) while values with different lowercase superscripts within the same row are statistically significantly different (P<0.05). S0: untreated mango cubes, S1: mango cubes were treated with 5% gum Arabic coating, S2: mango cubes were treated with 10% gum Arabic coating, S3: mango cubes were treated with 10% seaweed coating, S4: mango cubes were treated with 10% seaweed coating incorporating 5% gum, S5: mango cubes were treated with 10% seaweed coating incorporating 10% gum, S6: mango cubes were treated with 20% seaweed coating, S7: mango cubes were treated with 20% seaweed coating incorporating 5% gum, S8: mango cubes were treated with 20% seaweed coating incorporating 10% gum.

al., 2013) could inhibit the bacteria growth in Papaya fruit.

The changes in yeast and moulds of mango cubes stored at 5°C are shown in Table 4. It had a similar current on the changes of yeast, moulds and total plate count of all samples. The initial yeast and moulds of the mango cubes were 0.0×10^6 CFU/g at day 0. On day 7, the yeast and moulds ranged from 1.0×10^6 to 1.7×10^6 CFU/g in all coated samples. The uncoated sample was 2.9 x10^6 CFU/g on day 7, after 14 days of storage it reached 4.1×10^6 CFU/g, in all coated samples ranging from 1.8×10^6 to 3.1×10^6 CFU/g. Treated samples had a better effect than untreated samples. The highest inhibitory effects on yeast and mould growth in mango cubes samples were 10%SP+5%GA, 10%SP+10%GA, 20% SP+5%GA and 20%SP+10%GA, followed by 10%GA, 10%SP and 20%SP. Among all of the treated samples, Treatment 10%SP+5%GA, 10%SP+10%GA, 20% SP+5%GA and 20%SP+10%GA had significantly highest (P < 0.05) inhibitory effects on yeast and mould growth in mango cubes, although there was no significant difference between 10%SP+5%GA, 10% SP+10%GA, 20%SP+5%GA and 20%SP+10%GA (P > 0.05).

Coliform is an indicator organism that is used in the examination of different types of foods (Roberts and Greenwood, 2003; Addai *et al*., 2013). This indicates the quality of the food by showing the available contamination. On day 7, the coliform growth number of the control sample had 3.1×10^6 CFU/g, this change was not significantly different (P > 0.05) compared to 5% GA, in contrast, this number was significantly higher (P<0.05) than 10%GA, 10%SP, 10%SP+5%GA, 0% SP+10%GA, 20%SP, 20%SP+5%GA and 20%SP+10% GA on day 7. After 14 days of storage, the coliform number of the control sample reached 3.9×10^6 CFU/g, in all coated samples ranging from 2.1×10^6 to 3.3×10^6 CFU/g. Treated samples had a better effect than the untreated samples. 10%GA, 10%SP, and 20%SP significantly inhibited the growth of the coliform than 5%GA (P < 0.05). 10%GA had a significantly better (P < 0.05) effect than 10%SP and 20%SP. The highest inhibitory effects on coliform growth in mango cube samples were 10% SP+5%GA and 10%SP+10%GA, followed by 20% SP+5%GA and 20%SP+10%GA. Among all the treated samples Treatment 10%SP+5%GA and 10%SP+10%GA had the highest inhibitory effects on coliform growth in mango cubes, although there was no significant difference between 10%SP+5%GA, 20%SP+5%GA and 20%SP+10%GA (P > 0.05). The levels of detected microbes fit within the allowed ranges in previous reports such as 1×10^7 CFU/g. The fungal growth is due to moisture loss, the release of ions and other cell components, which provide a rich medium for the development of the microorganisms and the growth of the fungus is prevented with the application of edible coating (Brackett, 1987).

3.5 Sensory analysis

Sensory evaluation was conducted by 12 trained panelists and the results are shown in Figures 1-5. Coded

https://doi.org/10.26656/fr.2017.7(6).061

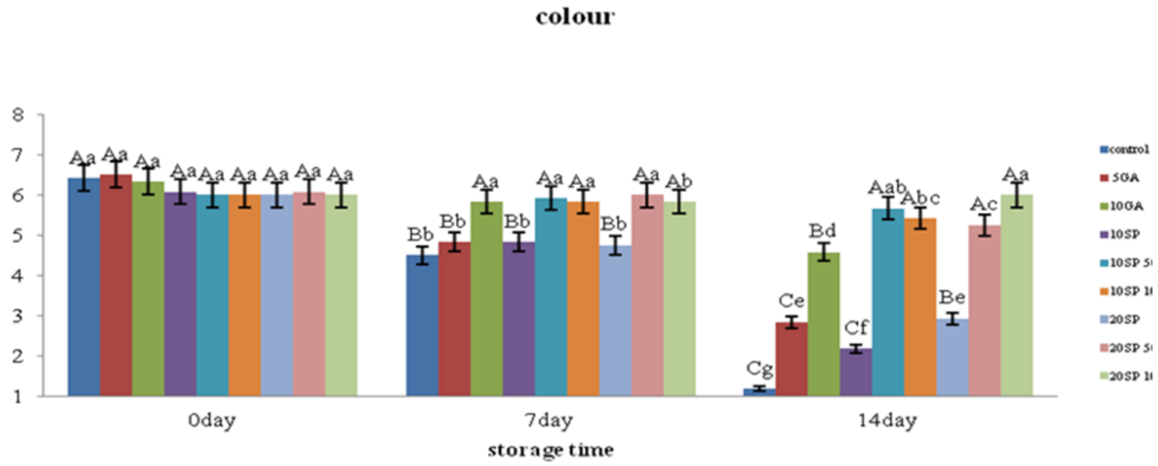

Figure 1. Sensory colour analysis scores for control (uncoated) and coated minimally processed mango fruit on day 0, 7 and 14 of storage at 5°C. Bars with different uppercase notations are statistically significantly different within the same colour (P<0.05) while bars with different lowercase notations are statistically significantly different within groups (P<0.05). SP: seaweed paste, GA: gum Arabic.

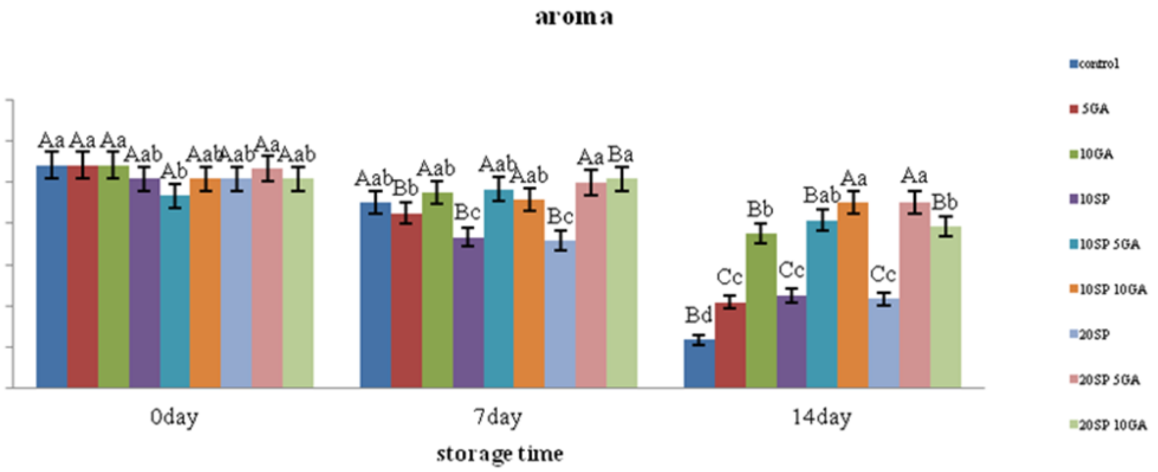

Figure 2. Sensory aroma analysis scores for control (uncoated) and coated minimally processed mango fruit on day 0, 7 and 14 of storage at 5°C. Bars with different uppercase notations are statistically significantly different within the same colour (P<0.05) while bars with different lowercase notations are statistically significantly different within groups (P<0.05). SP: seaweed paste, GA: gum Arabic.

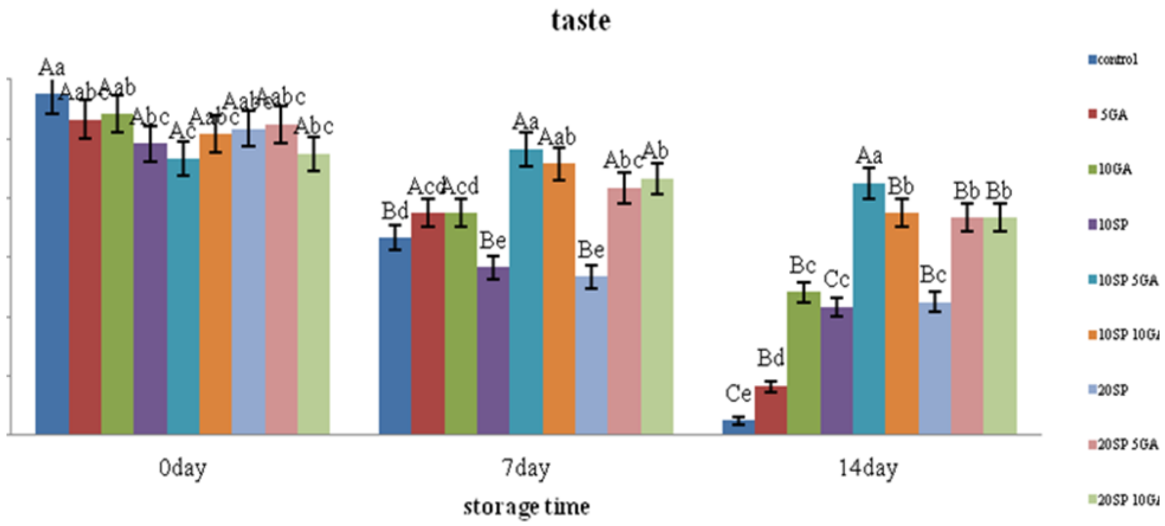

Figure 3. Sensory taste analysis scores for control (uncoated) and coated minimally processed mango fruit on day 0, 7 and 14 of storage at 5°C. Bars with different uppercase notations are statistically significantly different within the same colour (P<0.05) while bars with different lowercase notations are statistically significantly different within groups (P<0.05). SP: seaweed paste, GA: gum Arabic.

https://doi.org/10.26656/fr.2017.7(6).061

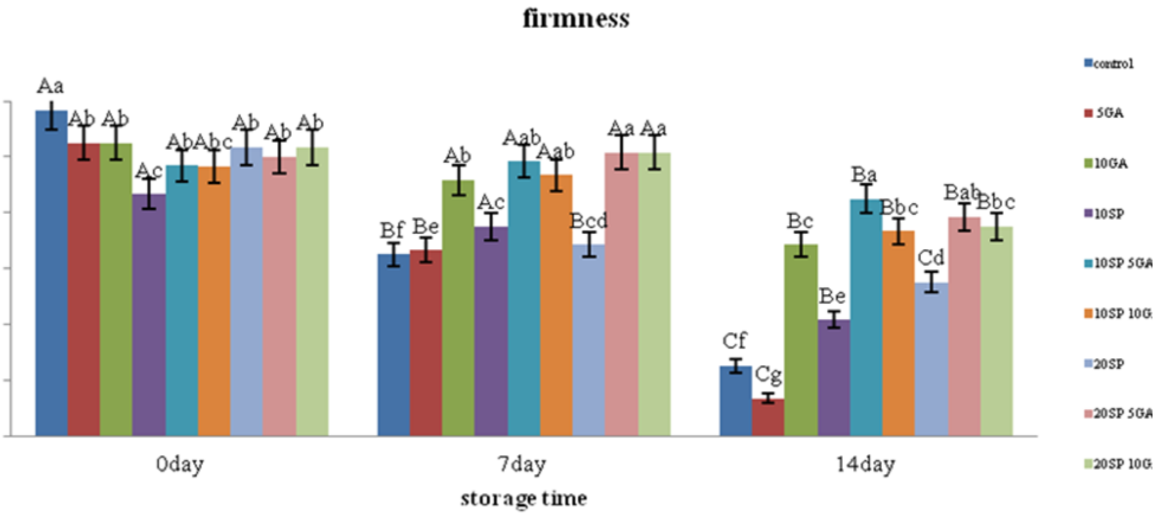

Figure 4. Sensory firmness analysis scores for control (uncoated) and coated minimally processed mango fruit on day 0, 7 and 14 of storage at 5°C. Bars with different uppercase notations are statistically significantly different within the same colour (P<0.05) while bars with different lowercase notations are statistically significantly different within groups (P<0.05). SP: seaweed paste, GA: gum Arabic.

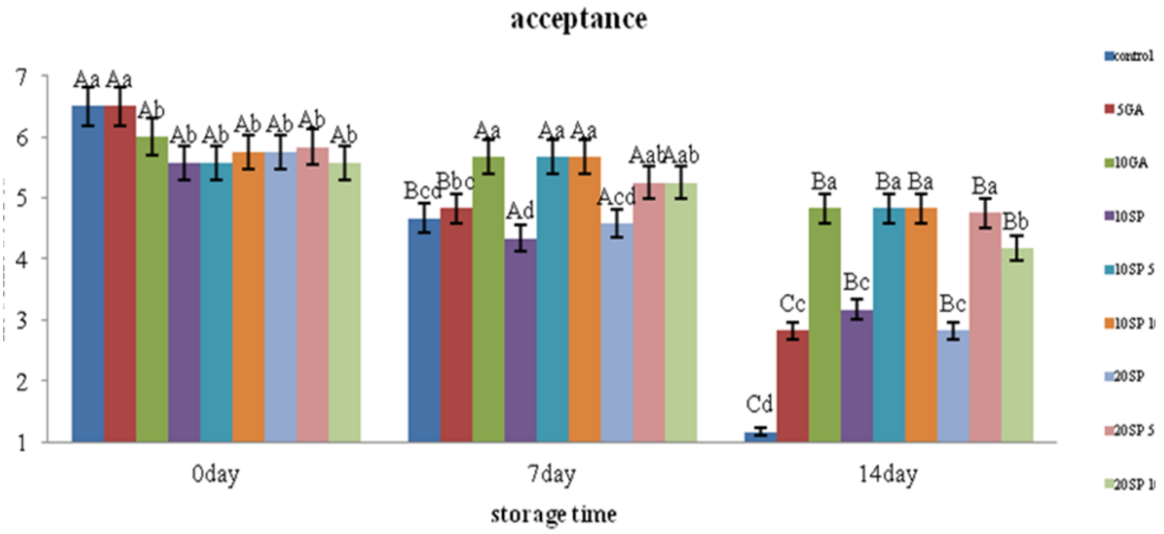

Figure 5. Overall acceptance scores for control (uncoated) and coated minimally processed mango fruit on day 0, 7 and 14 of storage at 5°C. Bars with different uppercase notations are statistically significantly different within the same colour (P<0.05) while bars with different lowercase notations are statistically significantly different within groups (P<0.05). SP: seaweed paste, GA: gum Arabic.

samples were introduced to panelists to evaluate the aroma, taste, surface color, firmness and overall acceptability of all samples at each interval. On day 0, there were no significant differences (P>0.05) between uncoated and coated mangoes, on day 14, the liking scores of uncoated and coated mangoes were significant differences (P<0.05) in color, aroma, taste, firmness and overall acceptability.

The color acceptability of control and treated fruits gradually decreased with the storage time. The acceptability of the color significantly ($p \leq 0.05$) decreased on day 14, especially for the control sample. However, coated samples 10%GA, 10%SP+5%GA, 10%SP+10%GA, 20%SP+5%GA and 20%SP+10%GA retained the brightness and yellow color of the fruits. All other sensory attributes such as aroma, taste, firmness and overall acceptability followed a trend similar to that obtained for the color. The coated samples 10%GA, 10%SP+5%GA, 10%SP+10%GA, 20%SP+5%GA and 20%SP+10%GA had the highest scores in most parameters on day 14 of storage. The control sample had the lowest score for the quality attributes and treated samples 5%GA, 10%SP, 20%SP had lower scores compared to the 10%GA, 10%SP+5%GA, 10%SP+10%GA, 20%SP+5%GA and 20%SP+10%GA. There was no significant (P>0.05) difference in liking score between the 10%SP+5%GA, 10%SP+10%GA, 20%SP+5%GA and 20%SP+10%GA. The results obtained suggest that seaweed coating with gum Arabic can be utilized successfully as an edible coating for extending the shelf-life and preserving minimally processed mangoes quality during storage at 5°C. The most attractive mango cubes with the characteristic best taste and firmness were found in the fruits with 10% seaweed paste mixed with 5% gum Arabic, which was rated excellent because the mango

https://doi.org/10.26656/fr.2017.7(6).061

cube was not only sweet and pleasant but also possessed a characteristic aroma. Seaweed has a strong gel-forming ability, gum Arabic is used as an emulsifier which increases the viscosity of the seaweed-based coating solution, and this could help to control the texture, flavor and shelf-life of minimally processed mangoes.

The results were supported by the study of Skelton and Senn (1969), which reported that seaweed sprays applied to peach trees generally resulted in a greater shelf-life of treated fruits. Al-juhaimi *et al.* (2012) have experimented with gum Arabic and reported that gum Arabic coating postponed the sensory quality deterioration of cucumber and fruits and vegetables are severely stressed after harvesting due to a decrease in the sources of energy, nutrients, hormones and water, and also this leads to rapid quality deterioration. Similarly, Addai *et al*. (2013) reported that gum Arabic coating changes in eating quality of papaya fruit. In the case of minimally processed mangoes, the most important signs of deterioration are browning and softening due to water loss. Seaweed coating with gum Arabic might reduce the loss of energy, nutrients, hormones and water by acting as a barrier and therefore prevent loss of weight and delay the initiation of deterioration which reduces the firmness and the sensory attributes of mango fruit. We can infer based on this study that minimally processed mango fruits coated with seaweed (10 and 20% SP) and gum Arabic (10% GA and 5% GA) showed a significant delayed sensory quality deterioration up to 14 days at 5° C of storage temperatures. In addition, sensory evaluation for color, aroma, taste, firmness and overall acceptability showed that seaweed coating with gum Arabic maintained the overall quality of the minimally processed mangoes during storage.

4. Conclusion

Seaweed-based edible coating could prolong minimally processed mangoes during storage at 5°C for 14 days. The 10% and 20% seaweed paste mixed with 5% and 10% (w/w) gum Arabic coating solutions were the most effective and desirable edible coating for application on minimally processed mango. Those solutions could reduce weight loss, maintain total soluble solids and retard the growth of microorganisms in minimally processed mangoes compared with the non-treated product at the end of the storage period and it also had better sensory quality. The best formulation of the coating in terms of low cost and the preservation of quality attributes of minimally processed mango fruit is the one made with 10% seaweed paste mixed with 5% gum Arabic. This particular treatment was shown to be an effective alternative to maintaining mango's original quality and preserving it for longer (14 days). Therefore, the application of seaweed appears highly promising in the food industry for maintaining minimally processed mangoes during refrigerated storage.

Acknowledgements

This research was supported by the National University of Malaysia under project Numbers STGL-004-2007 and STGL-016-2012.

References

Abdelgader, M.O. and Ismail. I.A. (2011). Application of Gum Arabic for Coating of Dried Mango Slices. *Pakistan Journal of Nutrition,* 10(5), 457-462. https://doi.org/10.3923/pjn.2011.457.462

Addai, Z.R., Abdullah, A., Mutalib, S.A. and Musa, K.H. (2013). Effect of Gum Arabic on Quality and Antioxidant Properties of Papaya Fruit during Cold Storage. *International Journal of ChemTech Research*, 5(6), 2854–2862.

Al-juhaimi, F., Ghafoor, K. and Babiker, E.E. (2013). Effects of Arabic gum coating on physico-chemical properties and kinetics of color change in tomato (*Solanum lycopersicum* L.) fruits during storage. *Journal of Food, Agriculture and Environment*, 11 (2), 142-148

Almuslet, N.A., Hassan, E.A. and Abd-el-magied, A.S. (2012). Diode Laser (532 nm) Induced Grafting of Polyacrylamide onto Gum Arabic. *Journal of Physical Science*, 23(2), 43–53.

Association of Official Analytical Chemists (AOAC). (1998). Official methods of analysis. Washington, DC., USA: AOAC.

Azarakhsh, N., Osman, A., Ghazali, H.M., Tan, C.P. and Mohd, A.N. (2012). Optimization of alginate and gellan-based edible coating formulations for fresh-cut pineapples. *International Food Research Journal,* 19(1)*,* 279-285.

Baldwin, E.A., Burns, J.K., Kazokas, W., Brecht, J.K., Hagenmaier, R.D., Bender, R.J. and Pesis, E. (1999). Effect of two edible coatings with different permeability characteristics on mango (*Mangi feraindica* L.) ripening during storage. *Postharvest Biology and Technology,* 17(3), 215-226. https://doi.org/10.1016/S0925-5214(99)00053-8

Bhowmik, S.R. and Pan, J.C. (1992). Shelf life of mature green tomatoes stored in controlled atmosphere and high humidity. *Journal of Food Science,* 57(4), 948-953. https://doi.org/10.1111/j.1365-2621.1992.tb14331.x

Brackett, R.E. (1987). Microbiological consequences of minimally processed fruits and vegetables. *Journal* *of Food Quality,* 10(3), 195-206. https://doi.org/10.1111/j.1745-4557.1987.tb00858.x

Burns, I.K. and Echeverria, E. (1990). Quality changes during harvesting and handling of Valencia oranges. *Proceedings of the Florida State Horticulture Society,* 103, 225-228.

Castricini, A., Coneglian, R.C.C. and Deliza, R. (2012). Starch edible coating of papaya: effect on sensory characteristics. *Ciência e Tecnologia de Alimentos*, 32(1), 84-92. https://doi.org/10.1590/S0101-20612012005000016

Contador, L., Shinya, P., Bunger, A., Sáenz, C. and Infante, R. (2014). Training a sensory panel for describing texture in peach and nectarines. *Journal of Food Agriculture and Environment*, 12(3), 65–70.

Ediriweera, S., Abeywickrama, K., Latifah, M., Othaman, F., Hussin, R.W. and Tham, S. (2014). Quality of minimally processed, modified atmosphere stored bell pepper, as affected by pre-treatments. *Tropical Agricultural Research and Extension*, 16(2), 40-48. https://doi.org/10.4038/tare.v16i2.5273

Gaspar, M.E.M. (2011). Edible coating development for fresh-cut cantaloupe. Texas, USA: Texas A&M University. MSc. Thesis.

Ghavidel, R.A., Davoodi, M.G. and Adib, A.F. (2013). Effect of selected edible coatings to extend shelf-life of fresh-cut apples. *International Journal of Agriculture and Crop Sciences,* 6, 1171–1178.

Kader, A.A. (2008). Fresh-cut mangos as a value-added product (literature review and interviews) Retrieved from website: http://ucanr.edu/datastoreFiles/608-653.pdf.

Kamel, H.M. (2014). Impact of Garlic Oil, Seaweed Extract and Imazalil on Keeping Quality of Valencia Orange Fruits During Cold Storage. *Journal of Horticultural Science and Ornamental Plants,* 6(3), 116–125.

Nithiya, R. and Alley E.W. (2000). Respiration rate and respiratory quotient of fresh-cut mango (*Mangifera indica L.*) in low oxygen atmosphere. *Acta Hort*, 509, 472-478.

Nithiya, R., Yuen, L., Tianxia, W. and Alley. E.W. (2001). Quality and Microbial Changes of Fresh-cut Mango Cubes Held in Controlled Atmosphere. *Hortscience,* 36(6), 1091–1095. https://doi.org/10.21273/HORTSCI.36.6.1091

Nongtaodum, S. and Jangchud, A. (2009). Effects of edible chitosan coating on quality of fresh-cut mangoes (Fa-lun) during storage. *Kasetsart Journal - Natural Science*, 43(5), 282–289.

Park, H.J., Chinnan, M.S. and Shewfelt, R.L. (1994). Edible coating effects on storage life and quality of tomatoes. *Journal of Food Science*, 59(3), 568-570. https://doi.org/10.1111/j.1365-2621.1994.tb05563.x

Povolny, M. (1969). Einflus Des Extrakts Von Seealgen Auf Di Lagerungs AehigkeitVon Aepflen, presented at the Proceedings of the 6th International Seaweed Sypmosium, p. 703-713. Santiago de Compostella, Madrid, Spain: Subsecretaria de la Marina Mercante.

Rajasulochana, P., Krishnamoorthy, P. and Dhamotharan, R. (2010). Amino acids, fatty acids and minerals in *Kappaphycus* sp. *ARPN Journal of Agricultural and Biological Science*, 5, 1–12.

Roberts, D. and Greenwood, M. (2003). Practical Food Microbiology. United Kingdom: Blackwell Publishing Ltd. https://doi.org/10.1002/9780470757512

Rocculi, P., Romani, S., Gómez, F. and Rosa, M.D. (2009). Effect of Minimal Processing on Physiology and Quality of Fresh-Cut Potatoes: a Review. *Global Science Books Journals,* 3(1), 18-30.

Rojas-grau, M.A., Tapia, M.S. and Martı, O. (2008). Using polysaccharide-based edible coatings to maintain quality of fresh-cut Fuji apples, *LWT- Food Science and Technology,* 41(1), 139–147. https://doi.org/10.1016/j.lwt.2007.01.009

Shobana, V. and Rajalakshmi, K. (2010). Quantitative analysis of primary metabolites in *Mangifera indica* (unripe mango). *Rasayan Journal of Chemistry*, 3(3), 597–599.

Siah, W.M., Aminah, A. and Ishak, A. (2014). Optimization of soaking conditions for the production of seaweed (*Kappaphycus alverazii*) paste using response surface methodology. *International Food Research Journal,* 21, 471-477.

Skelton, B.J. and Senn, T.L. (1969). Effect of seaweed sprays on quality and shelf life of peaches presented at the Proceedings of the 6th International Seaweed Sypmosium, p. 731-735. Santiago de Compostella, Madrid, Spain: Subsecretaria de la Marina Mercante.

Wyasu, G. and Okereke, N.Z-J. (2012). Improving the film forming ability of gum Arabic. *Journal of Natural Product and Plant Resources,* 2(2), 314–317.

Xiren, G.K. and Aminah, A. (2014). Elimination of seaweed odour and its effect on antioxidant activity. *AIP Conference Proceedings,* 1614, 399-401.

Yaman, O. and Bayoindirli, L. (2002). Effects of an edible coating and cold storage on shelf-life and quality of cherries. *Lebensmittel - Wissenschaft und Technologie,* 35(2), 46-150. https://doi.org/10.1006/fstl.2001.0827

https://doi.org/10.26656/fr.2017.7(6).061