

Psyllium (*Plantago*) Gum as an Effective Edible Coating to Improve Quality and Shelf Life of Fresh-cut Papaya (*Carica papaya*)

Basharat Yousuf, Abhaya K. Srivastava

Abstract—Psyllium gum alone and in combination with sunflower oil was investigated as a possible alternative edible coating for improvement of quality and shelf life of fresh-cut papaya. Different concentrations including 0.5, 1 and 1.5 percent of psyllium gum were used for coating of fresh-cut papaya. In some samples, refined sunflower oil was used as a lipid component to increase the effectiveness of coating in terms of water barrier properties. Soya lecithin was used as an emulsifier in coatings containing oil. Pretreatment with 1% calcium chloride was given to maintain the firmness of fresh-cut papaya cubes. 1% psyllium gum coating was found to yield better results. Further, addition of oil helped to maintain the quality and acted as a barrier to water vapour, therefore, minimizing the weight loss.

Keywords—Coating, fresh-cut, gum, papaya, psyllium.

I. INTRODUCTION

PAPAYA (*Carica papaya* L.), a tropical fruit is a globally important fruit and is a good source of various important dietary components including vitamin A, ascorbic acid, lycopene. The edible part of papaya has a firm texture with a smooth fruit surface, sweet taste and is orange to red in colour [1]. It is a climacteric fruit and has a very short shelf life [2].

Fresh-cut fruits and vegetables are being welcomed by the consumers due to the desire for new and natural products coupled with change in life style of the consumers. Fresh-cut papaya provides convenience and quality which could create great marketing opportunities [3]. However, fresh-cut fruits are more susceptible to spoilage than whole fresh fruit due to the influence of different processing steps during the preparation of fresh-cut fruits [4], [5]. In order to prolong their shelf life, many studies have been conducted including coating of fresh-cut papaya fruit. Edible coatings, being environmentally friendly are attaining popularity among people worldwide. Coating is considered a convenient and safe method and is therefore, more and more concerned in food industry [6]. This is a promising technology to preserve the quality and to prolong shelf life of fresh fruits and vegetables [7].

Different reports exist in recent literature regarding the use of polysaccharide-based edible coatings for fresh-cut products [8]–[11]. Besides, some popular polysaccharide materials,

Basharat Yousuf and Abhaya K. Srivastava are with the Department of Post-Harvest Engineering and Technology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh-202002, India (corresponding author; phone: 95557710717; e-mail: yousufbasharat@gmail.com, aksrivastava8@rediffmail.com).

various types of natural gums of plant origin have been investigated. For instance, basil seed gum [12], locust bean gum [13] and flaxseed gum [14].

Use of oil as a component in composite coatings has also been reported as the lipid components being hydrophobic, may play an important role by acting as an excellent water barrier [15], [16].

In this study, psyllium gum alone and in combination with sunflower oil was investigated as a possible alternative edible coating for improvement of quality and shelf life of fresh-cut papaya. Pre-treatments to fresh-cut papaya with calcium chloride were also applied in this study. Treatments with calcium salts have long been used to keep the tissue firm and extend the postharvest life of the fruits [17].

Psyllium gum is a mucilaginous substance that is traditionally obtained from Psyllium seed husk, which is good source of both soluble and insoluble fibers [18]. To the best of our knowledge, this is probably the first ever study utilizing psyllium gum as a coating material for quality maintenance and shelf life extension of fresh-cut papaya.

II. MATERIALS AND METHODS

A. Papaya

Fresh papaya of single variety, uniform colour, shape, size and maturity were procured from local market of Aligarh, India. Papaya free from defects were washed and allowed to equilibrate at 5°C. Papayas were peeled by using sharp peelers and cut into two equal halves. Seeds were scraped off from the halves. The halves were further processed by preparing uniform cube (1.5 cm) shaped pieces with the help of sharp edged knives. Food grade polyethylene gloves were used during each step of preparation of papaya cubes.

B. Packaging Materials

Polypropylene (PP) trays and transparent polyethylene (PE) wrapping films were used for the purpose of packaging of papaya cubes after application of coating for further analysis.

C. Extraction of Psyllium Gum

Psyllium gum was extracted according to the method described by [19] with modifications. Psyllium husk (Dabur India Limited) (50 gram) was dispersed in a beaker containing 2000 ml of deionized water kept in a water bath at a temperature of 60-70°C for 2 hours. The mixture was stirred intermittently while in water bath and was then kept for overnight at ambient temperature. Overnight stay resulted in

the separation of the mixture into three clearly distinct layers or portions. The upper portion containing lighter husk particles was carefully removed from the beaker. The bottom layer of the mixture contained heavier husk and any other extraneous material. The middle portion, free from any particulate matter, was clear psyllium gum which was carefully collected in another beaker. The gum so collected was then dried in a power assisted microwave oven (Kenstar, KE-20 CMGJ-MGK) modified to include hot air convection system. The gum was dried on a Teflon plate in order to avoid sticking of gum with container. The dried material was ground to powder in a laboratory grade grinder and was stored in a clean glass container for further use.

D. Coating Preparation and Experimental Design

Coatings of different concentrations were prepared by dissolving appropriate amount of psyllium gum powder in distilled water. The mixtures were heated and stirred to dissolve the powder efficiently. Prepared fresh-cut papaya cubes were divided into seven parts (samples). Samples were coated with psyllium gum alone and in combination with refined sunflower oil. The treatments were chosen based on the various preliminary trials. First sample (G1) was treated with 0.5% psyllium gum, second sample (G2) was treated with 1% psyllium gum and third (G3) was treated with 1.5% psyllium gum. Fourth (G1O), fifth (G2O) and sixth (G3O) sample was treated with coatings containing 0.5%, 1% and 1.5% psyllium gum respectively plus 0.5% refined sunflower oil for each treatment. Soya lecithin (CDH Chemicals, India) was used as an emulsifier to dissolve the oil effectively. Seventh sample (C) was not given any treatment and was labeled as control. All the samples except control (C) were given a pretreatment with 1% calcium chloride. The samples were placed in polypropylene trays and wrapped with transparent polyethylene wrapping films. The packed trays were stored at 4°C for further analysis and shelf life studies.

E. Weight Loss

Laboratory level electronic weighing balance (BL-220H, Shumadzu® Corporation, Japan) with accuracy of 0.001g was used to measure the net weight of whole package on day zero and on each subsequent day of analysis. The values were recorded and are reported as the percent weight loss as

$$\text{Weight loss (\%)} = \frac{(\text{initial weight}) - (\text{final weight})}{(\text{initial weight})} * 100$$

F. Total Soluble Solids (TSS)

Total soluble solids (TSS) content was measured by the method described by [20]. Samples were crushed manually to extract juice. TSS of the juice was measured by a bench refractometer (Metzer Optical Instruments, India) and values are expressed as degree brix.

G. pH

pH was measured by the method described by [21]. 10g of papaya was homogenized with 100 ml of distilled water was determined by using a digital pH meter (Cyberscan pH-1500,

Ectech Instruments, Singapore). The results were recorded on each day of analysis and expressed as unit of pH.

H. Titrable Acidity

Titrable acidity was determined by the AOAC method described in [22] and reported by [23]. 10 g of papaya pulp was crushed and homogenized with 40 ml of distilled water. The samples prepared were titrated with 0.1 N NaOH using phenolphthalein as indicator. Results were expressed as percentage with respect to citric acid.

I. Colour

Colour of papaya samples was determined by Hunter Lab Colorimeter (Mini Scan XE Plus, USA). Prior to measuring the colour of samples, the instrument was calibrated with black and white tiles supplied with the instrument. The results were displayed on the screen of the instrument in terms of L*, a* and b* values. Readings for each colour component (L*, a* and b*) were the average of three measurements. Colour change (ΔE) was determined for all the samples on each day of analysis.

J. Ascorbic Acid

Ascorbic acid content was determined by the AOAC method described in [24]. 10 g papaya pulp was homogenized with 90 ml of 3% metaphosphoric acid solution. 5 ml of aliquot was taken and titrated with 2, 6-dichloroindophenol standard solution. Quantity of titer consumed was recorded and used to calculate ascorbic acid content of sample (milligrams of ascorbic acid/g of sample, wet basis). The dye solution was first standardized by titrating with an ascorbic acid standard solution.

K. Gas Composition

Gas composition (oxygen, carbon dioxide and nitrogen) was measured using a digital gas analyser (Gaspac Advance GS3/P, Systech Instruments). Approximately 80 grams of papaya pieces were placed in PP trays wrapped with PE film. Gas composition inside the package was measured by inserting the needle or suction probe attached with the equipment, into the package through a septum placed on the PE wrapping film. The percentage gas composition was displayed on a small screen provided on the equipment after a while of inserting the needle. Prior to determining the gas composition of samples, the instrument was calibrated with gas composition of air.

L. Sensory Evaluation

Sensory analyses were carried out to see and compare the effect on visual appearance, taste, aroma, texture, juiciness and overall acceptability of the control and coated papaya cubes. The sensory panel consisted of ten semi-trained members including research fellows and faculty members of the department of Post Harvest Engineering and Technology, Aligarh Muslim University, India. The quality parameters were rated (scored) based on nine point Hedonic scale where, 1= extremely dislike; 5= neither like nor dislike; 9= extremely like.

M. Microbiological Analysis

Standard methods of microbiological analysis were used to examine the microbiological quality of papaya samples as described ahead. For each treatment 10 g of sample was homogenized in 90 ml of sterile NaCl solution (peptone water). Serial dilution was done and 1 ml each was added to nutrient agar and potato dextrose agar for total plate count and yeast and mold count respectively. Plates were incubated for 48 h at 37°C for total plate count and at 25°C for 3 days for yeast and mold count.

N. Statistical Analysis

All the analyses were conducted in triplicate and the data was expressed as mean ± standard errors. Results were subjected to Duncan's multiple range tests with ($P < 0.05$) to analyze the data and compare the uncoated and coated samples.

III. RESULTS AND DISCUSSION

A. Weight Loss

Percentage weight loss of fresh-cut papaya is shown in Fig. 1. Significant ($P < 0.05$) physiological weight loss was not observed in all the samples packaged in pp trays and stored under refrigeration. However, there was clearly higher weight loss in control samples than coated ones. The results suggested that the coating reduced the weight loss of fresh-cut papaya cubes. In addition, packaging of papaya samples in pp trays wrapped with LDPE and storing at refrigerated temperatures may also have contributed to less weight loss. Also, it was observed that samples treated with combination of gum and oil had less weight loss than those treated with gum alone. The lipid/oil components being hydrophobic may play an important role by acting as an excellent water barrier [15], [16].

B. Total Soluble Solids

Effect of coating on TSS of fresh-cut papaya samples is presented in Fig. 2. The initial TSS of all the samples on day zero of storage was in the range of 8.5 to 9.0 °B. Total soluble solids were increased with time for all the treated samples. Though, increase in TSS was not very high. In contrast, the control sample showed a decrease in TSS which may be due to degradation and conversion of sugars to acid. Similar results have been reported by [25]. Further, a slight decrease in TSS was observed in all other samples except G1 after 12 day of storage.

C. pH

All the samples showed a decreasing trend for pH (Fig. 3). The initial pH determined immediately after preparation of samples on day zero was above 6 in all samples. The pH of coated samples decreased but in no case was below 5 even after 16th day of storage whereas the pH of control sample dropped below 4.0 after at the end of storage period. Drop in pH values during storage may be attributed to growth of microorganisms and consequent production of organic acids [26].

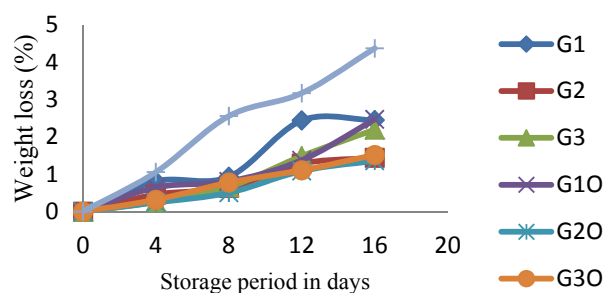


Fig. 1 Effect of coating on physiological weight of fresh-cut papaya

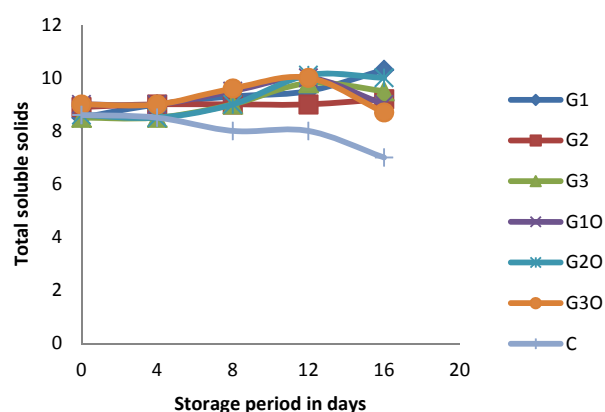


Fig. 2 Effect of coating on TSS of fresh-cut papaya samples

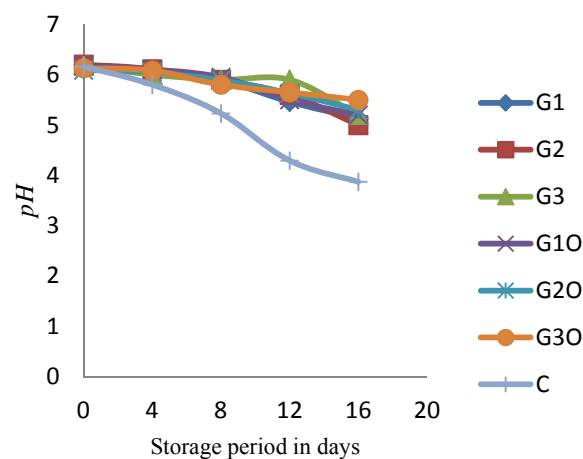


Fig. 3 Effect of coating on pH of fresh-cut papaya samples

D. Titrable Acidity

In case of coated papaya fruit samples, the titrable acidity almost remained constant throughout the storage period as compared to the control sample (Fig. 4). The initial TA of control sample was 0.115 which increased up to 0.185 by the end of storage period. The increase in acidity may be due to the production of organic acids by microorganisms.

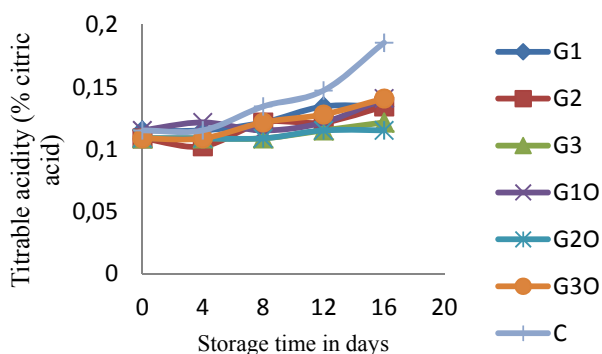


Fig. 4 Effect of coating on titrable acidity of fresh-cut papaya

E. Colour

The effect of coating on colour was monitored by measuring the colour change in terms of L^* , a^* , b^* values. The coatings maintained the colour of fresh-cut papaya cubes. The lightness, L^* values decreased significantly ($P < 0.05$) throughout the storage period and the decrease was more in control sample than the coated samples which indicates that the coatings were able to preserve the natural colour of fresh-cut papaya. The highest L^* values were maintained by combination coating containing 1% gum and oil. The a^* values also decreased throughout storage indicating a reddish colour.

Colour difference (ΔE), measure of qualitative change in sample with respect to the initial sample colour values was measured and is presented in Table I. The total colour change for all the coated samples varied between 7.06 and 13.27 whereas, colour change values crossed 15 for the control sample indicating maximum colour change in uncoated fresh-cut papaya. Lowest colour change was found in samples containing 1% psyllium gum.

TABLE I
COLOUR CHANGE VALUES OF FRESH-CUT PAPAYA

Sample name	Colour change (ΔE)			
	Day 4	Day 8	Day 12	Day 16
G1	5.81 ± 0.87	6.22 ± 0.07	7.28 ± 0.40	13.27 ± 0.58
G2	2.07 ± 0.27	8.09 ± 0.56	9.96 ± 0.46	11.93 ± 0.23
G3	2.51 ± 0.30	2.96 ± 0.17	6.43 ± 0.39	7.06 ± 0.15
G10	2.18 ± 0.84	4.52 ± 0.65	4.79 ± 0.78	8.73 ± 0.28
G20	0.91 ± 0.33	1.93 ± 0.38	4.81 ± 0.52	7.57 ± 0.71
G30	2.79 ± 0.73	3.43 ± 0.64	7.67 ± 0.32	9.62 ± 0.57
C	6.03 ± 0.90	12.42 ± 0.67	15.6 ± 0.02	15.89 ± 0.87

F. Ascorbic Acid

Ascorbic acid retention is an important parameter influencing the quality of the papaya in terms of nutritional values. Ascorbic acid is a labile component and is very sensitive towards heat, light and enzymes. In this study the ascorbic acid content decreased over time in all the samples. There were no significant ($P < 0.05$) differences in ascorbic acid content between the control sample and coated samples immediately after the treatment. Maximum decrease in ascorbic acid content was found to be in uncoated sample,

whereas in comparison the treated samples indicated a less reduction. The values of ascorbic acid content decreased from an initial value of 60 mg/100g sample to 38 mg/ 100g in coated samples and 22 mg/ 100g in control sample. However, the coated samples showed no significant variation in retaining the ascorbic acid. Coated samples were observed to have higher ($P < 0.05$) ascorbic acid content by the end of storage.

G. Gas Composition

Figs. 5 and 6 present the change in CO_2 and O_2 percentages respectively, in the samples. On day zero immediately after packaging the fresh-cut papaya cubes in polypropylene trays and wrapping with polyethylene wrapping films, the oxygen concentration was slightly decreased, whereas carbon dioxide was slightly increased in the packaged samples. After 4 days of storage, carbon dioxide concentration had increased steeply by reaching over 4% and then showed a slow increase over time. The CO_2 concentration, however, never crossed 6.1% in any coated sample and 9.3 in control, possibly due to use of LDPE wrapping films for packaging, which have a good permeability. Increase in CO_2 concentration was observed more in case of control samples. The O_2 concentration decreased due to the respiration of living tissue [27]. Again, the decrease in O_2 percentage was found to be more in control sample. Oxygen concentration decreased to 6.9 on the 16 day of storage.

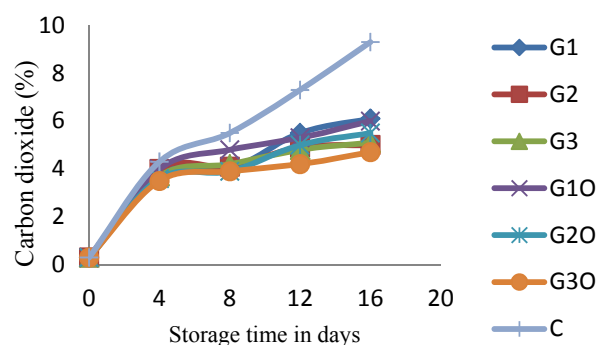


Fig. 5 Effect of coating on carbon dioxide concentration of fresh-cut papaya

H. Sensory Evaluation

Significant ($P < 0.05$) differences in sensory scores of fresh-cut papaya were observed for the uncoated and coated samples. The uncoated sample was below the level of acceptance after tenth day of storage. Juice leakage and accumulation together with surface roughness of the uncoated sample presented an unpleasant appearance. The parameters analyzed by the panelists included visual appearance, texture, aroma, taste, juiciness and overall acceptance. Taking all the sensory attributes into account, the coated samples were observed to possess better quality than the uncoated one. The panelist scores indicated that all the attributes were better retained in the coated samples. The overall acceptability for

some of the coated samples was as good as fresh papaya even on the twelfth day of storage.

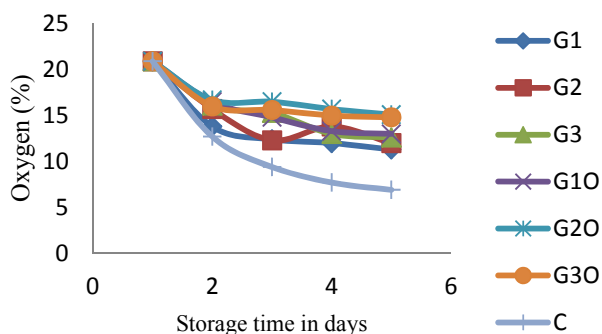


Fig. 6 Effect of coating on oxygen concentration of fresh-cut papaya

I. Microbiological Analysis

Total bacterial count and yeast and mold count were determined on each day of analysis during the storage period. The coating was found very effective in inhibiting bacterial and yeast and mold growth. Coated samples indicated significantly lower counts ($P < 0.05$) throughout storage whereas control showed increased microbial counts with time. Both coated and uncoated papaya samples had increased yeast and mold counts with time, but, the counts in coated samples were always lower ($P < 0.05$) throughout storage. The yeast and mold counts for coated samples does not exceeded 5 log CFU/g except G1 which showed 6 log CFU/g up to twelfth day of storage. The control sample exceeded 10 log CFU/g at the end of storage. The results are in agreement with findings of [28].

IV. CONCLUSION

Psyllium gum can be effectively used as an alternative edible coating for quality maintenance and shelf life improvement of fresh-cut papaya. Coating with combination of psyllium gum and sunflower oil can prolong the shelf life of fresh-cut papaya stored at refrigerated temperature up to two weeks. It can also be conclude that the coating helped to maintain the quality parameters of fresh-cut papaya. 1% psyllium gum in combination with sunflower oil was observed to yield overall better results. Further, use of more than 1.5% gum is not feasible due to the excessive thickness of the gum which poses difficulty while applying the coating to the fresh-cut papaya.

ACKNOWLEDGMENT

The authors are highly thankful to the Department of Post Harvest Engineering & Technology, Aligarh Muslim University, India for providing all the necessary laboratory facilities to carry out this research work. We also appreciate the kind support from all the faculty members of the department.

REFERENCES

- [1] S. Sujiprihati, K. Suketi, "Tanaman Betik", Synergy Media, Kuala Lumpur, 2010.
- [2] G. A. Gonzalez-Aguilar, E. Valenzuela-Soto, J. Lizardi-Mendoza, F. Goycoolea, M. A. Martinez-Tellez, M. A. Villegas-Ochoa, I. N. Monroy-Garcia, and J. F. Ayala-Zavala, "Effect of chitosan coating in preventing deterioration and preserving the quality of fresh-cut papaya 'Maradol'", *J. Sci. Food Agri.*, 89, 15–23, 2009.
- [3] M. M. Wall, K. A. Nishijima, M. M., Fitch, and W. T. Nishijima, "Physicochemical, nutritional and microbial quality of fresh-cut and frozen papaya prepared from cultivars with varying resistance to internal yellowing disease", *J. Food Qual.*, 33, 131–149, 2010.
- [4] P. M. A. Toivonen, and D. A. Brummell, "Biochemical bases of appearance and texture changes in fresh-cut fruit and vegetables", *Postharvest Bio. and Techn.*, 48, 1–14, 2008.
- [5] M. R. Corbo, B. Speranza, D. Campaniello, D. Amato, and M. Sinigaglia, "Fresh-cut fruits preservation: current status and emerging technologies. (Ed. Mendez-velas, A). In: Current research, technology and education topics in applied microbiology and microbial biotechnology. *Formatex research center*. Pp. 1143-1154, 2010.
- [6] N. Mantilla, M. E. Castell-Perez, C. Gomes, and R. G. Moreira, "Multilayered antimicrobial edible coating and its effect on quality and shelf-life of fresh-cut pineapple (*Ananas comosus*)", *Food Sci. and Tech.*, 51, 37-43, 2013.
- [7] R. K. Dhall, "Advances in Edible Coatings for Fresh Fruits and Vegetables: A Review. *Critical Reviews in Food Sci. and Nutr.*, 53, 5, 435-450, 2013.
- [8] P. J. Chien, F. Sheu, F. H. Yang, "Effects of edible chitosan coating on quality and shelf life of sliced mango fruit" *J. of Food Engi.*, 78, 225–229, 2007.
- [9] M. S. Tapia, M. A. Rojas-Grau, A. Carmona, F. J. Rodriguez, R. Soliva-Fortuny, and Martin O. Belloso, "Use of alginate- and gellan-based coatings for improving barrier, texture and nutritional properties of fresh-cut papaya" *Food Hydrcolids*, 22, 1493-1503, 2008.
- [10] G. Oms-Oliu, R. Soliva-Fortuny, and Martin- O. Belloso, "Using polysaccharide-based edible coatings to enhance quality and antioxidant properties of fresh-cut melon" *Food Sci. and Techn.*, 41, 1862-1870, 2008.
- [11] S. L. S. Bico, M. F. J. Raposo, R. M. S. C. Morais, and A. M. M. B. Morias, "Combined effect of chemical dip and / or carrageenan coating and / or Controlled atmosphere on quality of fresh-cut banana", *Food Control*, 20, 508-514, 2009.
- [12] N. Khazaei, M. Esmaili, Z. E. Djomeh, M. Ghasemlou, and M. Jouki, "Characterization of new biodegradable edible film made from basilseed (*Ocimum basilicum* L.) gum" *Carbohydrate Polymers*, 102, 199– 206, 2014.
- [13] C. Rojas-Argudo, M. A. Rio, and M. B. Perez-Gago, "Development and optimization of locust bean gum (LBG)-based edible coatings for postharvest storage of 'Fortune' mandarins" *Postharvest Bio. and Tech.*, 52, 227–234, 2009.
- [14] Y. Wang, D. Li, L. J. Wang, L. Yang, and N. Ozkan, "Dynamic mechanical proper-ties of flaxseed gum based edible films" *Carbohydrate Polymers*, 86, 2, 499–504, 2011.
- [15] V. Morillon, F. Debeaufort, G. Blond, M. Capelle, and A. Voilley, "Factors affecting the moisture permeability of lipid-based edible films: a review", *Crit. Reviews in Food Sci. and Nutr.*, 42,1, 67–89, 2002.
- [16] T. Karbowiak, F. Debeaufort, and A. Voilley, "Influence of thermal process on the structure and functional properties of emulsion-based edible films", *Food Hydrcolids.*, 21, 5–6, 879–888, 2007.
- [17] D. Rico, A. B. Martin-Diana, J. M. Barat, and C. Barry-Ryan, "Extending and measuring the quality of fresh-cut fruit and vegetables: a review" *Trends Food Sci. Techn.*, 18, 373–386, 2007.
- [18] Q. Guo, S. W. Cui, Q. Wang, Y. J. Christopher, "Fractionation and physicochemical characterization of psyllium gum", *Carbohydrate Polymers*, 73, 1, 35-43, 2008.
- [19] S. Banasaz, M. Hojatoleslami, S. H. Razavi, E. Hosseini, and M. A. Shariaty, "The Effect of Psyllium seed gum as an edible coating and in comparison to Chitosan on the textural properties and color changes of Red Delicious Apple" *Inter. J. of Farming and Allied Sci.*, 2, 18, 651-657, 2013.
- [20] X. Dong, R. E. Wrolstad, and D. Sugar, "Extending shelf life of fresh-cut pears", *J. Food Sci.*, 65, 1,181-186, 2000.

- [21] R. B. Waghmare, and U. S. Annapure, "Combined effect of chemical treatment and/or modified atmosphere packaging (MAP) on quality of fresh-cut papaya", *Postharst. Bio. and Tech.*, 85, 147–153, 2013.
- [22] S. Rangana, "Handbook of Analysis and Quality Control for Fruits and Vegetable Products". Tata McGraw-Hill Publication Co. Ltd., New Delhi, pages 105–106, 2006.
- [23] O. S. Qadri, and A. K. Srivastava, "Effect of microwave power on foam-mat drying of tomato pulp", *Agric Eng Int: CIGR Journal*, 16, 3, 238–244, 2014.
- [24] S. Ranganna, *Handbook of analysis and quality control for fruit and vegetable products* (2nd ed.). New Delhi: Tata McGraw-Hill Publishing Company Limited, 2004.
- [25] B. Tirkey, U. S. Pal, L. M. Bal, N. R. Sahoo, C. K. Bakhara, and M. K. Panda, "Evaluation of physico-chemical changes of fresh-cut unripe papaya during storage," *Food Pack. and Shelf Life.*, 1, 190-197, 2014.
- [26] G. M. Heard, "Microbiology of fresh-cut produce" In: Lamikanra, O. (Ed.), *Fresh-Cut Fruits and Vegetables: Science, Technology, and Market*. CRC Press, Boca Baton, FL, pp. 187–248, 2002.
- [27] E. Cocci, P. Rocculi, S. Romani, and M. D. Rosa, "Changes in nutritional properties of minimally processed apples during storage" *Postharvest Biol and Techn.*, 39, 265–271, 2006.
- [28] A. C. S. Arganosa, M. F. J. Raposo, P. Teixeira, & A. M. Morais, "Effect of cut-type on quality of minimally processed papaya", *J. of the Sci. of Food and Agri.*, 88, 12, 2050–2060, 2008.