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STABILITY OF VITAMIN C AND ß-CAROTENE DURING PROCESSING OF PAPAYA GUAVA FRUIT LEATHER

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ABSTRACT

Papayas and guavas are underutilized nutrient rich tropical fruits widely grown in Rwanda. It was envisaged that processing them into novel fruit leather would enhance their consumption. Hence, fruit leather was processed and their acceptability assessed after processing. Papaya (Mexican and Hawaiian varieties) and guava in 60:40 ratio with sugar (45 %) and citric acid (1 %) were blended; dried mechanically and subjected to chemical and sensory analysis. Moisture content was high in fresh fruits both in papayas (89.2%), guavas (84.2%); and decreased (16.4%) upon leather processing. Total Soluble Solids increased from 8.8^{0}Bx to 54.6 ^{0}Bx in Mexican papaya and 8.6 ^{0}Bx to 53 ^{0}Bx for Hawaiian papaya. Total reducing sugar doubled from approximately 8% - 9% in fresh fruits to 20% in the processed fruit leather. Carbohydrate increased by nine times in processed fruit leather when compare to fresh sample. Protein content in fresh papaya (0.55%) and guava (1.3%) increased to 3.35% in papaya leather. Fat in fresh fruits were low (0.2% - 0.5 %) but increased to 1.2% in leather. Vitamin C in both fresh fruits of papaya (20mg / 100g), irrespective of the variety, and guava (24.8 mg/ 100g) were nearly the same. Processing decreased it to 13.3 mg /100g and 13.5 mg /100g in the Mexican and Hawaiian variety respectively; titratable acidity increased while pH decreased (3.8). ß-carotene content in fresh papaya was quite less (0.120 mg / 100g) irrespective of its variety; while in guava it was 3.22 mg / 100g. Thermal processing brought about degradation of carotene content. There was no statistical difference (p-value>0.05; p-value>0.01) between papaya varieties.

1.Introduction

Fruits and vegetables form an integral part of the dietary habits of human beings. They are fundamental sources of vitamins and minerals (Kader, 2001). Vitamins are recognized to be potent compounds that perform vital tasks in the body such as growth, reproduction and maintenance of life. Since vitamins and mineral play a significant role in the body's metabolic activities, their deficiencies causes deficiency diseases; however, prolonged lack of micronutrients leads to hidden hunger. Fruits usually contain large amount of water and therefore are highly perishable. Hence, they are processed into various shelf stable forms adopting drying, freezing, concentration and fermentation technologies, not only to prevent their postharvest loss but also to enhance their acceptability. Rwanda being a small land locked country in East African region is also confronted with the challenges of micronutrient deficiency diseases. In Rwanda, 38% of children; it is high in rural than in urban and high among boys than girls under 5 years of age (World Bank, 2018). Anemia among preschool aged children and pregnant women were 42% and 11% respectively (WHO, 2008).

Rwandan diets are dominated by plant based foods such as cassava, maize, beans, potatoes, bananas and are very low in fat (≈8%) (Ho & McLean, 2011). One of the key actions recommended by World Bank for Rwanda is to improve dietary diversity through promoting home production of diversity of foods (World Bank, 2009). However, several collective efforts have been taken by the Ministries of Agriculture and Health to overcome them. According to the 2010/11 Integrated Household Living Conditions Survey in Rwanda, there has been a dramatic change in the production of cultivating only staple food crops at household levels to that of cultivating a combination of staple and wide range of fruits and vegetables (NISR, 2011).The widely cultivated fruits and vegetables include mangoes, papaya, avocadoes, pineapples, guava, oranges, mandarins, lemons, grapefruits, passion fruits, strawberries, fresh beans, green beans, tomatoes, onions, garlic, peppers, squash, zucchini, eggplants, carrots, leeks, lettuce, parsley and mushrooms. Such efforts have improved the dietary quality of meals but the postharvest loss is still high. The best approach is to adopt processing techniques and technologies to conserve and utilize them which otherwise would be easily jeopardized.

Papaya, *Carica papaya* L., is one such fruit that has not been exploited much to be processed. Of recent, they are widely cultivated and available in many of the homesteads. It is a large herb and member of the small family *Caricaceae* (Morton, 1987). They are major tropical and sub-tropical fruit crop in the world. Papayas are climacteric fruits and they undergo a series of desirable biochemical changes after harvesting. It has been documented that several tropical fruits are rich in antioxidants such as polyphenols, carotenoids and vitamins (Corral-Aguayo, Yahia, Carrillo-Lopez, & Gonzalez-Aguilar, 2008) of which papaya is one. ß carotene is an important pre cursor of vitamin A and contributes to the attractive color of the fruit. Papayas also contain vitamin C, B, potassium, magnesium, folic acid, fiber, low in calories, but aids in digestion (Ian, 2004); the lack of tartness is due to the low acidity in the fruit (Ursell, 2000) . Therefore they are vital for human nutrition and health and promote healthy cardiovascular system, protection against colon cancer (Nimmanpipug, Therdthai, & Dhamvithee, 2013) and would therefore be beneficial in the prevention of diabetic heart diseases (Fernandes, Rodrigues.S, & Oliveira, 2006). One way papayas are usually consumed is as fresh fruits but also as processed products. They are commonly made into sauce for shortcake or ice cream sundaes, added to ice creams just before freezing, used as pie filling, pickled, or preserved as marmalade or jam (Morton, 1987). They are also used as osmotically dehydrated preserves used as snacks or as fruit toppings in the bakery and confectionery industries (Nimmanpipug, Therdthai, & Dhamvithee, 2013). Mature green papayas are also consumed as a vegetable in several parts of India, Thailand and Vietnam (Morton, 1987). Furthermore, they can be consumed as restructured fruit in the form of leather. Consuming papayas as processed products helps to utilize and minimize the postharvest loss experienced through mechanical injury (Chonhenchob & Singh, 2005) during transportation and distribution. Guava is a fruit with pleasant sour-sweet taste and good source of vitamin C (212mg/100g) and dietary fiber (5.2g / 100g) (Gopalan, Rama Sastry, & Balasabramanium, 2009). They contain almost five times as much vitamin C as oranges viz., 30mg /100g in the fruit and 64mg /100ml in the juice (Gopalan, Rama Sastry, & Balasabramanium, 2009). National Institute of Nutrition, Hyderabad, India found antioxidant concentrations of 500mg / 100 g in guavas (Dean, 2011). Guavas (*Pisidium guajava)* are cultivated, in Rwanda, as a home garden crop and are considered as a low-priced food for poor but are inexpensive source of nutrients compared to other fruits grown in Rwanda.

Fruit leathers, otherwise called as fruit bars or fruit slabs are considered to be a nutrient dense, convenient, economically value added substitute for natural fruits and an excellent alternative for calorie dense snacks and very popular in United States of America (Artthey & Ashurt, 1984; Huang & Hsieh, 2005) than in Africa. It can also be used as nutrient dense food for people on hikes or mountain treks, astronauts on space mission. Fruit leathers can be made from any type of fruits including guava, durian, jackfruit, mango, pears, papayas, pineapples, banana, sweet potato and several other fruits (Phimpharian, et al., 2011; Chowdhury, Bala, & Haque, 2011; Huang & Hsieh, 2006; Babalola, Ashaye, Babalola, & Aina, 2002; Irwandi, Man, Yusof, Jinap, & Sugisawa, 1998; Wandi & Man, 1996; Chan & Cavaletto, 1978; Chan & Cavaletto, 1982). Fruit leathers are made by mechanical or solar drying of the fruit puree and combining other added ingredients such as sugar to enhance the sweetness, citric acid to increase the acidity and chopped nuts, coconut or spices to vary the taste and flavor (Huang & Hsieh, 2005). Blending of fruit purees to make fruit leathers enhances the nutritional quality and prevents postharvest loss. However, very little has been reported on the formulation of blended fruits in the development of fruit leathers. Both papayas and guavas are underutilized in Rwanda, except for fresh consumption, when compared to other tropical fruits such as pineapples, passion fruits, bananas, tree tomatoes, to name a few. Adding value to papaya and guava as they are less appreciated fruits and creation of new products from papaya and guava will help consumers to obtain vitamins when it is processed as leather. This will also complement the in-home fortification approach adopted in Rwanda to enhance the consumption of micronutrients and also balance school foods of the children. Hence blending papaya with guava would not only enhance the nutritional quality but also harmonize and complement the final product in its nutritional quality, sensory attributes and consumer preferences. Therefore the study aimed to process fruit leather from guava blended papaya and comparison of their chemical properties and consumer preference between the Mexican and Hawaiian varieties of papayas.

2. Materials and methods

2.1. Materials

2.2.1. Sample preparation and storage

Fresh papaya (Mexican and Hawaiian) and guava fruits were purchased from the local market and brought to the food processing laboratory and refrigerated until processing. All the fruits selected were ripe and free from bruising, to protect the color and flavor of the final leather product. The fruits were then washed in potable chlorinated water, peeled and their seeds removed. The fruits were hygienically cut into pieces and processed into homogenous puree individually in a stainless steel Waring commercial blender (Model no: HGBSSSS6, Torrington, Connecticut, USA) for 3 minutes; consecutively three times at 5 minutes interval. The liquidized fresh fruit puree (Papaya Haw, Papaya Mex & Guava) were strained or sieved to remove fibers to obtain smooth puree. The papaya – guava leather formulation was in the ratio of 60:40 for both the Mexican and the Hawaiian variety. Sugar and citric acid was added at the rate of 45% and 1% respectively. They were thermally processed at 90^0 C in a stainless steel double pan to prevent overheating. The fruit puree was poured in a thin layer (3-6mm thick) on stainless steel trays lined with greaseproof paper. The trays with the sample puree were left on the bench top at ambient temperature of 25 ^{0} C for a minute to allow the even distribution of the sample puree. They were then placed in a mechanical dryer (UNITEMP Drying cabinet, LTE Scientific Ltd., Greenfield, Odham, UK) and dehydrated at 60 ^{0}C for 8 h. They were hygienically cut, wrapped and stored at ambient temperature in air tight dry containers.

2.2. Chemical analysis

2.2.1. Moisture content

It was determined by using oven drying method (Ranganna, 2001) where the food sample of 5g was heated at 110 ^{0} C for 1hr and then weighed for weight loss. The experiment was continued until there was no variation in the consecutive weighing. Finally moisture content was expressed in percentage.

2.2.2. Sugar content

Lane-Eynon method was used to determine the sugar content. The carbohydrate solution to be analyzed was taken in a burette and added to a flask containing known amount of boiling copper sulphate solution and methyl blue indicator. Absorbance was measured at 490nm and the amount of sugar was determined by reference standard curve (Ranganna, 2001).

2.2.3. Protein content

Micro Kjeldahl method was adopted to determine protein content (Ranganna, 2001). The samples were prepared by blending manually in a mortar and pestle. Potassium sulphate (1g) was transferred to 250ml digestion tube. They were digested during 1h at 400-450^{0}C, therefore there was distillation and titration with 0.1N hydrochloric acid and sulphuric acid solution and the end point was shown by a light color. The crude protein was expressed in percentage.

2.2.4. Fat content

Soxhlet method after 8-16hrs extraction was followed. The sample was digested by heating it for 1h in the presence of 3N-HCl then the fat content was expressed in percentage (Horwitz & Latimer, 2005).

2.2.5. Ash

Ash content was determined using a muffle furnace (LF3, Vecstar Ltd, Furnace Division, Chesterfield, UK). 5g of the sample was accurately weighed into a crucible. The muffle furnace was heated to 550^0 to 600^0 C and the sample was incinerated for 6 to 8 hrs. It was cooled in desiccators and then weighed to obtain the weight of the ash. The experiment was repeated three times.

2.2.6. Ascorbic acid content

It was determined by using 2, 6 dichloro - phenolindophenol visual titration method (Ranganna, 2001). This method was based on the reduction of 2, 6 dichlorophenolindo - phenol by acid and those based on the reaction of dehydroascorbic acid with 2,4 dinitrophenyl hydrazine. 5g of papaya leather for both treatments were weighed and subjected to final ascorbic acid content determination and standardization of indophenols solution.

2.2.7. Total reducing sugar

Lane-Eynon procedure was followed as outlined in Official Method of Analysis of AOAC International (Horwitz & Latimer, 2005) where the Fehling solution was standardized and the preliminary titration and final titration was done. Then total reducing sugar was expressed in percentage.

2.2.8.Total Soluble Solids (TSS)

Refractometer (model number: digit 090; 0- 42^{0}Bx and 42^0 – 71^{0}Bx- precision 0.2^{0}Bx; CETI, Medline, Oxfordshire, UK) was used to determine the total soluble solids.

2.2.9. pH

Bench model pH / mV meter (HANNA Instruments, model no: HI-122, Romania) was used.

2.2.10. ß carotene

Spectrophotometer Camspec (model: M 501single beam scanning UV visible spectrophotometer) was used to determine the ß carotene content (Horwitz & Latimer, 2005).

2.3. Sensory analysis

Descriptive analysis was used to define the sensory properties of the newly developed papaya-guava fruit leather. The protocol and procedures employed in the research study were reviewed and approved by the review committee of the Directorate of Research and Publication office, CAVM. The study followed ethical standards and procedures laid down for the sensory analysis of newly developed food products. A total of thirty final year fellow graduate students between the ages of 21 and 25 years comprising of both males and females were recruited for this analysis. All panelists volunteered to participate and were encouraged to test the products from two varieties (Hawaiian and Mexican) of papaya, blended with guava, where a list of parameters was used to identify the products and to make a comparison of both varieties from papaya. Sensory quality parameters measured included: overall acceptability, taste, flavor, texture and color. Panelists were also instructed to comment in detail regarding the above parameters what in particular they have liked or disliked about these products.

2.4. Statistical analysis:

All laboratory analysis were carried out in triplicates. The mean and standard deviation was calculated using MS Excel for all the chemical parameters analyzed and sensory attributes were investigated by using differences in Analysis of variance (ANOVA) at 5% and 1% level of significance.

3.Results and discussions

The fresh fruit pulp and developed papaya – guava fruit leather products were analyzed for their carbohydrates, protein, fat, ash, moisture content, brix, reducing sugar pH, TTA, vitamin C and β-carotene. Three replicates were done (Table 1).

3.1. Chemical analysis of fresh and processed samples

3.1.1. Carbohydrates, TSS and total reducing sugar content

The carbohydrate content in fresh papayas irrespective of the varieties ranged from 8.4% to 8.6%; guavas had nearly double the amount (14%). The addition of sugar and the concentration of the fruit puree mixture through thermal processing increased the concentration of sugar that reflected an increase in TSS from 8.8^0Bx to 54.6^0Bx in the Mexican papaya and 8.6^0Bx to 53^0Bx for the Hawaiian papaya; which indicated that no significant difference existed in TSS between the varieties of papaya (Fig 1). The total reducing sugars in the fresh papaya and guava fruits ranged from 8% to 9% whereas the leather irrespective of the variety of papayas had 20% of reducing sugar. Carbohydrates are very prominent constituents of plants that serve not only as a source of available energy but also as reserve food and as structural materials. They are one of the main groups of food substances other than proteins, and fats to be synthesized in the plant from simple organic substances. Sugars are an important component in fruits; total sugars vary from 3% to 18% and consist of a mixture of sucrose, fructose and glucose (Swaminathan, 1988). Sugars can act as reducing agents and these sugars contain aldehyde as the functional group. Reducing sugars are the free hexose and pentose content of foods and are generally reported only as "total reducing sugars" (Lee, Shallenberger, & Vittum, 1970) which is lower than the carbohydrate content in the papaya leather which had a score of 76.0% as shown in table1. It is known that papaya leather contains high carbohydrates than fresh papaya.

3.1.2. Protein content

The protein content in fresh papaya was 0.55% while in guava it was 1.3%; it increased to 3.35% in final product of papaya guava leather. In dried or dehydrated form, nutrients increase and this resulted in concentrated form of protein. Protein content in fruit is very minimal.

3.1.3. Fat

The fat in the fresh fruits were low and ranged from 0.2% to 0.5 % while in the leather it increased to1.07±0.01 to 1.2±0.00%. Fruits are poor sources of fats and range from 0.1% to 0.5% (Desrosier & Desrosier, 2006).

Table 1. Nutrient content in fresh and processed papaya, guava and its blend

Nutrients	**Fresh Pulp**			**Blended & Processed Leather**	
	Papaya (Mex. var)	**Papaya (Haw. var)**	**Guava fruit**	**Papaya (Mex. Var) / guava**	**Papaya (Haw. Var) / guava**
Carbohydrate (%)	8.67±0.01	8.40±0.03	14.00 ±0.03	75.53 ±0.89	71.87±0.25
Total reducing sugars (%)	8.0±0.09	8.2±0.03	9.0±0.06	20±0.00	20±0.2
Total Soluble Solids (TSS ^{0}Bx)	8.8±0.06	8.6±0.0	9.8±0.00	54.6±0.2	53±0.00
Fat (%)	0.2±0.00	0.27±0.01	0.53±0.00	1.2±0.00	1.07±0.01
Protein (%)	0.6±0.00	0.53±0.01	1.27±0.01	3.40±0.00	3.27±0.01
Moisture content (%)	89.27±0.03	89.23±0.00	84.20±2.16	16.47±0.44	16.43±0.58

Source: Primary data; **Note:** Haw. var – Hawaiian variety; Mex. var – Mexican variety

3.1.4. Moisture

Fruits are naturally rich in water content (table 1). The moisture content was higher in fresh papayas (89.2%) and it decreased to 16.4% in papaya-guava (84.2%) and the moisture content of papaya – guava leather. Dried and dehydrated foods are highly concentrated, less costly to produce and require minimum storage needs (Desrosier & Desrosier, 2006). Besides thermal processing, dehydration was one of the unit operations used to process fresh guava - papaya fruit leather. Dehydration permits food preservation by reducing the water activity level that does not support microbial growth whilst thermal processing inactivates microorganism and deteriorative enzymes to preserve food. This concept of hurdle technology relies on two or more factors or hurdles (Leistnera & Gorris, 1995) in order to ensure that a given food product remains stable. When free water content is reduced, the osmotic pressure is increased and it facilitates the control of microbial growth in such a system; and moisture content is one of the water related criteria used to study food stability (Salguero, Gomez, & Carmona, 1993).

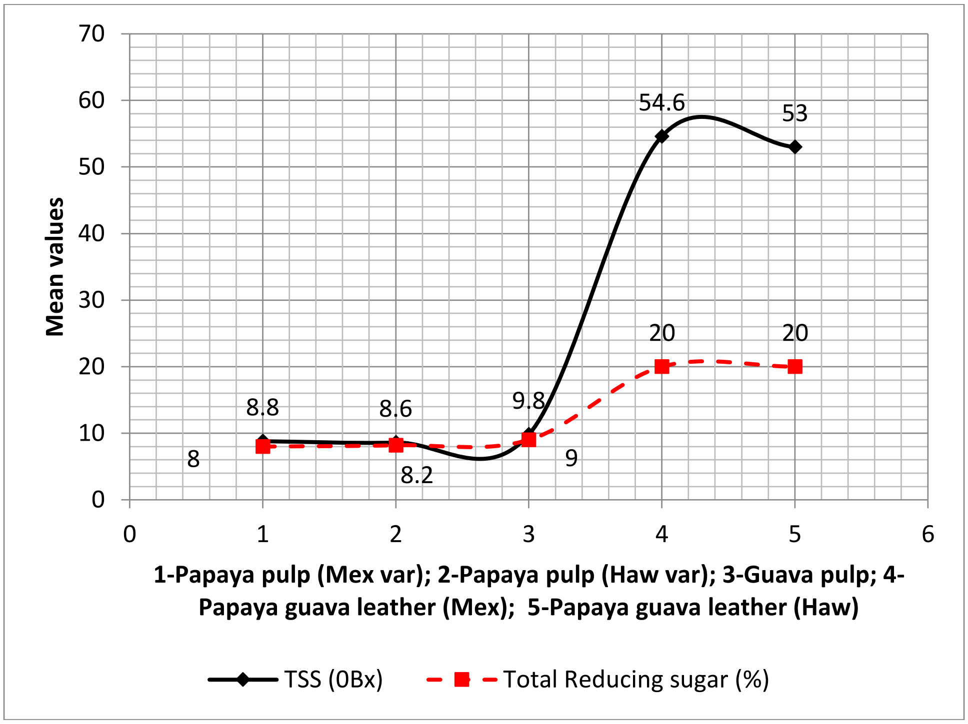
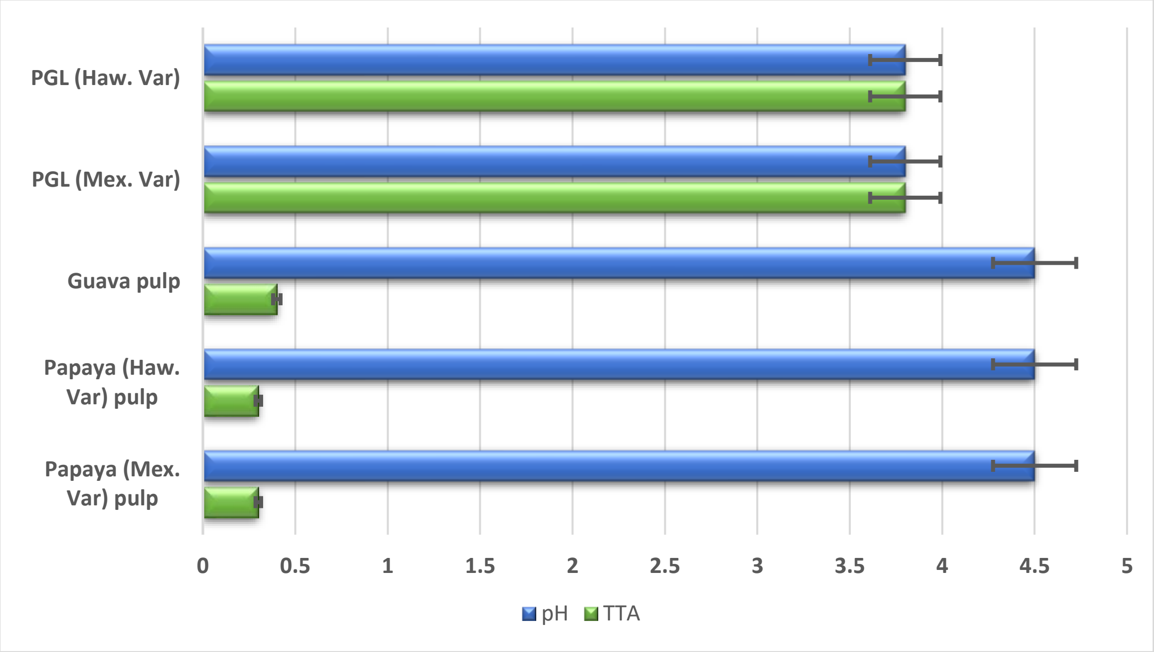
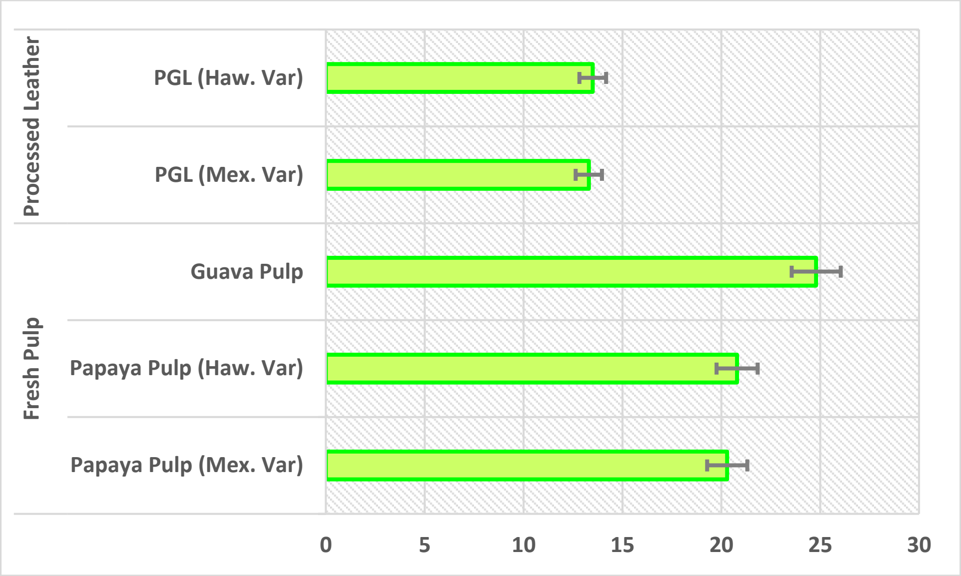


Figure 1. TSS and Total Reducing sugar content in fresh fruits and the processed papaya guava leather



Note: PGL – Papaya Guava Leather; Haw. Var – Hawaiian variety; Mex. Var – Mexican variety

Figure 2. TTA and pH content in fresh fruits and the processed papaya guava leather



Note: PGL – Papaya Guava Leather; Haw. Var – Hawaiian variety; Mex. Var – Mexican variety

Figure 3. Vitamin C content in fresh fruits and the processed papaya guava leather

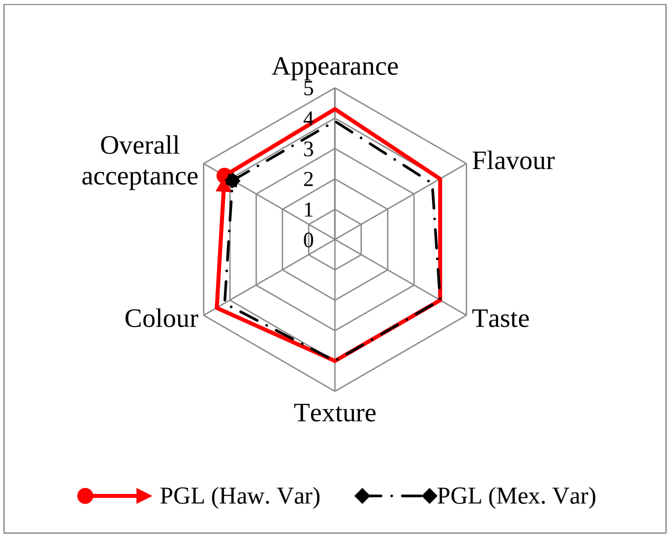


Figure 4. Descriptive sensory attributes of fruit leather between two papaya varieties blended with guava

3.1.5. TTA and pH

There are two interrelated concepts in food analysis that deal with acidity; they are pH and titratable acidity. From the analysis it was clear that both varieties of papayas and guava had meagre levels of acidity but their pH was all uniform and fair (4.5). In the papaya-guava leather prepared from both varieties, the titratable acidity increased while the pH decreased and they gave a uniform value of 3.8 (fig 2). However, titratable acidity is a better predictor of acid’s impact on flavour than pH (Nielsehn, 2001). The addition of citric acid (1%) increased the titratable acidity and made the product acceptable; otherwise papaya is a bland fruit. Titratable acidity deals with the measurement of total acid concentration that is contained within a food (Nielsehn, 2001) . Citric and malic acids largely occur in fruits apart from the many other organic acids that occur in them (Desrosier & Desrosier, 2006). Mango leather developed was reported to have low pH of 3.8 that enabled it to be stored and microbiologically safe for a period of six months (Azeredo, Brito, Moreira, Farias, & Bruno, 2006). This pH value correlated with the present study.

3.1.6. Vitamin C

Vitamin C in both the fresh fruits of papaya, irrespective of the variety, and guava were nearly the same; they were 20mg / 100g and 24.8 mg/ 100g in fresh papayas and guavas respectively. On processing they decreased to 13.3 mg /100g and 13.5 mg /100g respectively in the Mexican and Hawaiian variety (Fig 3). This decrease in the vitamin C content could be due to its chemical nature of being sensitive to heat and light. Vitamin C also known as ascorbic acid is derived from simple sugars (Klenner, 1953). It is the most active reducing agent known to occur naturally in living tissues and abundant water soluble antioxidant in the body (Salunkhe & Kadam, 1998). It is important for the growth and maintenance of healthy bones, teeth, gums, ligaments and blood vessels; responsible for the chemicals in the production of neurotransmitters and adrenal gland hormones; involved in the response of the immune system to infection and wound healing Vegetables (Salunkhe & Kadam, 1998) and fruits are good sources of vitamin C and generally citrus fruits are said to be rich source. However, the Indian gooseberry (*Phyllanthus emblica*) has higher (600mg /100g) amount than the citrus fruits. Papaya and guava are excellent sources of vitamin C and contain 57 mg and 15 mg / 100g respectively (Gopalan, Rama Sastry, & Balasabramanium, 2009).

Several studies have indicated that Vitamin C content in fruits and vegetables can be influenced by various production factors such as genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures (Nagy, 1980; Lee & Kader, 2000). Ascorbic acid content in the fruits decreases significantly during ripening storage periods (Othman, 2009). Studies on the chemical changes and sensory quality during processing and storage of aseptically “bag-in-box” packaged papaya and guava puree revealed that ascorbic acid loss was 6% during aseptic processing (Cavaletto, 2008). In the present study the loss was quite high (39.24%); which may be due to the open pan thermal processing technique that was adopted. Durian leather was developed and reported to have high amount of ascorbic acid content (21.6 to 26.6 mg / 100g) (Wandi & Man, 1996). The Recommended Dietary Intake (RDI) per day for an adult is 45 mg and 100g of the processed leather can provide 16% of the RDI.

3.1.7. ß Carotene

Colour of fruits and vegetables are very important from the point of view of ultimate quality of the product and eye appeal that enhances consumer acceptability. Chlorophyll, anthoxanthins, anthocyanins and carotenoids are the chief pigments that are present in fruits and vegetables; carotenoids are a group of yellow, orange and orange red fat soluble pigments that are widely distributed in nature. They are highly unsaturated, and are susceptible to isomerization and oxidation during the processing and storage of food. Carotenoid composition in papaya and major carotenoids found in papaya extracts are lycopene and carotenol fatty acid esters of ß-cryptoxanthin and ß-cryptoxanthin-5, 6 epoxide (Cano, de Ancos, & Lobo, 1996). Other xanthophylls detected were ß cryptoxanthin, transzeaxanthin and cryptoflavin. The present study revealed that ß-carotene content in fresh papaya was 0.120±0.00 mg / 100g irrespective of the papaya variety used in the study. This correlated with literature values of 0.0045-.676 mg / 100g (Pamplona, 2003). While in fresh guava, the ß-carotene content was high with a value of 3.22 mg / 100g when compared to papaya. Guava contains very high lycopene and contains 26 RAE ß-carotene (Percival & Brooke, 2014). The 'Horana red' variety of guava contained 2.0 +/- 0.2 µg/g fresh weight of β-carotene (Chandrika, Fernando, & Ranaweera, 2009) while carotenoid content of papaya (13.8 mg/100 g dry pulp) was low compared to mango, carrot and tomato (Pamplona, 2003). Thermal treatment induced the degradation of carotenol fatty acid esters of xanthophylls while freezing and canning of papaya slices led to significant decreases in the total carotenoids quantified by HPLC (Cano, de Ancos, & Lobo, 1996). Irrespective of the variety, the guava blended papaya fruit leather had very meagre amount of 0.001mg /100mg of ß-carotene. This indicated that use of open pan boiling destroyed the minimal amount that existed in the papaya guava blend. Therefore this method is not suitable if ß-carotene is to be retained through processing.

3.2. Sensory analysis

The sensory evaluation was conducted on the two products of papaya leather prepared from the two types of papayas which were acting as basic ingredients and guava in different proportions. Each panelist was given the time to assess the organoleptic attributes of the two different leather product and the five point hedonic scale evaluation form to fill according to their preference. Conferring to the results obtained, the Hawaiian papaya-guava leather (60% of Hawaiian papaya pulp and 40% of guava pulp) was the most preferred by panelists. The appearance and flavor of the papaya leather from Hawaiian variety were more preferred than those of the Mexican variety; however in terms of color Hawaiian papaya-guava leather were the most liked. But statistical analysis indicated that difference between the two papaya varieties in terms of the appearance, flavor, taste, texture, color and overall acceptability of resulting papaya-guava leather was not significant neither at 5% nor at 1% level of significance. Fig 4 shows the descriptive sensory attributes of the two samples studied.

4. Conclusions

Fruit leathers are made from fruit puree and other ingredients such as sugar and citric acid to enhance the acceptability and storage stability. They are nutrient dense; their calories and acceptability can be further enhanced by the addition of nuts or spices. Blending of fruit purees to make fruit leathers enhances the nutritional quality apart from preventing postharvest losses. Vitamin C loss in the processed fruit leather ranged from 33.5% to 45.6% of the original level. Thus nearly half of the vitamin C was lost upon processing of leather which was quiet high. The study proved that there was no statistical difference (p-value>0.05; p-value>0.01) in sensory attributes between Hawaiian papaya leather and Mexican papaya leather. Hence, underutilized fruits such as papaya and guavas can be successfully blended and processed into organoleptically acceptable fruit leather as revealed through this study. However further studies would be necessary to appraise available technologies to improve the vitamin C stability in papaya-guava leather.

5.References

Artthey, & Ashurt. (1984). *Fruit processing Nutrition, Products and Quality Management*. Springer.

Azeredo, M. H., Brito, E. S., Moreira, G. E., Farias, V. L., & Bruno, L. M. (2006). Effect of drying and storage time on the physicochemical properties of mango leathers. *Journal of International Food Science and Technology, 41*(6), 635 - 638.

Babalola, S. O., Ashaye, A. O., Babalola, A. O., & Aina, J. O. (2002). Effect of cold temperature storage on the quality attributes of pawpaw and guava leathers. *African Journal of Biotechnology*, 1(2), 61 - 63.

Cano, M., de Ancos, B., & Lobo, G. (1996). Effects of freezing and canning of papaya slices on their carotenoid composition.

Zeitschrift für Lebensmittel-Untersuchung und Forschung, 202(4), 279 - 284. doi: https://doi.org/10.1007/BF01206097

Chan, H. T., & Cavaletto, C. G. (1982). Aseptically Packaged Papaya and Guava Puree: Changes in Chemical and Sensory Quality During Processing and Storage. *Journal of Food Science*, 47(4), 1164-1169. doi:https://doi.org/10.1111/j.1365-2621.1982.tb07641.x

Chan, T. H., & Cavaletto, G. C. (1978). Dehydration and Storage Stability of Papaya Leather. *Journal of Food Science*, 1723 - 1724.

Chandrika, U. G., Fernando, S. K., & Ranaweera, K. K. (2009). Carotenoid content and in vitro bioaccessibility of lycopene from guava (Psidium guajava) and watermelon (Citrullus lanatus) by high-performance liquid chromatography diode array detection. *International Journal of Food Science and Nutrition*, *60*(7), 558 - 566

Chonhenchob, V., & Singh, S. P. (2005). Packaging performance comparison for distribution and export of papaya fruit. *Packaging Technology Science*, 18, 125-31.

Chowdhury, M. M., Bala, B. K., & Haque, M. A. (2011). Mathematical modelling of thin-layer drying of jackfruit leather. *Journal of Food Processing and Preservation*, *35*(6), 797–805.doi:https://doi.org/10.1111/j.1745-4549.2011.00531.x

Dean, N. (2011). http://www.telegraph.co.uk/health/healthnews/8822303/Guava-the-ultimate-superfood.html. Retrieved February 27, 2013, from http://www.telegraph.co.uk.

Desrosier, N., & Desrosier, J. (2006). *The Technology of Food preservation*. Connecticut, USA: AVI Publishing Co., Inc., Westport.

Fernandes, F. A., Rodrigues.S, P. G., & Oliveira, E. L. (2006). Optimization of osmotic dehydration of papaya followed by air-drying. *Food Research International*, 4, 492 - 498.

Ho, K., & McLean, J. (2011). *The Implementation of In-Home Fortification and Nutrition Education to Combat Anaemia and Micronutrient Deficiencies Among Children 6-23 Months in Rwanda*. Kigali: Ministry of Health, Republic of Rwanda.

Horwitz, W., & Latimer, J. G. (2005). *Official Methods of Analysis of AOAC International* (18th edition ed.). International Suite 500481 North Frederick Avenue Gaithersburg, Maryland 20877-2417, USA: AOAC.

Huang. (2006). Physical Properties, Sensory Attributes and Consumer Preference of Pear Fruit Leather. 70(3), E177-E186.

Huang, X., & Hsieh, F. H. (2005). Physical Properties, Sensory Attributes, and Consumer Preference of Pear Fruit Leather *Journal of Food Science*, 70, E177–E186.

Ian, C. (2004). Follow the Thing: Papaya. 9600 Garsington Road, Oxford OX4 2DQ, UK: Blackwell Publishing.

Irwandi, J., Man, Y. B., Yusof, S., Jinap, S., & Sugisawa, H. (1998). Effects of type of packaging materials on physicochemical, microbiological and sensory characteristics of durian fruit leather during storage. Journal Science Food Agriculture, 76, 427–434. 76, 427–434.

Kader, A. (2001, May). Importance of Fruits, Nuts, and Vegetables in Human Nutrition and Health. Perishables Handling Quarterly(106).

Klenner, F. R. (1953). The Use of Vitamin C as an Antibiotic. The Journal of Applied Nutrition, 6, 274-278.

Lee, C., Shallenberger, R., & Vittum, M. (1970). *Free sugars in fruits and vegetables*. Retrieved January 28, 2016

Lee, S. K., & Kader, A. A. (2000). Pre-harvest and postharvest factors influencing vitamin C content of horticultural crops. *Post Harvest Biology*, 207 – 220.

Leistnera, L., & Gorris, L. G. (1995, February). Food preservation by hurdle technology.

Trends in Food Science and Technology, 6(2), 41–46.

Morton, J. F. (1987). Fruits of warm climates. Miami, Florida: Julia F. Morton, Purdue University.

Nagy. (1980). Vitamin C content of citrus fruits and their product: A review. Journal of Agricultural Food Chemistry, 28, 8-18.

Nielsehn, S. (2001). Food analysis. USA: Springer Publication.

NISR. (2011). EICV3 THEMATIC REPORT Agriculture total pages 76. Kigali: National Institue of Statistics of Rwanda

Nimmanpipug, N., Therdthai, N., & Dhamvithee, P. (n.d.). Characterisation of osmotically dehydrated papaya with further hot air drying and microwave vacuum drying. *International Journal of Food Science and Technology*, *48*(6), 1193-1200.

Othman, C. O. (2009). Physical and chemical composition of storage-ripened papaya (Carica papaya L.) fruits of eastern Tanzania. *Tanzanian Journal of Science*, 35, 47-59.

Othman, C. O. (2009). Physical and chemical composition of storage-ripened papaya (Carica papaya L.) fruits of eastern Tanzania. *Tanzanian Journal of Science*, 35, 47-59.

Pamplona, G. D. (2003). Healthy Foods ,. Madrid, Spain: Editional Safaliz.

Percival, S. S., & Brooke, F. (2014, April). What's in Your Tropical Fruit? Retrieved June 24, 2014, from University of Florida, IFAS Extension: http://edis.ifas.ufl.edu.

Phimpharian, C., Anuvat, J., Kamolwan, J., Nantawan, T., Witoon, P., & Kyoon, N. H. (2011). Physicochemical characteristics and sensory optimisation of pineapple leather snack as affected by glucose syrup and pectin concentrate. International Journal of *Food Science and Technology*, 46(5), 972–981.

Phimpharian, C., Anuvat, J., Kamolwan, J., Nantawan, T., Witoon, P., & Kyoon, N. H. (2011). Physicochemical characteristics and sensory optimisation of pineapple leather snack as affected by glucose syrup and pectin concentrate. International Journal of Food Science and Technology, 46(5), 972–981.

Ranganna, S. (2001). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. New Delhi: Tata MC Graw-Hill Llimited Company.

Salunkhe, & Kadam. (1998). *Handbook of vegetable science and technology: Production, composition, storage, and processing*. New York: Marcel Dekker.

Swaminathan, M. (1988). *Food science, Chemistry and Experimental Foods*. Bangalore, India: BAPCO.

Ursell, A. (2000). *The Complete Guide to Healing Foods: Nutritional Healing for Mind and Body*. USA: D K Book Publishers.

Wandi, I., & Man, Y. B. (1996). Wandi, I. and Man, Y. B. C (1996) Durian Leather: Development, Properties and Storage Stability *Journal of Food Quality*, 19: 479–489.

WHO. (2008). Worldwide Prevalence OF ANAEMIA 1993-2005: WHO Global database on Anaemia.

World Bank. (2009). *Nutrition at a Glance*. Retrieved January 28/01/2016, 2016, from http://siteresources.worldbank.org/NUTRITION/Resources/281846-1271963823772/Rwanda.pdf: www.who.org

World Bank. (2018). *Rwanda economic update: tackling stunting - an unfinished agenda (English). Rwanda economic update*. http://documents.worldbank.org/curated/en/360651529100512847/Rwanda-economic-update-tackling-stunting-an-unfini

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