Original Research Article

Effect of processing methods on the nutritional quality of ripe papaya (*Carica papaya* L.)

ABSTRACT

The present study was conducted to investigate the effect of different processing methods on the nutritional quality of ripe papaya fruits. The fruits were processed into pulp and powder using standard procedures and the results revealed that some of the nutrients decreased after processing compared to fresh form. The heat-sensitive nutrients such as ascorbic acid and β-carotene were highly significantly affected by processing methods. The ascorbic acid decreased in pulp (55.95 mg/100 g) and powder (48.69 mg/100 g) compared to fresh (59.26 mg/100 g). The amount of β-carotene was noticed to drop (10.16 mg/100 g) and (8.80 mg/100 g) for pulp and powder respectively compared to fresh (13.04 mg/100 g). On the other hand, non-heat sensitive nutrients (ash, fibre, protein, fat, titratable acidity, total carbohydrates, total energy, reducing sugars and total sugars) were significantly increased in powder compared with fresh and pulp The moisture content of fresh and pulp was significantly increase although highly significance difference ($p<0.05$) observed in moisture between fresh (89.98 %), the pulp (91.60 %) and powder (8.20 %). The colour was recorded to be (L* 0.14, a* 2.30, b* 0.61), (L* 58.70, a* 7.41, b* 34.39) and (L* 41.32, a* 8.44, b* 30.13) for fresh, pulp and powder respectively. The products (pulp and powder) processed in this study can be used as food ingredients in food industries to produce hundreds of value-added products like papaya concentrate, jam, juice, syrup, cordial, crush, wine, confectioneries, bakery products, ready to cook instant food premixes as well as reconstituted products etc. The products produced in the current study are of low cost and affordable compared to commercial products of the same quantity and quality.

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Keywords: Ripe papaya fruit; processing methods; nutritional quality; pulp; powder.

INTRODUCTION

Papaya (*Carica papaya* L.) is a deliciously sweet tropical fruit with musky undertones and a distinctive pleasant aroma. It is a powerhouse of nutrients like antioxidant vitamin C, vitamin A and vitamin E. Apart from nutrients, it is a rich source of minerals (magnesium potassium), vitamins (vitamin B, pantothenic acid and folate) and fibre. All the nutrients of papaya as a whole improve the cardiovascular system, protect against heart diseases, heart attacks, strokes and prevent colon cancer. The fruit is an excellent source of beta-carotene that prevents damage caused by free radicals that may cause some forms of cancer. Papaya lowers high cholesterol levels as it is a good source of fiber (Aravind *et al*., 2013). Papaya also seems to have antibacterial, antifungal, antiviral, anti-inflammatory, antioxidant and immune-stimulating effects. The papaya fruit contains two enzymes, papain and chymopapain. Both enzymes digest proteins, meaning they can help with digestion and reduce inflammation. Papain is an ingredient in some over-the-counter digestive supplements to help with a minor upset stomach. Both papain and chymopapain also help to reduce inflammation. They may help with acute pain, like those from burns or bruises, and they can help with chronic inflammatory conditions like arthritis and asthma. In addition, papain enzyme is used as an industrial ingredient in brewing, meat tenderizing, pharmaceuticals, beauty products and cosmetics.

Papaya fruits are among climactic fruit, which is highly perishable fruit with very poor keeping quality since it contains approximately 90 per cent of moisture and its skin is thin therefore, post-harvest losses is high in this fruit. During the ripening process, the fruits emit ethylene along with an increased rate of respiration. A few days ripe fruits become soft and delicate which can no longer withstand the rigours of transport and handling. Therefore, the fresh fruits need to be processed into value-added products to improve their quality and shelf life throughout the year and to stabilize the price during the glut season. Post-harvest losses of papaya are ranging from 40-100 per cent as reported in developing countries (Teixiera da Silva *et al*., 2007). Processing is a solution offered to overcome the post-harvest losses, increase the shelf life, simplify the storage by reducing bulkiness and diversify the utilization. The different value-added products can be produced from ripe papaya fruits such as pulp, concentrate, syrup, cordial, juice, crush, dried slices, powder, jam, puree, frozen cubes, candy etc. The present study used different processing methods such as blanching and drying of papaya fruits as well as nutrients analysis of final products before and after processing.

MATERIALS AND METHODS

Fresh ripe and firm papaya fruits (8 kg) were purchased from the local market of Solan and brought to the product development laboratory. The ripe papaya fruits and packaging material (PET jars) were purchased from a local food market, Solan. All chemicals and reagents used in this study were of analytical grade and were procured from Loba Chemie, International Scientific and Surgicals, Solan (HP). All treatments and analyzes were done using three replicates and results were reported on a dry and wet weight basis. The present investigation was conducted in the Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni Solan (HP).

Processing of ripe papaya fruits into pulp and powder

Preparation of papaya pulp: The papaya fruits were washed and cut into halves. After removing the fluffy portion/brains/fibrous strains and seeds, the halves were cut into strips. The strips were peeled and cut into pieces of uniform size. The pieces were steam blanched for 2 min followed by dipping in 0.1 per cent KMS solution for 20 min (Attri *et al*., 2018). The treated slices were ground in a mixer cum grinder (Havells, Model MX-1155) and passed through a 36 mesh sieve to get the fine and uniform pulp. The pulp was kept for storage in PET jars, sealed properly, labeled and stored under refrigerator condition for analysis of various nutritional parameters. The processing steps for the preparation of ripe papaya pulp are depicted in Fig 1.

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Ripe papaya fruit
↓
Washing
↓
Cutting and removal of seeds and fluffy portion
↓
Peeling and cutting into uniform pieces
↓
Steam blanching (2 min)
↓
Dipping in 0.1 per cent KMS solution (20 min)
↓
Grinding in a mixer cum grinder
↓
Sieving (36 mesh sieve)
↓
Papaya pulp
↓
Packaging in PET jars
↓
Labelling
↓
Storage under refrigerator condition

Fig 1: Unit operations for preparation of papaya pul

Preparation of papaya powder: The papaya fruits were washed and cut into halves. After removing the fluffy portion/brains/fibrous strains and seeds, the halves were cut into strips. The strips were peeled and cut into pieces of uniform size. The pieces were steam blanched for 2 min followed by dipping in 0.1 per cent KMS solution for 20 min (Attri *et al*., 2018). The treated slices were spread on trays for drying in a mechanical dehydrator at 55±2 °C for 18 h or till constant moisture content was achieved. The dried slices were ground in a mixer cum grinder (Havells, Model MX-1155) and passed through a 36 mesh sieve to get fine and uniform powder. The papaya powder was packed in a PET jar, sealed tightly, labelled and kept for storage under ambient condition till further use. The unit operations followed for the preparation of papaya powder are shown in Fig 2.

Ripe papaya fruit
↓
Washing
↓
Cutting and removal of seeds and fluffy portion
↓
Peeling and cutting into uniform pieces
↓
Steam blanching (2 min)
↓
Dipping in 0.1 per cent KMS solution (20 min)
↓
Mechanical drying (55 ± 2 °C for 18 h)
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Grinding of pieces into powder
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Sieving (36 mesh sieve)
↓
Papaya powder
↓
Packaging in PET jars
↓
Labeling
↓
Storage under ambient condition

Fig 2: Unit operations for preparation of papaya powder

CHEMICAL AND NUTRITIONAL ANALYSIS

The moisture content (%), ash (%), protein (%) and minerals (iron mg/100 g) was determined **as per** the method suggested by AOAC (2012). Crude fibre (%) was analyzed **as per** (AOAC, 2010), Crude fat (%) was determined using (AOAC, 2009) method. Ranganna (2009) procedure was employed in scrutinizing *β*-carotene (mg/100 g), total carbohydrates (%) and total

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Comment [LMJdC7]: In all of time are cited energy (Kcal/100 g) were calculated by the differential method **as per** AOAC (2006) method. Ascorbic acid, titratable acidity and Total Soluble Solids (TSS) were determined **as per** the procedure given by AOAC (2004), reducing sugars and total sugars were analyzed according to the method suggested by Dubois *et al*. (1956). Colour of fresh, pulp and powder was measured measured in a Lovibond Colour Tintometer Model PFX-I series spectrocolourimeter in which RYBN colour units were obtained along with CIE readings i.e. L*, a* and b* values. Each sample was measured three times for colour (Ranganna, 2009). Change in colour (Δ E), chroma (C*), and hue angle (h^0) were calculated **as per** the formula proposed by Goswami *et al*. (2015).

DATA ANALYSIS

The chemical parameters were analyzed by Complete Randomized Design (CRD) and sensory evaluation was analyzed using Randomized Block Design (RBD) as described by Cochran and Cox (1967) and Mahony (1985), respectively. The means were separated for comparison by Tukey's honest significant difference (HSD) and the statistical significance was defined as $p \leq 0.05$.

COST OF PRODUCTION OF PULP AND POWDER

The ripe papaya fruits were procured **as per?????** the prices prevailing in the local market Solan (Rs 60/ kg). The packaging materials (PET jars) were also procured in the local Solan market (Rs 5/ jar). The overhead charges @10 per cent of expenditure on manufacturing labour cost, depreciation cost on machinery and equipment, building, etc. were also included.

RESULTS AND DISCUSSION

Moisture content

Table 1 compiled the nutritional components of ripe papaya fruits in different forms (fresh, pulp and powder). The moisture content was highest in pulp (91.60 %), fresh (89.80 %) and lowest in powder (8.20 %). Drying reduces the moisture content of ripe papaya by more than 10 per cent compared to fresh and pulp. The shelf life of powder is extended by reducing the moisture content. Attri *et al*. (2019) analyzed similar moisture (89.94 %) in ripe fresh papaya fruit. The value was higher than the value found by Alam (2001) who reported (88.5 %) moisture and within the range of the value found by Nwofia *et al*. (2012) who reported (87.47-91.32 %)

moisture. Gupta (1997) reported that moisture in oven-dried papaya powder within the range of 5.48-6.76, while higher moisture content was reported in the present study. This difference may be due to different drying equipment used (oven drier and cabinet drier). Ali *et al*. (2011) noticed a range from 86.90 to 89.80 per cent in fresh ripe papaya fruit contains moisture which is similar to the present study.

Total Ash

The papaya powder had a significantly higher mean ash content (5.48 %) as compared to fresh (0.72 %) and pulp (0.39 %). The ash content of dried papaya powder is higher due to the difference in their moisture content (Table 1). This result is similar to Pandey and Singh (2014) in oven-dried papaya fruit powder. Chukwuka *et al*. (2013) noticed 5.24 per cent ash in ripe papaya powder which is near to the present study.

Crude fibre

The mean crude fibre was highly significant in powder (4.24 %) as compared to fresh (0.91 %) and pulp (0.77 %) due to their moisture content differences. Adepoju *et al*. (2021) analyzed (9.61 %) fibre in oven-dried papaya powder which is significantly higher than the present study. This difference may be due to variety differences, location and soil type. The consumption of food fibres including fruits and vegetables daily has been recommended to prevent different non-communicable diseases (Chuwa *et al*., 2020).

Crude fat

The mean crude fat content was (0.14), (0.08) and (0.72) per cent in fresh, pulp and powder respectively. The result obtained in the current study for papaya powder is similar to Pandey and Singh (2014) in oven-dried papaya powder (0.145 per cent). This difference in fat between fresh pulp and powder may be due to the difference in moisture content. This value is in conformation with the findings of Gupta (1997).

Crude protein

A high significance difference was observed in mean crude protein between fresh (0.65 %), the pulp (0.59 %) and powder (4.05 %). Pandey and Singh (2014) reported (6.04) crude protein of oven-dried papaya powder which is significantly higher than the present study. King *et al*. (1951)

investigated 6.61 per cent protein in papaya powder which is higher than the current study. These differences might be due to variety differences, location and soil type.

β-carotene

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The mean β-carotene content was realized to be significantly decreased in papaya powder 8.80 mg/100g whereas 13.04 mg/100 g and 10.16 mg/100 g were recorded in fresh papaya and pulp respectively. The decrease in β-carotene in powder may be due to heat sensitivity of the carotenoids and photosensitive nature; isomerization and epoxide forming nature of carotene (Mir and Nath, 1993).

Ascorbic acid

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The mean ascorbic acid content of fresh papaya and pulp were found 59.26 and 55.95 mg/ 100 g respectively, whereas dried papaya powder contained 48.69 mg/ 100 g ascorbic acid. Drying causes great losses in vitamin C and it had been reported by Davidek *et al*. (1991) that heating at a higher temperature for a short time has less effect on vitamin C losses but if drying is prolonged, there will be more losses therefore, mechanical dehydrator caused the vitamin C losses. Similarly, this study also supports this finding. The losses may be attributed to the heat and light sensitivity of the ascorbic acid. Mugula *et al*. (1993) reported a loss of 90 per cent ascorbic acid content during drying. The results confirm Dev *et al*. (2019) who evaluated 67.89 mg/ 100 g in ripe papaya pulp. According to Ali *et al*. (2011), the amount of vitamin C in fresh papaya fruit was 57-108 mg/100 g. The present study result is within the range. Nwofia *et al*. (2012) evaluated 36.37-43.41 mg/ 100 g in fresh papaya fruit which is low in comparison to the present study due to varieties and location differences.

Total soluble solids

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The mean Total Soluble Solids (TSS) of fresh papaya in the present study was 9.5˚B while the papaya pulp and powder were noted to be 5.00˚B and 13˚B, respectively. This is similar to Attri *et al*. (2019) who analyzed 9.50˚B in fresh papaya fruit but the non-significantly difference to Attri *et al*. (2018) who recorded 9.00˚B in fresh papaya fruit. Kandasamy *et al*. (2019) analyzed 12.63˚B in foam-mat dried papaya fruit powder whereas Dev *et al*. (2019) analyzed 7.00˚B in ripe papaya pulp which was significantly higher than the current study. This difference may be due to location and variety differences.

Titratable acidity

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The present study reported meanly titratable as 0.06 in fresh, 0.06 in pulp and 0.78 per cent in ripe papaya powder. Attri *et al*. (2018) analyzed similar results of 0.057 and 0.76 per cent titrable acidity in fresh and powder respectively in ripe papaya fruit which is in line with the present study.

Total carbohydrates

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The mean carbohydrates analyzed in the present study revealed that papaya fruit and its products i.e. 8.51, 7.34 and 82.55 per cent for fresh, pulp and powder respectively has low calories. Chuwa *et al*. (2021) recommended the utilization of low glycemic index foods (fruits and vegetables) to ameliorate diabetes type 2. Adepoju *et al*. (2021) analyzed (72.12 %) mean carbohydrate in oven-dried papaya powder which is low as compared to the present study. The difference may be due to location and soil type. Dev *et al* (2019) recorded (85.80 %) carbohydrate higher than the present study in dry papaya powder. Ali *et al*. (2011) analysed total carbohydrates (7.5 - 10.98 g/100 g) in fresh papaya fruit similar to the present study. Nwofia *et al*. (2012) evaluated 6.50-9.51 per cent carbohydrate in fresh papaya fruit. In the current study fresh and pulp fall to this range.

Total energy

The high significance difference observed in mean total energy was 34.26, 29.36 and 335.92 Kcal /100 g for fresh, pulp and powder respectively in the current study. The low energy value in fresh and pulp papaya is due to the highest moisture content compared to powder.

Reducing sugars

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The mean values for reducing sugar i.e. 2.05, 1.72 and 20.45 % in fresh, pulp and powder was analyzed in ripe papaya respectively showed a higher significance difference The reducing sugars decrease with an increase of moisture content and vice versa. Attri *et al*. (2018) evaluated 2.30 per cent reducing sugars in fresh papaya fruit which is non-significantly to reducing sugars scrutinized in the present study. Similarly, Attri *et al.* (2019) analysed 2.50 per cent reducing sugars in fresh papaya fruit higher but non-significant to the present study. Canuto *et al.* (2014) reported 36.13 per cent reducing sugars in freeze-dried papaya powder which is significantly higher than the present study. This difference may be due to drying techniques mechanical dehydrator viz. bench freeze drier. Freeze drier is the best technique for the retention of nutrients in fruits and vegetables.

Total sugars

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The total sugars of 7.35, 6.15 and 43 per cent were investigated in the current study. The total sugars decrease with an increase of moisture content and vice versa. Attri *et al*. (2019; 2018) analyzed 5.74 and 6.59 per cent total sugars respectively in fresh papaya fruit which differ significantly from the present study. This difference may be due to varieties differences. Ali *et al*. (2011) obtained similar total sugars (7.20- 9.80 g/100 g) in fresh papaya fruit to present study. A highly significant difference was obtained by Canuto *et al.* (2014) in total sugars (92.26 %) in freeze-dried papaya powder in comparison with the present study due to different drying techniques used in drying papaya.

Table 1: Nutritional characteristics of fresh and processed papaya fruits

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Parameters	**Ripe papaya fruits**		
	Fresh	**Pulp**	**Powder**
	(Mean ± SE)		
Moisture (%)	89.98 ± 2.51^{b}	91.60 ± 2.55^{a}	8.20 ± 0.03^{c}
Ash (%)	0.72 ± 0.04^{b}	0.39 ± 0.07^{c}	4.48 ± 0.02^{a}
Crude fibre (%)	0.91 ± 0.06^{b}	0.77 ± 0.03^{c}	4.24 ± 0.04^{a}
Crude fat (%)	0.14 ± 0.04^{b}	0.08 ± 0.001^{c}	0.72 ± 0.01^{a}
Crude protein (%)	0.65 ± 0.03^{b}	0.59 ± 0.02^{c}	4.05 ± 0.05^{a}
β-carotene (mg/ 100 g)	13.04 ± 0.25^{a}	10.16 ± 0.01^{b}	8.80 ± 0.04^{c}
Ascorbic acid (mg/ 100 g)	59.26 ± 1.11^{a}	55.95 ± 1.53^{b}	48.69 ± 2.33^{c}
Total Soluble Solids (TSS^{o}B)	9.50 ± 0.20^{b}	5.00 ± 0.07^{c}	13.00 ± 2.17^{a}
Titratable acidity (%)	0.06 ± 0.02^{b}	0.06 ± 0.01^{b}	0.78 ± 0.01^{a}
Total carbohydrates (%)	8.51 ± 0.14^{b}	7.34 ± 0.05^{c}	82.55 ± 3.19^{a}
Total energy (Kcal/ 100 g)	34.26 ± 1.68^{b}	29.36 ± 1.55^{c}	335.92 ± 5.45^{a}
Reducing sugars (%)	2.05 ± 0.02^{b}	1.72 ± 0.03^{c}	20.45 ± 0.06^{a}
Total sugars (%)	7.35 ± 0.07^{b}	6.15 ± 0.25^{c}	$43 \pm 15 \pm 2.18^{a}$

Colour

Colour is often used as an indication of the quality and freshness of food products. The colour was recorded to be (L* 0.14, a* 2.30, b* 0.61), (L* 58.70, a* 7.41, b* 34.39) and (L* 41.32, a* 8.44, b* 30.13) for fresh, pulp and powder respectively (Table 2) and pictorial representation of the same is depicted in Fig 1, 2 and 3. a* and b* represents the redness and yellowness of the product while a* indicates the lightness. According to Basulto *et al*. (2009), the increment of L* and a* values in papaya pulp and powder means a more pure and intense yellow colour. In this case, positive values indicate red. The higher b* values indicated yellowness (Table 1). Therefore, yellowness was highly observed in powder and pulp than fresh samples due to enzymatic browning which occurs in fresh samples during preparation. In pulp and powder, the slices were soaked in 0.1 per cent KMS solution after blanching therefore no change in colour. The changes in redness and yellowness of papaya powder can be evaluated by chroma. The higher value of chroma obtained were 35.18 and 31.29 (Table 2) in pulp and powder respectively indicated a more pure and intense colour (Pomeranz and Meloan, 1971). This result is in line with Meena *et al*. (2014) which investigated the same trend chroma in papaya powder (37.55). Hue angle (h^o) which is the dimension of the colour perceived were observed as higher in pulp (77.84), powder (74.35) and fresh (14.85). The higher the hue angle the pure the colour perceived and vice versa. In fresh samples, enzymatic browning may be due to the effect of low hue value compared to pulp and powder.

Table 2: Colour of ripe papaya fruits

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Food material	Colour				
	L*	**a***	**b***	**Chroma (c*)**	**Hue angle (h^o)**
Fresh	0.14	2.30	0.61	2.38	14.85
Pulp	58.70	7.41	34.39	35.18	77.84
Powder	41.32	8.44	30.13	31.29	74.35

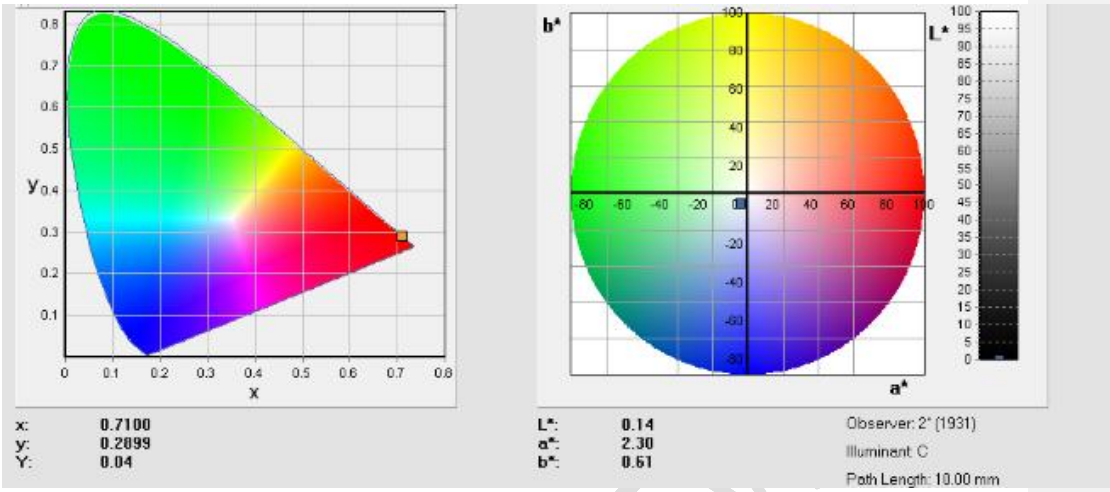

Fig 3: CIE readings of ripe fresh papaya fruit

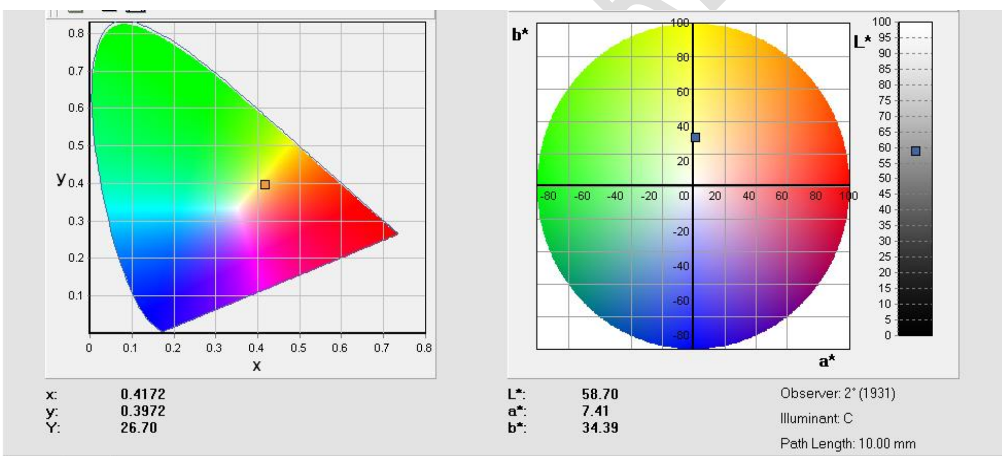

Fig 4: CIE readings of ripe papaya pulp

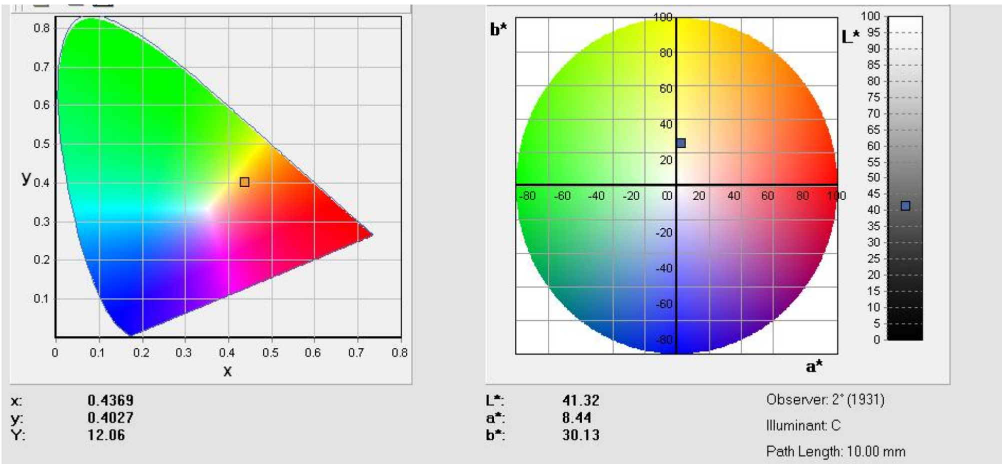

Fig 5: CIE readings of ripe papaya powder

COST OF PRODUCTION OF PAPAYA PULP AND POWDER

The cost of production of papaya pulp and powder is expounded in Table 3. A total of 500 g of pulp and powder were prepared and kept in PET jars for evaluation of different chemical parameters. The results revealed the highest significant difference ($p<0.05$) in cost of production. Papaya pulp cost Rs 38 if packed in PET jars and Rs 33 without packaging while papaya powder is produced by Rs 335 with PET jars and Rs 330 without packaging. The difference in cost of production is due to moisture content difference (Table 1) which require 8 kg of fresh papaya fruits to get 500 g of powder. In the Indian market, papaya powder 1kg cost Rs 2,336 packed in Aluminium Laminated Pouches (ALP) while frozen papaya pulp packed in LDPE cost Rs 95 per 1kg. The products produced in the current study are of low cost and affordable compared to commercial products of the same quality.

Table 3: Cost of production of papaya pulp and powder

Particular	**Rate (Rs.)**	**Pulp**		**Powder**	
		Quantity (g)	**Amount (Rs.)**	**Quantity (g)**	**Amount (Rs.)**
Ripe papaya fruits	60/ Kg	500.00	30.00	-	-
Papaya powder	600/ Kg	-	-	500.00	300.00

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Total		(500)	30.00	(500)	300.00
Processing cost @ 10 %		25.00	3.00	25.00	30.00
Cost (PET jars)	5/jar	1	5.00	1	5.00
Total cost with PET jars			**38.00**		**335.00**
Total cost without packaging			**33.00**		**330.00**

CONCLUSIONS

The fresh papaya fruit and its products are loaded with varying amounts of nutrients. It is recommended to use fresh papaya or products to improve vitamins and minerals in the diet. Although papaya is a powerhouse of nutrients, post-harvest losses of papaya is a big challenge. Therefore, processing is more worth preserving papaya and utilizing it throughout the year. The products prepared in this study (pulp and powder) can be used to prepare value-added products like jam, concentrate, juice, syrup, cordial, crush, wine, confectioneries, bakery products, ready to cook instant food premixes as well as reconstituted products. If papaya fruits will be processed immediately after harvesting, post-harvest losses will be minimized, the economy of the people, food and nutrition security will be improved. The cost of production was low compared to market products

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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