Review Article

International Journal of Food, Nutrition and Dietetics
Volume 3 Number 3, September - December 2015
DOI: https://dx.doi.org/10.21088/ijfnd.2322.0775.3315.3

A Review on Composition, Processed Products and Medicinal Uses of Papaya (*Carica Papaya L.*)

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Abstract

Papaya is a very popular fruit grown in tropical countries and belongs to the family of *Carcicaceae.* Nutritionally papaya is a rich source of carotenoids and also provides fair amounts of B complex vitamins, ascorbic acid and minerals. Papaya can be processed to obtain many preserved products such as candy, jams and jellies. It also can be converted to beverages such as ready-to-drink beverages and nectar. Dried and canned papaya products are also available. By-products of papaya such as pectin and papain are useful for the food industry. Papaya is also prized for its medicinal properties, which have been documented by many researches. The present review focuses on the salient features of nutritional composition, processed products, and medicinal uses of papaya.

Keywords: Production; Nutritional Composition; Flavor Components; Preserved Products; By Products.

Introduction

Papaya (*Carica papaya* L) is a rapid growing hollow stemmed and short lived perennial tree, belonging to the family *Carcicaceae* which is usually propagated from seeds. Because of open pollination, papaya is a notoriously difficult crop to maintain as a pure or tree cultivar. This family includes 4 genera and about 20 species of *carica* native to tropical and subtropical areas of the world (Sidhu, 2006). It may be male, female, or hermaphrodite, the fruits from female trees are round whereas fruits from hermaphrodite trees are elongated (Figure 1a) (Bruce and Peter, 2008). The fruit is melon-like, oval to nearly round, somewhat pyriform, or elongated club-shaped, 15-50 cm long and 10-20 cm thick and weighing up to 9 to 10kg. Semi wild (naturalized) plants bear small fruits 2.5-15 cm in length. The skin of the fruit is waxy and thin but fairly tough. When the fruit ripens it develops a light- or deep- yellow-orange coloured skin (Figure 1b), while the thick wall of succulent flesh becomes aromatic, yellow orange or various shades of salmon or red. The ripened fruit is juicy, sweetish and develops a characteristic papaya flavor which resembles the flavor like a cantaloupe. Mature fruits contain numerous grey-black ovoid seeds (Figure 1c) attached lightly to the flesh by soft, white, fibrous tissue (Morton, 1987).

(a) Papaya Tree (b) Papaya Fruit (c) Papaya Seeds

Fig. 1: Papaya Fruit and Seeds

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The fruit is a popular fruit grown more prominently in recent years, the volume of production being next to fruits such as mango, banana, citrus and pineapple at the global level. Even in India, the fruit is more common with a number of varieties. Some of the common varieties of papaya throughout the world are Coorg Honey Dew, Pusa Dwarf, Pusa Giant, Pusa Majesty, Pusa Delicious, Co.1, Co.2, Co.3, Co.5, Washington, Solo, Ranchi, IIHR39, IIHR54, Taiwan-785, Taiwan-786, Solo, Solo Sunrise, Solo Sunset, Red Amazon, Hortus Gold, Betty and Improved Peterson (National Horticulture Board, 2012). The fruit is given different names in various localities throughout the world as given in Table 1. Papaya is considered as one of the important fruit because it is rich source of antioxidants, phytochemicals, nutrients such as; carotenes, vitamin C, and flavonoids, the B vitamins including folate and panthothenic acid, minerals such as potassium and magnesium, and dietary fiber (Murcia *et al*., 2001; Leong and Shui, 2002, Gopalan *et al.,* 2004). In addition, papaya is a source of digestive enzyme papain, which is used as an industrial ingredient in brewing, meat tenderizing, pharmaceuticals, beauty products, and cosmetics. The fruit is mostly consumed fresh but the immature fruit is also cooked or used in fruit salads, preserves, sauces and pies. The fruit is characterized for its active pectinolytic enzymes during ripening. A number of products are prepared by drying, canning, pickling and processing the raw fruit latex. Pureed papaya is a good source of β-carotene (Ncube *et al*, 2001). Brazil, Nigeria, India, Mexico, Indonesia, China and Thailand are leading producers of papaya. However other countries such as USA, Taiwan, Puerto Rico, Peru, Bangladesh and Australia are also producing sizeable quantity of this fruit (FAO, 2001). The world production of papaya is given in Table 2. Papaya is produced in about 60 countries, with the bulk of production occurring in developing economies. Global papaya production in 2012 was estimated at an annual rate of 3.85 % between 2004 & 2012. India is the leading papaya producer, with a 41.56% share of the world production during 2010-2012 and the total production during 2014 (APEDA) was 5,639,310 tonnes, followed by Brazil (12.25%) and Indonesia (7.30%). Other important papaya producing countries and their share of global production include Nigeria (6.79%), Mexico (6.18%), Ethiopia (2.34%), Democratic Republic of the Congo (2.12%), Colombia (2.08%), Thailand (1.95%), and Guatemala (1.85%) (FOSTAT, 2012a, b). This review article comprises of physiology and ripening of papaya, chemical composition, different products prepared by papaya and the health benefits of papaya.

Physiology and Ripening

Papaya trees are very fast growing, prolific fruit bearers and the first fruit is ready in 10-14 months from the time the plants are transplanted into the orchard (Sommer, 1985). In India, the fruit takes about 135-155 days from pollination to fruit maturity (Selvaraj *et al*, 1982a, b). The weight and length of a fruit shows a typical double sigmoid type of growth curve (Selvaraj *et al*, 1982a, b; Ghanta *et al*, 1994; Ong, 1983). Change of latex colour from white to watery, is another index of maturity of papaya fruit (Akamine and Goo, 1973).

Some researchers report that, application of micronutrients during fruit growth and ripening influence the fruit quality and increase the production of papaya fruit. Chattopadhyay and Gogoi (1992) carried out a study on the effect of treating plant with micronutrients such as boron, zinc, copper, iron and manganese on the composition of the fruit. The application of boron (40ppm) increased total sugars (7.69% versus 6.6%) and ascorbic acid (65.63 versus 60.84 mg / 100g pulp). Treatment with boron, copper and zinc (all 40 ppm) reduced titrable acidity (TA), and increased carotene content was higher (2.07-2.33 versus 2.01 mg / 100g). The researchers concluded that a combined foliar application of these micronutrients (40 ppm of each) will result in good quality papaya fruits. Lavania and Jain (1995) reported that the yield and quality of papaya fruits are greatly influenced by nitrogen, phosphorus and potassium (NPK) fertilizer application. They reported that the application of nitrogen (200g), phosphorous (50g) and potassium (100g), per tree was found to be the most effective dose for increasing fruit yield and quality parameters such as ascorbic acid, total soluble solids (TSS) and sugar contents of mature papaya fruits. Yunxia *et al.*, (1995) carried out a similar study on the ripening process of the "Sunset" papaya (*Carica papaya* L) fruit with the treatment of calcium. The researchers reported that the higher concentration of calcium in mesocarp was associated with slower fruit softening rate when compared with a lower calcium concentration. Kavitha *et al.,* (2000 a, b) reported that application of boron and zinc affected the biochemical and quality characters of papaya. The two minerals treated samples produced higher levels of TSS, total sugars, reducing sugars and non reducing sugars. The TA and ascorbic acid in the mineral treated fruits averaged approximately 0.29% and 47.1mg/g respectively.

Paull and Chen (1990) studied the effect of heat processing on the softening process of the papaya at various stages of maturity and harvest date. Mesocarp softening during papaya ripening was impaired by heating at 42ÚC for 30 mins followed by 49ÚC for 70 mins. The fruit samples which were subjected to heat processing failed to be softer and the researchers observed that the disruption of the softening process varied with the stage of maturity and harvest date. The treated fruits had the highest ethylene production than in the non treated fruits. Camara *et al.,* (1993) stated that the softness to touch is another indicator used as the ripening index. Among the physicochemical determinants, pH and TSS (° Brix) are very good indicators of ripening of papaya fruit. Calegario *et al.,* (1997) compared the physical methods; reflectance measurement, delayed light emission intensity, and body transmission spectroscopy and subjective methods; change in skin colour to evaluate the ripening stage of the papaya fruit and reported that the subjective method is more useful than the physical methods.

Bron and Jacomino (1996) investigated about the effect of different maturity stages at harvest on the ripening physiology and quality of 'Golden' papaya. Papayas were harvested at four different maturity stages (Stage 0: totally green; Stage 1: up to 15% of yellow skin; Stage 2: 16-25% of yellow skin; and Stage 3: 26-50% of yellow skin) and evaluated during ripening at 23ºC. Physical and physico-chemical (skin color, pulp firmness, soluble solids, titrable acidity, and ascorbic acid), physiological (respiratory activity and ethylene production), and sensorial (flavor, odor, firmness, and appearance) characteristics were evaluated. The authors reported that the fruit harvested at stages 0, 1, 2 and 3 reached the edible condition after 7, 6, 4, and 3 days respectively. There was an increase in ascorbic acid concentration (20-30%) during ripening, skin hue angle and titrable acidity were reduced and soluble solids did not alter. The fruits which were harvested at stages 2 and 3 had superior scores for sensorial evaluation, mainly for flavor and appearance and the authors concluded that harvest at different maturity stages altered fruit postharvest physiology. Brishti *et al.,* (2012) studied the effect of Bio preservatives on storage life of papaya. In this experiment the effect on post-harvest preservation of papaya (*Carica papaya* L.) fruit coated with either Aloe gel (AG; 100%) or papaya leaf extract with Aloe gel (PLEAG; 1:1) was studied. To evaluate the role of coating on ripening behaviour and quality of papaya, the uncoated and coated fruits were stored and ripened at room temperature (25ºC - 29ºC) and 82-84% relative humidity. Physico-chemical properties were analyzed at 4 day intervals during the storage period. The incidence of disease attack was also visually observed. The overall results showed the superiority of AG and PLEAG coating in lengthening the shelf-life of papaya fruit compared to controls which showed significant decay from 6th day onward and complete decay within 12 days of storage. The AG and PLEAG coated fruits maintained their shelf life for 12 days and decayed at 16th day. The coated fruits also maintained their colour, flavour and firmness up to 12 days of storage. An increase in ascorbic acid content (120.2 mg / 100 g) was also found in coated fruits in contrast to the control (59 mg / 100 g). Only 27% disease incidence was observed in AG and 13% in PLEAG coated fruits as compared to control (100%) during the storage period. The results of this study showed that both AG and PLEAG coatings have excellent potential to be used on fresh produce to maintain quality and extend shelf-life.

Chemical Composition

The chemical composition of papaya, viz, proximate composition – moisture, protein, fat, total ash, vitamins – fat soluble: total carotenoids, water soluble: thiamine, riboflavin, niacin, vitamin C, minerals – iron, sodium, phosphorus, potassium, magnesium and calcium; in different parts of the fruit is compiled in Table 3 and flavor components in Table 4 as reported by some of the researchers. As observed, it is noteworthy to mention that papaya is a wholesome fruit rich in sugar and vitamins C, A, B_1 and B_2. Among the carbohydrates, sugar is the major constituents of papaya fruits but amounts vary considerably depending upon the cultivar and agronomic condition. Indian cultivars have higher sugar content (10 – 10.2% TSS) than the papaya cultivars grown in the United States (5.6 – 7.1%) (Pal and Subramanian, 1980; Madhav Rao, 1974). Papaya is second only to mango as a source of β-carotene, a precursor of vitamin A. The researchers studied the influence of various agronomic practices and planting time on changes in the physicochemical quality parameters of papaya fruit, such as mean fruit weight, pulp, yield, pulp-peel ratio, TSS as brix, vitamin C and total carotenoids. They reported that, September planting produced heavier mean fruit weight (2.30 kg), maximum TSS (11.2°Brix), vitamin C (74.55 mg / 100g) and total carotenoids (1152.50 mg / 100g), higher pulp – peel ratio than that of the fruits harvested from other months of planting. Selvaraj *et al*, (1982a, b) and Birth *et al*, (1984), observed that the change in outer color of the skin of fruit is an indicator of ripeness, and this change is mainly due to an increase in the carotene content and decrease in chlorophyll. The authors reported that, the total carotenoids contents increased manyfolds from the mature green stage to nearly about 4mg / 100gm at the fully ripe stage of maturity. Papaya fruits are also good source of many minerals (potassium, phosphorus and magnesium) in human diet. The papaya fruit belongs to the group of low acid content fruit and the pH of pulp ranges from 5.5 to 5.9. Citric acid and malic acid are the major acids with smaller quantities of ascorbic acid and β-ketoglutaric acid (Chan *et al.,* 1971, 1973). The major enzymes present in papaya are invertase, papain esterase, myrosinase and acid phosphates, which play important role in the quality and stability of processed products made from papaya (Jagtiani *et al*, 1988).

The hydrolytic change of protopectin to pectin during the ripening of the fruit reduces firmness or softens the fruit. During the ripening stage, the enzymatic demethylation and depolymerization of protopectin leads to the formation of low molecular weight compounds with less methoxyl group which are insufficient to maintain the firmness and thereby it reduces structural firmness of the fruit (Kertesz, 1951). The author reported that the enzymes such as polygalacturonase and pectin methyl esterase play an important role for the textural changes of the fruit. The chemical composition of the pectin is influenced by the variety of fruit, the growing condition and the state of development at the time of harvest (Lassoudiere, 1969a, b). Loss of firmness is not uniform in papaya fruit as some time the fruit become soft before the complete development of total soluble solids (Pelag, 1974). Ali *et al*., (1998), reported that â-galactosidase is an important enzyme present in papaya which has the ability to depolymerize pectin and hemicelluloses, which helps in softening of the fruit. Various caroteniods such as β-carotene, lycopene, β-cryptoxanthin and β-zeacarotene are present in varying amount in papaya (Chan, 1983; Bhaskarachary *et al*, 1995; Wilberg and Rodriguez, 1995; Cano *et al*., 1996; Irwig *et al*, 2002; Sugiura *et al*, 2002). A study conducted by Selvaraj *et al*, (1982a, b), showed increase in carotenoids content (as β-carotene) by five to ten folds in yellow fleshed cultivars. During ripening the color of papaya flesh turns yellow or reddish from green unripe fruit. The major difference between yellow and red fleshed cultivars is the total absence of lycopene in the yellow fleshed papaya. Carotenoids, which are relatively heat stable, showed higher retention than anthocyanins after blanching and drying in papaya fruit. Pretreatment of papaya fruits with sodium metabisulphite, prevented the oxidation of carotenoids but caused bleaching of anthocyanins while blanching (Sian and Soleha, 1991).

Table 1: Common names of Papaya

Sl.No	Place	Common names
1.	Africa, Australia, and Jamaica	Paw-paw, papayer and papaw
2.	Arabic	Fafay, babaya
3.	Argentina	Maman
4.	Bali	Gedang castela, Spanish Musa
5.	Burmese	Thimbaw
6.	Creole	Papayer, papaye
7.	Cuba	Fruta bomba
8.	English	Bisexual pawpaw, pawpaw tree, melon tree, papaya
9.	Europe	Tree melon
10.	Filipino	Papaya, lapaya, kapaya
11.	French	Papaya, papayer, figuier des Îles
12.	German	Papaya, melonenbraum
13.	India	Pappaiya (Bengali), papeeta (Hindi), papaya (English) and pappali or pappayi (Tamil)
14.	Indonesia	Dangandangan, gedang, papaya
15.	Khmer	Lhong, doeum lahong
16.	Lao	Sino-Tibetan, houng
17.	Luganda	Papaali
18.	Malaysia, Singapore	Betik
19.	Mexico, Panama	Olocoton
20.	Philippines	Kapaya, kepaya, lapaya, tapayas and papyas
21.	Sinhala	Pepol
22.	Spanish-speaking countries	Melon zapote, payaya (fruit), papayo or papayero (the plant), fruta bomba, mamón or mamona, figuera del monte, papaita, lechosa
23.	Swahili	Mpapai
24.	Thai	Ma kuai thet, malakor, loko
25.	Thailand	Malakaw, lawkaw, teng ton
26.	Tigrigna	Papayo
27.	USA	Pawpaw, paw paw, papaw, poor man's banana, or hoosier banana
28.	Venezuela	Lechosa
29.	Vietnamese	Du du
30.	Worldwide	Papaya

Source: Silva *et al.,* (2007); Saran and Chaudhary (2013); Roshan *et al.,* (2014)

Table 2: Global Papaya Production (in metric tonnes)

Country	Production
India*	5,639,310
Brazil	1,517,696
Indonesia	906,312
Nigeria	775,000
Mexico	742,017
Ethiopia	308,654
Democratic Republic of Congo	295,770
Colombia	283,078
Thailand	271,584
Guatemala	201,000
Other	1,889,758
TOTAL	**12,413,031**

Source: FAOSTAT (2012 a, b)
* APEDA (2014)

Table 3: Chemical Composition of papaya (per 100g)

Reference	Part of the plant studied	Energy (Kcals.)	Moisture (%)	Carbohydrate (%)	Protein (%)	Fat (%)	Ash (%)
Das and Siddappa, 1955	Pulp	-	88.9	-	0.5	-	0.57
Fredrich and Nichols, 1975	Fruit flesh	30	-	10	0.6	0.1	-
Gopalan *et al.*, 2004	Whole fruit	32	90.8	7.2	0.6	0.1	-
Puwastien *et al.*, 2000	Ripe papaya	-	89.1	9.5	0.9	0.1	0.51
Puwastien *et al.*, 2000	Green papaya	-	92.6	6.0	0.8	0.1	0.50
		Total carotenoids (µg)		**Thiamine (µg)**	**Riboflavin (µg)**	**Niacin (mg)**	**Vitamin C (mg)**
Das and Siddappa, 1955	Pulp	927		40	250	0.20	42.90
Singh and Singh, 1998	Whole fruit	1152		-	-	-	74.55
Gopalan *et al.*, 2004	Whole fruit	666		40	250	0.20	57.00
Munsell, 1950	Whole fruit	-		25	29	0.24	-
Asenjo *et al.*, 1950	Whole fruit	-		30	38	0.40	-
Puwastien *et al.*, 2000	Ripe papaya	7807		31	31	0.31	62.57
Puwastien *et al.*, 2000	Green papaya	0		40	192	0.29	29.00
		Iron (mg)	**Sodium (mg)**	**Potassium (mg)**	**Phosphorus (mg)**	**Calcium (mg)**	**Magnesium (mg)**
Gopalan *et al.*, 2004	Whole fruit	0.50	6.0	69	13.0	17.0	-
Hardisson *et al*, 2001	Whole fruit	-	120.0	210	10.0	30.0	20
Munsell, 1950	Whole fruit-Variety 1	0.25	110.0	-	1.8	18.3	-
	Whole fruit-Variety 2	0.42	97.0	-	15.5	17.5	-
Puwastien *et al.*, 2000	Ripe papaya	1.41	14.1	137	NR	16.2	25
Puwastien *et al.*, 2000	Green papaya	0.60	21.0	203	NR	31.9	47

*NR-Not reported

Table 4: Flavour Components of papaya

Reference	Part of the plant studied	Flavour components
Flath and Forrey, 1977	Whole fruit	Linalool, β-ionone
Macleod and Pieris, 1983	Whole fruit	Methyl butanoate
Mohammed *et al*., 2001	Whole fruit	Linalool, benzaldehyde, benzenemethanol, cyclohexane and hexanoic acid
Sheikh and Krishnamurthy, 2013	Fruit	Linalool, benzylisothyocynate, cis and trans 2,6-dimethyl 3,6 epoxy-7 octen-2-ol,Alkaloid,α carpine, benzyl-β-D gucoside,2-phenyl ehyle-β-D gucoside,4-hydroxyphenyl-2-ehyle-β-D gucoside
Sheikh and Krishnamurthy, 2013	Juice	N-butyric, n-hexanoic and n-octanoic acid, lipid, myristic, palmitic, stearic, linoleic, linolenic and cis-vasanic and oleic acid

Papaya Based Products

As the papaya fruit grows faster with higher yields and as it has various varieties which are diverse in range, this fruit can be used for development of economically viable products on commercial scale, with ample scope for blending with other fruits. Because of the mild flavor of the fruit, the products can be supplemented with other strong flavors, to obtain tailor made sensorial products. Besides consumption as a fresh fruit, a number of processed food products developed using papaya are used in the form of puree (Brekke *et al*., 1972; Martin *et al*., 1972; Flath and Forrey, 1977; Nath and Ranganna, 1981), jam (Parsi, 1976, Teangpook and Poasantong, 2013), jelly (Yi-zhuo *et al*., 2013; Mie, 2013), pickle (Su and Liu, 2006; Nurul and Asmah, 2012), candied fruit (Chan and Caveletto, 1978; Cherian and Cheriyan, 2003; Ahmad *et al*., 2005; Jadhav *et al*., 2012), mixed beverages (Rodriguez and George, 1971; Martin *et al*., 1972; Chan *et al*., 1975; Salomon *et al*., 1977; Kalra *et al.,* 1991; Sheeja and Prema, 1995; Mostafa *et al.,* 1997; Ukwuru and Adama, 2003; Saravana and Manimegalai, 2001; Boghani *et al.,* 2012; Yadav *et al*., 2013), canned slices / chunks (Lynch *et al*., 1959; Nath and Ranganna, 1981; Dos – Amagalhaes *et al*., 1990), concentrate (Siddappa and Lal, 1964; Ponting *et al*., 1966; Chan and Caveletto, 1978; Mehta and Tomar, 1980a, b; Arya *et al*., 1983; Aruna *et al.,* 1999; Barbaste and Badrie, 2000; Kaleemullah *et al.,* 2002; Mendoza and Schmalko, 2002; Moyano *et al*., 2002; Kandasamy and Varadharaju, 2014) on a commercial scale. The functional components of the papaya such as pectin content of the fruit aids in jam preparation and easy setting. The biochemical constituents of the fruit related to health benefits such as reducing cholesterol and the provision for development of wide spectrum of processed products dictate the scientific merit of the fruit, with national and international strategies for the future. Varieties of papaya products developed by research with low sweetness have proved its importance in reducing the blood sugar levels. The mature fruit, at its various stages of ripening, can also be processed to give several products and a few are mentioned below in this review.

Papaya Candy

Papaya candies are fruit prepared by using high percentage of sugar. Papaya and sugar are the main raw materials. The processing of papaya candy according to Kumar (1952) is as given in Figure 2.

Fully mature but unripe fruit is hand peeled, deseeded, and cut into 0.5–1.0 cm cubes.

⇩

These cubes are soaked in 4% brine solution for 2 weeks, taken out and leached in running tap water to remove the salty taste.

⇩

The fruit is boiled in 25° Brix syrup for a few minutes and then allowed to stand overnight.

⇩

The sugar content of syrup is increased by 10% by boiling the mixture of fruit / syrup and allowed to stand overnight.

⇩

This process is repeated for 5 days until the syrup concentration reaches between 70 and 75° Brix after standing.

⇩

Other fruit essences such as orange, pineapple, raspberry, and strawberry are added to the syrup and allowed to stand overnight.

⇩

A translucent candied papaya is obtained at this stage, which can be rolled in powder sugar to prevent stickiness.

Fig. 2: Processing of Papaya Candy

Some of research studies reported on the processing of papaya leather / candy are as follows. Chan and Caveletto (1978) studied the effect of (i) drying temperature (77°C, 84°C or 94°C), (ii) storage times (1, 2 or 3 months), (iii) storage temperature (18°C, 24°C or 38°C) and (iv) sulphur dioxide (SO_2) on the quality attributes viz (a) drying rate, (b) sensory analysis – colour, flavor, off flavor of papaya leather. The researchers concluded that, drying rate was decreased when high SO_2 levels were used. The colour of the leather was dependent on drying and storage temperature, and the addition of SO_2 protected against darkening at high drying and storage temperature respectively. Cherian and Cheriyan (2003) carried out the study on sensory acceptability of papaya leather by developing 2 different products viz, papaya leather and papaya+mango (60:40) blended leather and compared the two leathers with a control plain mango leather. Ahmad et al., (2005) developed a fruit bar from blend of ripe papaya pulp + tomato pulp (75:25). Seven different fruit bars were developed with the combination of the three hydrocolloids, which were added at different percentages. It was found that seven different samples of fruit bar had moisture contents of 20.9–22.1% and total soluble solids 78.1–78.8°Brix while pH, browning index, and vitamin C contents were in the following ranges, 4.3–4.50, 0.137–0.150 (OD), and 40.5–41.4 mg / 100 g respectively. Jadhav et al., (2012) prepared toffee by blending noni-pulp with papaya pulp at a ratio of (i)100:0, (ii) 95:5, (iii) 93:7 and (iv) 90:10 and studied the effect of varying pulp concentration of fruit pulp on sensory quality of noni (*Morinda citrifolia* L). Toffee comprising 90% noni pulp with 10% of papaya pulp and 93% noni pulp and 7% guava pulp had higher overall sensory acceptability such as appearance, colour, flavor, consistency.

Papaya Jam

Jams are fruit preserves, which are 45 parts prepared fruit with 55 parts of sugar concentrate to 65% or higher solids, resulting in semi solid product. The processing method for the preparation of papaya jam according to Lal and Das (1956) is given in Figure 3.

Cooked slices are mashed, mixed with equal weight of sugar, and the mixture is cooked.

⇩

Citric acid at the rate of 5 g / kg of pulp is added to improve the sugar–acid ratio and it also helps in the production of inverted sugars, which prevent sugar crystallization in jam during storage.

⇩

Cooking of fruit pulp / sugar mixture is continued until it attains a thick consistency, which usually corresponds to a TSS of 65–68^{o} Brix.

⇩

Jam is filled hot into clean, dry, and sterilized glass jars, sealed airtight and cooled.

Fig. 3: Processing Method of Papaya Jam

Teangpook and Poasantong, (2013) developed low sucrose papaya jam from ripe papaya pulp and green lime juice and studied the storage stability of the jam. The developed jam was comprised of papaya (32%), lime juice (8%), low ester pectin (0.55%), konjac flour (0.5%), glucose syrup (9%), salt (0.03%) and calcium lactate (0.01%) and consisted of 52.10% moisture, 45.61% total carbohydrate, 0% fat and 1.52% dietary fiber. It contained 36.46% sucrose in comparison with control jam which had sucrose concentration of 55%, 46° Brix TSS and a pH of 3.22. The average sensory evaluation score was moderate preference and 79.31% of consumers liked it.

Papaya Jelly

Fruit jelly is preserved fruit product with characteristic texture and body. The steps involved in jelly making is same as that for jams, but the cut fruits are boiled in enough water and citric acid is added to extract pectin, which is then decanted and heated with sugar until it forms sheets or flakes when let down from a spoon. It is then set at cold temperature. Papaya jelly was optimized and developed by Yi-zhuo *et al.,* (2013) through single factor experiments and orthogonal tests. The results showed that the best formula of papaya jelly contained a ratio of sodium alginate, agar and xanthan gum of 6:5:4 (3.0 g in total), 40g of papaya, 0.2g citric acid and 16g sugar. The papaya jelly was homogeneous smooth and had a good flavor. Investigation on the best processing technology for production of health jelly with papaya was carried out by Mei (2013). Results showed that the optimal mixture was gum - 1.0%, sugar - 20%, papaya juice - 30% and citric acid - 0.25%. The product had the aroma and colour of papaya, a good acidic and sweet flavor, a uniform texture and a smooth taste.

Papaya Beverages

Juice or nectar is obtained by blending the thin pulp of the fruit with sugar and citric acid. The finished product has 15-20° brix and mild acid taste. The method for the preparation of papaya juice and nectar according to Payumo *et al*., (1968) is given in Figure 4.

Papaya pulp is mixed with sugar (1.5-2.0kg/kg pulp).

⇓

Citric acid (12.5-17.5g/kg pulp), color and flavour are added.

⇓

Nectar is filtered and heated to 85-88°C.

⇓

Filled in plain or lacquered cans and cooled in running water about 38°C.

Fig. 4: Processing Method of Papaya Nectar

Rodriguez and George (1971) developed a good quality canned papaya beverage from the pulp of peeled and unpeeled fruit. To enhance the flavor of the beverage, 0.4% of sliced, ripe Indian lime was added before pasteurization. The beverage was adjusted to 15° brix and pH of 3.7 and pasteurized at 88°C and canned. The product was excellent organoleptically even after 1 year of the storage. Chan *et al.,* (1975) studied changes in ascorbic acid, carotenoid and sensory quality of papaya puree at different stages of processing. About 5.5% ascorbic acid was destroyed during pulping in preparation of puree and 14% more was lost during vacuum concentration. There was no change in quality, flavor or aroma seen with alteration of the concentration. Salomon *et al.,* (1977) studied the blending of papaya/passion fruit nectar. The results showed that the 82.5:17.5 and 87.5:12.5 blends were preferred to the 75:25 blends. Kalra *et al.,* (1991) evaluated the quality of mango – papaya blended beverage. Mango and papaya pulps were blended in ratio 1:0, 1:1, 2:1, 3:1 and 0:1 and these pulps were stored for 1 year. The stored pulp contained 15% pulp, 20% total soluble solids and 0.3% acidity, and could be preserved for 1 yr in glass bottle under ambient conditions. The study indicated that 25-33% papaya pulp could be incorporated in blended beverage without affecting the quality and acceptability of the beverage.

Formulation of different types of papaya juice blends and nectars have been reported by different authors. Mostafa *et al.,* (1997) developed two different fruit nectars from (i) papaya pulp and (ii) papaya and mango pulps. The two nectars contained, total pulp concentration of about 20, 30 or 40%, TSS - 15% and acidity as citric acid - 0.55%. Mango pulp was added at 0, 15, 25, 37.5 or 50% of total pulp content. A blend of 15% papaya + 15% mango was rated excellent and it was characterized by higher acceptability. Ukwuru and Adama (2003) prepared beverages by blending soya flour (SF) and papaya pulp flour (PF) in the ratio of (i) 100:0, (ii) 70:30, (iii) 50:50, (iv) 30:70 and (v) 0:100, and fortified the above beverages with vitamin C. Storage stability of a whey based papaya fruit juice ready to serve (RTS) beverage was studied by Saravana and Manimegalai (2005). The beverage was prepared by blending 10% papaya juice with whey. In another study, the authors formulated mango-papaya blended squash by mixing them in proportions of 50:50, 75:25 and 25:75 (Saravana and Manimegalai, 2001). Boghani *et al.,* (2012) developed a blended papaya and aloe vera ready-to-serve beverage in concentration of 90% and 10% respectively. Blended RTS beverages were prepared using 12% TSS, 0.3% acidity and 10% blended juices in blending ratio of 90% papaya juice + 10% *Aloe vera* juice. Optimization studies on the development of blended fruit nectar, based on papaya and bottle gourd were studied by Yadav *et al*., (2013). The nectar was optimized with the ingredient composition (%) of papaya: bottle gourd juice (2.47:1), sugar (20.95) and citric acid (0.30). The nectar had a pH of 3.99, acidity 0.35%, TSS of 20.80 with hedonic scale sensory ratings of 7.43 and 7.18 for flavor and taste respectively.

Fermented Papaya Products

Wen-Jun and Hong (2008) studied the brewing technology of papaya and jujube to make healthy wine. A method was described for preparation of wine by fermentation of papaya, jujubes, powdered Eucommia extract and honey for 48 hours at 30-34° C. Lee *et al.,* (2011) studied the impact of amino acid addition on aroma compounds in papaya wine fermented with *Williopsis mrakii.* The study suggested that papaya juice fermentation with *W.Saturnus mrakii* in conjunction with the addition of selected amino acid (L-leucine, L-isoleucine, L-valine and L-phenylalanine) can be an effective way to modulate the aroma of papaya wine.

Papaya Pickle

Raw papaya can be used for making salted pickles by brine curing and adding spiced vinegar in the traditional way. Su and Liu (2006) studied the processing technique of papaya pickle preparation with the addition of spices (including garlic, hot pepper and ginger). Nurul and Asmah (2012) developed a papaya pickle and compared the pickle with the fresh papaya for its total phenol (TPC), total flavonoid (TFC), â- carotene, lycopene, ascorbic acid contents and antioxidant activity. With the process of pickling the researchers found that there was a significant decrease in the above mentioned parameters in comparison with the fresh papaya.

Papaya Pulp

Papaya puree is the major semi processed product that finds use in juices, nectars, fruit cocktails, jams, jellies, and fruit leather. Earlier the processing of papaya into puree was difficult, mainly due to product gelation and off-flavour development. The development of undesirable odours, due to the presence of butyric, hexanoic and octanoic acids and their methyl esters was observed in puree prepared by commercial methods. Therefore, few studies have been carried out to rectify this problem by modifying the processing technologies and a few are discussed below. Brekke *et al.,* (1972) reported the composition of Hawaii varieties of papaya puree as total soluble solids – 11.5 to 13.5%; total acid (after acidification) – 1.05 to 1.10; ascorbic acid – 50 to 90mg%; carotenoids – 3.5 to 3.9mg%; and moisture – 84 to 88%. The authors reported that the technology in the processing included preliminary steaming, the use of crusher scrapper device and acidification. In addition to the above study, Chan *et al.*, (1973) also reported that acidification and heat inactivation of enzymes prevented the development of the above mentioned unpleasant flavours and odours in the papaya puree. Chan *et al.*, (1975) reported that, during the process of making a puree and a concentrate from papaya, small but statistically significant losses in vitamin C had occurred. Microwave treatment of papaya puree produced a small change in qualitative and quantitative composition of carotenoid pigments, without significant alterations to the original colour of the fruit puree (de Ancos *et al.*, 1999). Parker *et al.,* (2010) developed optimized papaya pulp nectar using a combination of irradiation and mild heat treatment.

Canned Papaya Products

Canned papaya chunks or slices are some of the popular ingredients employed for the preparation of fruits salads. Although fully ripe, soft papaya fruits are ideal for fresh consumption, but they are not suitable for canning purpose. For canning only the green mature or semi ripe papaya fruits are used. Lynch *et al.,* (1959) described a canning procedure for papaya chunks. Nath and Ranganna (1981) recommended thermal processing of 3-cm papaya cubes in cans (hot filled with syrup at pH 3.8) at 100^{0}C for 16.2 mins to achieve F-value of 1.33 or D-value of 2.5 during the canning process. For the establishment of required thermal processing time for canned papaya puree, the use of destruction studies with *Clostridium pasteurianum* was conducted by Dos-Amangalhaes *et al.*, (1996). Higher temperature was used for the inactivation of the polyesterase enzyme.

Dried Papaya Products

A number of low-moisture products such as fruit leather, powder, toffees, chunks, rolls, and slices have been prepared from papaya puree, which finds their place in food commodity market. Siddappa and Lal (1964) patented a process for drying mixtures of papaya juices, previously concentrated, with sugar and other additives. A procedure for the dehydration of ripe papaya slices after steeping in 70° brix syrup containing 1000 ppm of SO_2 was standardized to give the best quality product by Mehta and Tomar (1980 a, b). Ponting *et al.*, (1966) reported that pulp can also be dried after adding 5–7.5% sugar, 0.5% citric acid, and 0.3% potassium metasulphite. This mixture is spread on greased trays in 1 cm thickness layer and dried in cabinet drier at 55–60^{0}C. The dried product developed a leathery consistency; which was rolled and cut into desirable sizes. This fruit leather had a shelf life of about 8 months when stored at 24–30°C. Chan and Caveletto (1978) developed papaya toffee similar to fruit leather from puree. Papaya fruit bars when stored at room temperature for 9 months retained 54%, 46%, and 43% of total carotenes, â-carotene, and vitamin C, respectively, and were judged to have superior texture and aroma with fewer physicochemical changes (Aruna *et al.*, 1999). For cheese product containing fruit blends, optimal ratio of papaya puree to pineapple puree was 2:1 with 2% pectin and processed to 77–80° Brix (Barbaste and Badrie, 2000). Sensory analysis indicated a significant preference for the blended fruit cheese. Shelf life of these products at 4–5°C was around 8 weeks. Kandasamy and Varadharaju (2014) carried out the experiment to find out the effect of drying air temperatures (60, 65 and 70°C), foaming agents (methyl cellulose, glycerol-mono-stearate and egg white) and foam thickness (2, 4, 6 and 8 mm) on biochemical qualities of foam and non-foam dried papaya powder. It was observed that there was significant ($p \leq 0.05$) variations in ascorbic acid and β-carotene content with temperatures, foaming agents and foam thickness.

Freeze Drying

Most of the dried products prepared from papaya fruit suffer from undesirable darkening effects. To overcome these defects, less severe treatments have been tried. Freeze-drying is one such method that produced good results to reach a moisture content of as low as 3% in the finished papaya powder. Storage of freeze-dried powder in glass jars did not show significant adverse effects on the quality or composition of finished products after 3 months (Salazar, 1968). Carotenoids were found to be most stable in freeze-dried powder at water activity of 0.33 (6–7% moisture content) and the researchers recommended freeze drying for the storage of papaya (Arya *et al.,* 1983). A combination of osmotic dehydration and freezing was investigated for the preservation of papaya slices (Moyano *et al*., 2002). Two models have been developed by Mendoza and Schmalko (2002) to predict the contents of moisture and sugar during osmotic drying of papaya slices. The osmotic (60° brix, 60°C) and air-drying (60°C) methods were used for drying papaya slices.

Papaya Preserves

Papaya preserves are developed by washing, peeling, deseeding papaya and then cutting into pieces; the pieces are soaked for 1-2 days in solution containing sulfite and calcium chloride. The treated pieces are blanched in water (90^{o}C), cooled, and then submerged in 30^{o} Brix sucrose syrup. More sucrose is added to the syrup gradually until its concentration reaches 45^{o} Brix. The syrup-infiltrated fruit are dipped into boiling water to wash off the sugar on their surface, taken out, and then dried in hot air oven, until the water activity drops to 0.75 or lower (Chen *et al.,* 2005).

Minimally Processed Products

Minimal processing is based on a combination of mild heat treatment (blanching), a_w reduction, pH reduction, and addition of potassium sorbate and sodium metabisulphite. This process is also known as the hurdle technology and has been used for the preservation of fruit slices. Papaya chunks treated with increasing levels of preservatives up to 680ppm of metabisulphite and 826ppm of sodium benzoate exhibited good storage stability up to 90 days at 2°C and ambient temperature (Vijayanand *et al*., 2001). O'Connor-Shaw *et al.,* (1994) studied the shelf life of minimally processed (peeled, deseeded, and diced) honeydew melon, kiwifruit, papaya, pineapple, and cantaloupe by storing the fruits at 4°C and comparing it with the fruits which were stored at more than 4°C. Minimal processing helped to store the fruits for longer duration, where as the control fruits stored at >4°C and without any processing technology showed greater rate of spoilage. Lopez-Malo *et al*., (1994) produced shelf-stable high-moisture minimally processed papaya slices. The moisture and soluble solids contents, pH, and a_w remained almost constant in treated papaya slices during storage. Minimally processed papaya slices had good acceptability even after 5 months of storage at 25°C. The use of vacuum osmotic dehydration (VOD) techniques for the production of high moisture minimally processed papaya has also been reported by Tapia *et al*., (1999). It was possible to obtain minimally processed papaya (a_w 0.98, pH 3.5) by applying (i) vacuum osmotic drying for just 10 min when sucrose syrup contained 7.5% citric acid, or (ii) by applying pulsed VOD treatment (vacuum pulses for less than 15 min followed by osmotic drying for less than 45 min) when the citric acid concentration in sugar syrup was 2.5% or 5%..

By-Products from Papaya

Papain

Papain is the major by-product from dried latex derived from papaya fruit, which contains a protein hydrolyzing enzyme. This enzyme has a number of specific technological applications such as in food, meat tenderization, beverages, and animal feeds; pharmaceutical industry; textile industry and detergents; paper and adhesives; medical applications; sewage and effluent treatment; and research and analytical chemistry (Flynn, 1975; Sanchez- Brambila *et al.,* 2002; Kaul *et al.,* 2002). Among the food applications, the use of papain in chill haze removal during beer clarification as well as in the tenderization of meat has shown a steady increase over the past years. There is also a belief in some countries of Asia that eating papaya by pregnant ladies results in abortion (Adebiyia *et al*., 2002). Based on rat feeding studies, the authors suggested that normal consumption of ripe papaya during pregnancy may not pose any significant risk but unripe or semi ripe papaya may be unsafe in pregnancy, as the high concentration of latex produces marked uterine contractions. Papaya cultivars differ in papain yield, Red Panama

(Lassoudiere, 1969a, b; Foyet, 1972), CO6 (Balmohan *et al*., 1992), CO2 (Wagh *et al*., 1992), and the line CP1512, CP1513, CP4 (Auxcilia and Sathiamoorthy, 1995), and CP5911 (Kanan and Muthuswamy, 1992) are shown to be high yielding. Other factors affecting the papain yield from papaya plants are fruit shape (Lassoudiere,1969a, b), stage of maturity (Singh and Tripathi, 1957; Bhalekar *et al*.,1992), season of tapping (Reddy and Kohli, 1992), tapping time of the day (Lassoudiere, 1969 a, b; Foyet, 1972), pattern of tapping (Madrigal *et al*., 1980), and frequency of tapping (Bhutani *et al*., 1963). Muthukrishnan and Irulappan (1985) have described the procedure for the collection of latex as well as crude papain manufacturing process using simple equipment. The yield of crude papain powder obtained from raw green papaya is reported to be usually around 0.025% (Nanjundaswamy and Mahadeviah, 1993).

Pectin

To make papaya cultivation and papain industry viable, the profitable use of promising fruit is essential. The green fruits, whether scarred or not, are rich source of pectin (10% pectin on dry basis), which can be extracted for use in food industry (Das *et al*., 1954; Varinesingh and Mohammed-Maraj, 1989). Peel is shown to be higher in pectin content than the papaya pulp, and pectin content increases at a higher rate with fruit maturity up to a stage (Paul *et al.,* 1998). The integrated processing of papaya fruits for the production of papain and pectin has been found to be economical (Nanjundaswamy and Mahadeviah, 1993). The process as described by the above authors reported that, it gave a papain yield of 0.25% and a pectin (jelly grade 200) yield of 1% on fresh fruit basis. The variety of the fruit, the growing conditions, and the stage of maturity of fruit are all known to influence the chemical composition of pectin (Lassoudiere, 1969a, b).

Medicinal Values, Traditional usage and Scientific Studies

Since ancient times, humans worldwide have used papaya to alleviate effects of ailments (Table 5). Thousands of plant species are used for medication in modern and traditional medicine systems and most of the world populations use them to cure acute and chronic health problems. Some of the work carried out on the scientific studies in human and animal models is compiled in Table 5 which shows that papaya is a promising fruit which helps to reduce many health disorders. The different parts of the plant such as latex is used as anthelmintic, relieves dyspepsia, cure diarrhoea, pain of burns and topical use, bleeding haemorrhoids, stomachic, whooping cough. Ripe fruits can be used as stomachic, digestive, carminative, diuretic, dysentery and chronic diarrhoea, expectorant, sedative and tonic relieves obesity, bleeding piles, wounds of the urinary tract, ringworm and skin disease psoriasis. Unripe fruits are used as diuretic, laxative, dried fruit reduces enlarged spleen and liver, used in snake bite to remove poison, abortificient and anti implantation activity, anti bacterial activity. Seeds can be used as carminative, emmenagogue, vermifuge, abortificient, counterirritant, as paste in ringworm disease, psoriasis, antifertility agent in males and seed juice helps in bleeding piles and in large liver and spleen. Root can be used as abortificient, diuretic, in checking irregular bleeding from uterus and anti fungal activity, piles. Young leaves used as vegetables in curing jaundice, urinary complains, urinary tract infection and gonorrhea, dressing wounds, anti bacterial activity, vermifuge in colic, fever, beriberi, abortion, asthma. Flowers have emmengogue, jaundice, febrifuge and pectoral properties. And stem bark has jaundice, antifungal activity and antihelmantic activity.

Table 5: Some of the salient works carried out by researchers on Papaya

Scientific study or activity	Part of the plant used	Report/findings	References
Anticancer activity	Papaya seed	Highly effective in inhibition of super oxide generation and inducing apoptosis in acute promyelocytic leukemia cell line HL-60 and the activity was mainly contributed by benzyl isothiocyanate	Nakamura *et al*., 2007.
	Papaya fruit extract	The benzyl isotiocyanate induced cytotoxic effect in proliferating human colon CCD-18Co cells to the quiscient state	Miyoshi *et al*., 2007
	Papaya flesh	The aqueous extract of papaya flesh treated with breast cancer cell line MCF7 revealed significant inhibition of cell proliferation	García *et al*., 2009
	Papaya leaves	Aqueous extract of papaya leaves shown to possess anticancer activity and inhibition of cell proliferation in a variety of cancer cell lines	Morimoto *et al*., 2006.
	Papaya leaves	The aqueous extract demonstrated antitumor activity and immunomodulatory activity in tumor cell lines and it proved upregulation of immunomodulatory genes by microarray studies	Otsuki *et al*., 2010
	Aerial part	Showed that petroleum extract has significant anticancer effect on MCF7 (breast) cancer cells. *C. papaya* could be a natural source of anticancer compounds with anti proliferative and/or apoptotic properties and as well, due to its anticancer pharmacological effect	Khaled *et al*., 2013

	Flesh	The effects of papaya flesh extracts on the viability of breast cancer cell line MCF-7 were examined concurrently with extracts from other fruits. In these studies, the authors also evaluated antioxidants such as β-carotene, polyphenols, and flavonoids in the fruits to focus on the contribution of these antioxidants in the inhibition of proliferation	Garcia *et al*., 2009; Jayakumar and *et al*., 2011
Anti-inflammatory activity	Papaya leaves	The C.papaya leaf extract was examined in rats using edema, granuloma and arthritis models. The extract showed significant reduction in paw edema, granuloma formation and reduced inflammation in rats and proved its anti-inflammatory activity	Owoyele *et al*., 2008
	Papaya fruit	Intake of papaya fruits in healthy individuals alleviated anti-inflammatory response mediated through regulatory T-cells (Tregs) .	Abdullah *et al*., 2011
Treatment for dengue fever	Leaves	Aqueous extract of C.papaya leaves administered to a patient affected with dengue fever twice daily for 5 consecutive days exhibited elevated platelet count from 55×10^3/µl to 168×10^3/µl.	Ahmad *et al*., 2011
	C.papaya extract	Evidenced to increase in platelet and RBC count without any acute toxicity after oral administration	Dharmarathna *et al.,* 2013
	Leaves	Supplementation of juice recorded significance increase of platelet count in randomized controlled trial conducted on patients with dengue fever and dengue hemorrhagic fever	Subenthiran et al., 2013
Antidiabetic activity	Leaves	The aqueous extract significantly reduced plasma blood glucose level and serum lipid profile in diabetic rats	Juárez *et al*., 2012; Maniyar and Bhixavatimath, 2012
	Leaves	The ethanolic extract demonstrated significant reduction in blood glucose level and regeneration of the beta cells of pancreas in diabetic mice	Sasidharan *et al.,* 2011
	Unripe papaya fruit	Aqueous extract significantly inhibited the key enzymes α-amylase and α-glucosidase involved in type 2 diabetes and also inhibited the lipid peroxidation in rat pancreatic cells studied in vitro	Oboh *et al.,* 2014
Wound healing activity	Fruits and seeds	Extracts were evaluated for wound healing activity using wound excision model. Diabetic rats showed significant reduction in the wound area compared to untreated diabetic control. It also showed increased granulation, elevated hydroxyproline content and deposition of collagen in the wound area	Nayak *et al.,* 2007; Nayak *et al.,* 2012
	Papaya latex	Used for treatment of burns demonstrated significant increase in hydroxyproline content as well as wound contraction in swiss albino mice	Gurung and Skalko-Basnet, 2009
	Fruit	Diabetic mice supplemented with fermented papaya preparation (FPP) showed effective recruitment of monocytes and proangiogenic response by the macrophages at the wound site resulting in wound closure	Collard and Roy, 2010
Antifertility effects	Seeds	Shown to have antifertility properties in male albino rats and reduced the cauda epidymal and testicular sperm counts	Lohiya and Goyal, 1992
	Seed	Male Wistar rats treated orally with papaya seed extract (200mg/kg) demonstrated hypertrophy of pituitary gonadotrophs and gradual degeneration of germ cells, sertoli cells and leydig cells of testis thereby drastically affecting the male reproductive functions	Udoh *et al*., 2005
	Seed	The aqueous extract administered to male Sprague-Dawley rats suppressed the steroidogenic enzymes in the testis and reversible changes occurred when the extract was withdrawn after 30-45 days of treatment	Uche-Nwachi *et al*., 2011
Antifungal activity	Latex	The latex of papaya and Fluconazole has synergistic action on the inhibition of *Candida albicans* growth and synergistic effect resulted in	Giordani *et al*., 1997
Antifungal activity	Latex	The latex of papaya and Fluconazole has synergistic action on the inhibition of *Candida albicans* growth and synergistic effect resulted in partial cell wall degradation.	Giordani *et al*., 1997
Antimalarial Activity	Rind of the raw papaya fruit	The petroleum ether extract exhibited significant antimalarial activity.	Bhat and Surolia., 2001
Anti-helmenthic activity	Latex	The latex of papaya has anthelmintic efficacy against *Heligmosomoides polygyrus* in experimentally infected mice, which suggests its potential role as an anthelmintic against potent intestinal nematodes of mammalian hosts	Satrija *et al*., 1995
Antimicrobial activity	Seed and pulp	Shown to be bacteriostatic against several enteropathogens such as *Bacillus subtilis, Enterobacter cloacae, Escherichia coli, Salmonella typhi, Staphylococcus aureus, Proteus vulgaris, Pseudomonas aeruginosa* and *Klebsiella pneumoniae* by the agar cup plate method	Osato *et al.,* 1993
	Ripe and	Purified extracts produces very significant antibacterial activity on *S.*	Emeruwa, 1982.

	unripe fruits	*aureus, Bacillus cereus, E. coli, P. aeruginosa* and *Shigella flexneri*	
Anti-amoebic activity	Seeds	The cold macerated aqueous extract of matured papaya seeds has shown anti-amoebic activity against *Entamoeba histolytica*	Tona *et al,* 1998
Immuno-modulatory activity	Fruit	Fermented papaya preparation exerts both immunomodulatory and antioxidant activity in the macrophage cell line RAW 264 and it is a macrophage activator, which augments nitric oxide synthesis and TNF-alpha secretion independently of lipopolysaccharides	Rimbach *et al*., 2000
	Fruit	The antioxidant cocktail derived from fermentation of unpolished rice, papaya and sea weeds with effective microorganisms of lactic acid bacteria, yeast and photosynthetic bacteria has shown inhibition of lipid peroxidation in vivo, a point dependent on the concentrations of bioactive flavonoids	Aruoma *et al*., 2002
Antisickling activity	Fruit	The extract was found to have the highest antisickling properties with 93% inhibitory and 84% reversal activities.	Oduala *et al*., 2006
Nephro-protective activity	Seeds	The aqueous seed extract of *Carica papaya* Linn. has been evaluated by carbon tetrachloride induced renal injury in wistar rats as a dose and time-dependent study. The study showed that *Carica papaya* Extract has nephroprotective effect on Carbon tetra chloride renal injured rats, an effect which could be mediated by any of the phytocomponents present in it via either antioxidant and / or free radical scavenging mechanism	Debnath *et al*., 2010

Summary

Carica papaya is considered as one of the important fruits because of its nutritional, medicinal and neutraceutical properties. Papaya is an excellent source of nutrients such as; carotenes, vitamin C, and flavonoids, the B vitamins including folate and panthothenic acid, minerals such as potassium and magnesium and dietary fiber and phytochemicals. Besides consumption as a fresh fruit, a number of processed products developed using papaya are used in the form of puree, jam, jelly, pickle, candied fruit, blended beverages, canned slices / chunks, concentrate, fermented juices, dried products, minimally processed products and by products on a commercial scale. The functional components of the papaya such as pectin content of the fruit aids in preparation of many processed products such as jams, jellies. Similarly nutritional components of papaya help in developing blended beverages, which has many health benefits. Papaya contains several unique protein-digesting enzymes including *papain* and *chymopapain.* These enzymes have been shown to help lower inflammation and to improve healing from burns. The enzyme papain is a digestive enzyme that helps in natural digestion. The biochemical constituents of the fruit related to health benefits such as reducing cholesterol and the provision for development of wide spectrum of processed products dictate the scientific merit of the fruit, with national and international strategies for the future. Varieties of papaya products developed by research with low sweetness has proved its importance in reducing the blood sugar levels and the phytochemical constituents of the fruit has shown its functional role as anti caner, anti inflammatory and anti microbial fruit. The bioavailability of carotenoids from papaya is higher than that of other fruits and vegetables which can help in reducing the incidence of vitamin A deficiencies.

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