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Nutritional Potentials and Uses of Pawpaw (*Carica papaya*): A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author PNO reviewed on cultivation, production, ecology and uses. Author FZI reviewed on Origin/History, nutritional composition, taxonomy and description. Author AAD reviewed on Phytochemical and nutritional composition, uses and economic importance, allergies, side effect and toxicity as well as compilation, all editorials and correspondence. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Pawpaw is a fast growing fruit tree with edible fruits which are consumed in many countries of the world. The fruits are edible in its unripe and ripe forms such as in salads, juices, smoothies, soups and for therapeutic purposes. Other uses include in medicine and cosmetic industries were the fruits as well as other parts of the tree are used in the production of drugs and several cosmetic items. Pawpaw fruits are rich in several nutrients especially vitamins and minerals however its consumption is low when considered to other popular fruits. Hence this review looks at the nutritional potential of pawpaw fruit as a good micronutrient source just as other fruits.

Keywords: Pawpaw; micro-nutrients; malnutrition; fruits.

1. INTRODUCTION

Pawpaw is a fast-growing herbaceous, soft-wooded perennial tree-like plant in the Caricaceae family that lives for about 5-10 years [1]. Pawpaw plant is grown across all tropical countries such as Nigeria and many sub-tropical regions of the world [1,2]. In some countries an

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unrelated plant native to North America *Asiminia triloba* (Annonaceae), is also called pawpaw.

In Nigeria pawpaw trees are grown throughout the year, its fresh and ripe fruits are available all year round with its peak period towards the end of the raining season [3]. Pawpaw fruits are one of the most nutritious and cheapest fruits found and consumed in Nigeria and its Vernacular names include Hausa-*Gwandar gida*, Igbo-*Mgbimgbi,* Yoruba- *Ibepe* and Tiv-*Mbuawe.* However the production of this crop remains low as compared to the country's population [3].

Pawpaw fruits are ready for harvest about five to eight months after seed germination which is usually around five to six months after flowering [1,4,5]. An average fruit ranges in size from about 7-30 cm long and vary in mass from about 250 to 3000 g [1]. Fruits from the female trees are usually spherical although this also depends on variety and can be affected by environmental factors particularly temperatures which can modify the floral morphology during early development of the flower [2,6]. Ripe papaya fruit have a smooth and thin yellow to orange skin; depending on the cultivar flesh thickness also varies from 1.5 to 4 cm containing numerous grey-black spherical seeds which are usually about 5mm in diameter [2,6].

Pawpaw has several uses which include: its ripe fruits eaten as food and also used in the production of smoothies and juices. The medicinal properties are found in the leaves and latex of the raw fruits which contains papain or papayotin majorly used in tenderizing meat and when fermented becomes an important product in the pharmaceutical industry. The latex is used in treating fever, stomach aches, beriberi and also as an anthelmintic [7]. The Tiv tribe of Benue State from the Middle Belt region of Nigeria process the unripe fruits into chips or flakes and used for soup preparation while in Asian countries it is used for salad preparation.

Nutritionally pawpaw is higher in vitamin C, Niacin, Calcium and potassium than apples, oranges and bananas [8]. Pawpaw is the only fruit with all essential amino acids and it is also loaded with antioxidants. It contains Carotenoids (β-carotene, crytoxanthin), energy about 163KJ, Carbohydrates, Sugars, Vitamin A and C, Dietary fibre, and minerals such as Calcium, potassium and sodium [9]. The vitamin content of fruits and vegetables is nutritionally superior when compared to many cereals and leguminous crops [10]. Daily consumption of fruits available in the tropics such pawpaw, mangoes, oranges etc will help in the prevention against micronutrient deficiencies affecting the region especially in Sub Saharan Africa [11-19]. Pawpaw trees are easy to cultivate and are grows well in most parts of the country for its nutritional and medicinal potentials [20].

2. ORIGIN/HISTORY OF PAWPAW

Carica papaya plant which produces pawpaw fruits is native to the tropics of American and was first domestically cultivated in Mexico [21,22]. Even though there are varying opinions on the origin of *C. papaya* in tropical America [23], it is likely that it originates from the lowlands of Eastern Central America (Mexico) to Panama [6]. It is believed pawpaw seeds were distributed to the Caribbean and south-east Asia during Spanish exploration in the 16th Century, where it spread rapidly to the Pacific, India and Africa [1, 24]. *Carica papaya* has never been found wild, but it is probable that it originated in Southern Mexico and Costa Rica from there; it has now spread to all tropical and sub-tropical countries of the world [25].

Pawpaw trees are now grown in all tropical countries and many sub-tropical regions of the world such as Florida, Hawaii, Eastern British, West Africa, South Africa, Sri-Lanka, India, Canary Islands, Malaysia and Australia and were deliberately introduced to Australia more than a century ago as a horticultural crop for its fruits [2, 23].

Pawpaw was first described in 1526 by the Spanish chronicler Oviedo, who found it first on Panamanian and Colombian coasts [1]. The fruit rapidly propagated in the tropics, due to its abundant and highly viable seeds. The crop has adapted quite well to tropical areas due to its fertile soils and abundant rainfall. The history of pawpaw spread was initiated approximately in about 1500 years ago, when the Spanish conquerors carried its seeds to Panama and Dominican Republic respectively after which in the following century Spanish and Portuguese sailors took the seeds to the Philippines, Malaysia and India [26]. For over 1600 years now the fruit had been produced in many other warm regions of the world such as South and Central America, Southern Mexico, the Antilles, Bahamas, Bermuda and Florida [1,27]. In the same century pawpaw seeds were taken from India to Naples in Italy and the crop also reached

Hawaii between 1800 and 1820. Until 1900 pawpaw seeds were taken to Florida, probably from Bahamas' plantations. The *Solo* variety has been cultivated in Hawaii since 1911, probably brought in from Barbados and Jamaica while the *Maradol* variety were introduced into Mexico in 1978, through CONAFRUT in Xalapa and Veracruz [1,27].

3. TAXONOMY/DESCRIPTION

There are two distinct types of *C. papaya* plants known these are dioecious papayas that have male and female flowers on separate trees and gynodioecious papayas that bare female flowers on some trees and bisexual (hermaphrodite) flowers on others [1]. Pawpaw normally grows as single-stemmed tree growing from 5 to 10 m which is about 16 to 33 ft tall with a crown of large palmate leaves with seven lobes and about 20-28 inches emerging spherically from the top of the trunk however, the tree may become multi-stemmed if the stem re-grows after a damaged [24,28]. Its fruit is a fleshy berry about 7-30 cm long, weighing up to 9kg, ovoid-oblong to nearly spherical in shape if there are from the pistillate flowers; pyriform, cylindrical or grooved if there are from hermaphrodite flowers with its central Cavity full of seeds which are white when unripe and turn deed grey to black when ripe . The fruits also have a thin skin which is smooth to feel, green in colour when unripe, turning yellowish or orange when it's ripe, with a mild and pleasant flavour [26]. The typical percentage composition of an average typical pawpaw fruit contains seed (8.5 %), skin (12 %) and pulp (79.5%) [29].

4. CULTIVATION, PRODUCTION AND ECOLOGY

Worldwide production of papaya stands at 13,016,281 tons in about 61 countries per annum and top 10 producers of the fruit for the period of 2007 – 2019 as shown in the Table 3.

Pawpaw is propagated by seed. For proper germination the seeds must be removed from their gelatinous envelope before planting. The seeds should be air-dry so that they will remain viability for 2-3 years. Germination usually takes 2-3 weeks and is epigeal. Prior to field planting the seed are first pre-planted in flat wooden boxes, which are placed in the sun for germination to occur. 3 - 4 weeks old seedlings from the wooden box are then transplanted into containers or polythene bags where there are allowed to grow further for 5 – 8 weeks making 8 - 10 weeks of germination in total. The 8-10 weeks old seedlings which are usually about 15 – 20cm high, are finally transplanted to the permanent planting site or field [3].

Pawpaw is a tropical plant and is best grown between latitudes 32ºN and 0-3ºS, making it extremely sensitive to frost which can kill the plant thus requires full sun for proper growth and fruit production [3]. It thrives well in a well-drained fertile soil with pH of 6-6.5. If it is grown in dry regions, irrigation can be provided in the absence of adequate rainfall, although pawpaw is considered to be drought resistant plant. [1]. For optimal fruit production pawpaw requires an area with a minimum monthly rainfall of about 100 mm and relative humidity of 66% as well as temperatures between 21º-33ºC where as temperatures below 12-14ºC strongly retard fruit production, maturation and flavour development [1,6]. Both dioecious and gynodioecious varieties of papaya are grown commercially all over the world, but the dioecious varieties are generally recommended due to high fruit yields and relatively predictable fruit shape [4,30]. Pawpaw plantations are established by sowing seeds which may be pre-germinated in nurseries and transplanted to the plantation site when seedlings are about 150 – 200 mm tall. Since the sex of plants can be difficult to determine before they start flowering 3-4 plants are established in each planting site within the plantation to ensure that the optimum ratio of sex types is achieved. When the sex can be determined the plants are thinned to achieve the desired sex ratio and to reduce competition between plants which would affect optimal fruit production a spacing of 2-2.5 by 3 m is maintained in between plants and under optimal conditions, trees can reach 8-10 meters in height by first fruiting [4,6,24].

Pawpaw fruits are ready for harvest about five to eight months after seed germination which is usually around five to six months after flowering [1,4]. An average fruit ranges in size from about 7-30 cm long and vary in mass from about 250 to 3000g [1,2]. Fruits from the female trees are usually spherical although this also depends on variety and can be affected by environmental factors particularly temperatures that can modify floral morphology during early development of the flower [5,6]. Ripe papaya fruit have a smooth and thin yellow to orange skin; depending on the cultivar flesh thickness also varies from 1.5 to 4 cm containing numerous grey-black spherical seeds 5 mm in diameter [1,6,24]. The seeds are

attached in 5 rows to interior wall of ovary, spherical and, about 5 mm in diameter, black or grayish, unwrinkled, enclose in gelatinous sarcotesta formed from the outer integument; embryo median, straight, with ovoid, flattered cotyledons surrounded by fleshy endosperm. For harvesting of fresh ripe fruit, pawpaw fruits are ready for harvest when the first traces of yellow colour appears on the skin, after which they will ripen in 4-5 days and the fruits harvested with a sharp knife [31,32]. During harvest pawpaw fruits yields per tree vary from 30–150 fruits per annum, giving up to 35tonnes of marketable fruit per hectare.

Table 1. Scientific classification of *C. papaya*

Domain	Flowering plant
Kingdom	Plantea
Sub Kingdom	Tracheobionta
Class	Magnolipsida
Sub Class	Dilleniidae
Super Division	Spermatophyta
Phylum	Steptophyta
Order	Brassicales
Family	Caricaceae
Genus	Carica
Botanical Name	*Carica papaya*

Source: [33,34,35]

Table 2. Fruit characteristics of pawpaw cultivars in major producing countries

Cultivar	Country of origin	Fruit characteristics
Kamiya	Hawaii	A rose-fleshed pawpaw that is lighter in flavor than Mexican Yellow. Medium to very large fruit. Generally not as sweet as Hawaiian types.
Mexican Red	Mexico	A rose-fleshed pawpaw that is lighter in flavor than Mexican Yellow. Medium to very large fruit. Generally not as sweet as Hawaiian types.
Mexican Yellow	Mexico	A very sweet and flavorful, yellow-fleshed pawpaw. Medium to large fruit can grow up to 10 pounds. Generally not as sweet as Hawaiian types.
Maradol Roja	Cuba	Small to medium-sized fruit. A very sweet and flavorful.
Vista Solo	USA	Medium to large fruit depending on climate, 5 inches wide, up to 18 inches long. Skin yellow, flesh orange to Yellow-orange. Hardy, compact Solo type producing high quality fruit. Needs fairly hot weather to develop Sweetness
Waimanalo	Hawaii	Fruit round with a short neck, average weight 16 to 39 Ounces, Skin smooth, and glossy, cavity star-shaped, Flesh thick, firm, orange-yellow in colour, flavor and quality high, keeps well. Recommended for fresh market and processing. Fruits of female plants rough in appearance. Average height to the first flower is 32 inches.
Sunrise solo	Hawaii	Pear-shaped fruit with a slight neck. Averages 22 to 26 Ounces depending on location. Skin smooth, flesh firm, Reddish-orange, sweet, sugar content high. Quality similar to Solo. Seed cavity not as deeply indented as other Solo strains, making seed removal easier. Plant precocious, maturing fruit about 9 months after transplanting, at a height of about 3 feet.
Sunset	Hawaii	Solo type, Small to medium-sized, pear-shaped fruit. Orange-red skin and flesh, Very sweet, Dwarf, high yielding plant.

Source: [36]

Table 3. Top 10 producers of pawpaw in the World

Country	2007 (KT)	Country	2014(T)	Country	2017(T)	Country	2019 (T)
Brazil	1.573.82	India	5,639,300	India 5,940,000		India	5,500 500
Nigeria	834.04	Brazil	1,603.351	Brazil 1,057,101		Brazil	1,600,000
India	783.38	Nigeria	850,000	Mexico	961,768	Nigeria	951,000
Mexico	709.48	Indonesia	840,121	Indonesia 875,112		Indonesia	900,000
Indonesia	646.65	Mexico	836,370	Dominican Rep. 869,306		Mexico	836,370
Ethiopia	259.17	Dominican Rep.	704,786	Nigeria	837,738	Philipines	172,628
D. R. Congo	215.98	D. R.Congo	220,483	D.R. Congo 214,836		Domincan Rep.	704,786
Peru	171.06	Philippines	172,628	Cuba	189,086	D.R. Congo	220,483
Columbia	137.66	Venezuela	165,102	Colombia	179,979	Venezula	165,102
Philippines	132.00	Thailand 157,571		Venezuela178,740		Thialand	157,571

KT – kilo tonnes, T - Tonnes
Source: FAOSTAT Database [70,38,39,40,41]

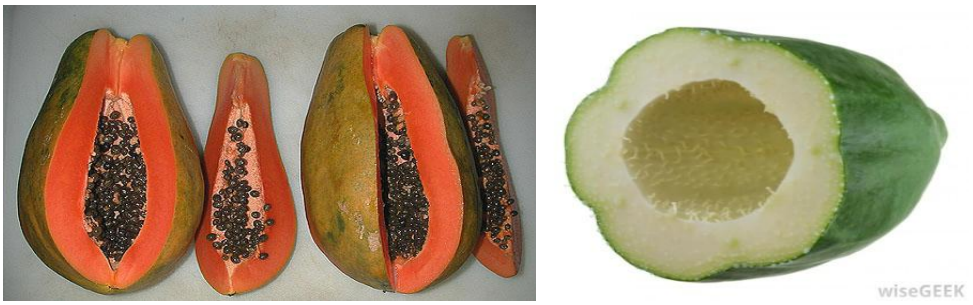

Fig. 1. A Picture of a ripe and an unripe pawpaw (*Carica papaya)* fruits

5. PHYTOCHEMICAL AND NUTRITIONAL COMPOSITION

Olarewaju [3] reported that 100 g edible portion of fresh and ripe pawpaw fruits contains approximately: 88% - water, 10% - sugar, 0.5% - protein, 0.1% - fat, 0.1% - acids, 0.6% - ash and 0.7% - fibre.

Pawpaw is a powerhouse of vitamin A, E, pantothenic acid, folate as well as vitamin C, it also contains magnesium, potassium, calcium and dietary fibre [6]. The latex contains the enzymes papain that effectively treats trauma, allergies and sports injuries and chymopapain as well [42]. Both papain and chymopapain contains protein – digesting and milk clotting properties. The vitamin A and C content of one medium papaya fruit (approx 350 g edible portion) exceed the dietary reference minimum intake established for adults by the US Food and Nutrition Board and much higher than tomatoes or oranges [2, 31]. Papaya fruit is marked as a power house of many minerals and vitamins necessary for wellbeing [61]. The extracts from an unripe *C. papaya* fruit may contain a little of terpenoids, alkaloids, flavonoids, glycosides, saponins and steroids [9].

Table 4. Papaya fruit (ripe) nutritional values (Per 100 g edible portion only)

Nutrient	papaya Australia 2007	USDA nutrient database 2007	USDA nutrient database 2019
Water	89.3 g	88.83 g	88.06 g
Energy	123 kj/29kcal	163 kj/39 kcal	43 Kcal
Protein	0.4 g	0.16 g	0.47g
Fats	0.1 g	0.14 g	0.26 g
Carbohydrates(total)	6.9 g	9.81 g	10.82 g
Carbohydrate(sugar)	6.9 g	5.9 g	7.82 g
Dietary fibre	2.3 g	1.8 g	1.7 g
Cholesterol	Nil	Nil	Nil
Sodium	7 mg	3 mg	3 mg
Potassium	140 mg	257 mg	182 mg
Calcium	28 mg	24 mg	20 mg
Magnesium	14 mg	10 mg	21 mg
Iron	0.5 mg	0.1 mg	0.25 mg
Zinc	0.3 mg	0.07 mg	0.08 mg
Beta-carotene	910µg	276 µg	47 µg
Thiamin	0.03 mg	0.0027mg	0.023 mg
Riboflavin	0.03 mg	0.032 mg	0.027 mg
Niacin	0.3 mg	0.338 mg	0.357 mg
Vitamin C	60 mg (171% of RDI)	61.8 mg	60.9 mg
Vitamin A eq.	150 ug	N/A	47 µg
Vitamin K	-	-	2.647 µg
Vitamin E	-	-	0.3 mg

Source: [43,44,45]

Table 5. Papaya fruit (Unripe) nutritional value per 100 g

Nutrient	2013 quantities	2016 quantities
Energy	163 KJ	43 Kcal/179 KJ
Sodium	3 mg	8 mg
Potassium	257 mg	182 mg
Phosphorus	5 mg	10 mg
Magnesium	10 mg	21 mg
Iron	0.10 mg	0.25 mg
Calcium	24 mg	20 mg
Vitamin C	61.8 mg	60.9 mg
Folate (vit.B9)	38 µg	37 µg
Vitamin B6	0.1 mg	0.038 mg
Niacin (vit.B3)	0.338 mg	0.357 mg
Riboflavin (vit.B2)	0.05 mg	0.027 mg
Thiamine (vit.B1)	0.04 mg	0.023 mg
Vitamin A	328 IU	950IU
Protein	0.61 g	0.47 g
Fat	0.14 g	0.26 g
Dietary fibre	1.8 g	1.7 g
Sugars	5.9 g	7.82 g
Carbohydrates	9.81 g	10.82
Moisture	80 g	88.06 g

Source: [9,46]

Table 6. *Carica Papaya* Is a pack of phytoconstituents

Phytoconstituents	*Carica papaya* part
Enzyme (Papain, chymopapain)	Unripe fruit
Carotenoids (β-carotene, crytoxanthin)	Fruits
Carposide	Roots
Glucosinolates (Benzyl isothiocynate, papaya oil)	Seeds
Minerals (Ca, K, Mg, Zn, Mn, Fe)	Shoots, leaves, fruits
Monoterpenoids (Linalool,4-terpinol)	Fruits
Flavonoids (Myricetin, kaemferol)	Shoots
Alkaloids (Carpinine ,carpaine),	Leaves, fruits
vitamin C and E	Fruits

Source: [9,33]

6. NUTRITIONAL COMPARISM OF PAWPAW, ORANGE, BANANA AND APPLES BY [8]

Pawpaw fruits are very nutritious. They are high in vitamin C, magnesium, iron, copper, and manganese. They are a good source of potassium and several essential amino acids, and they also contain significant amounts of riboflavin, niacin, calcium, phosphorus, and zinc. Pawpaw contains these nutrients in amounts that are generally about the same as or greater than those found in bananas, apples, or oranges.

In comparison with banana, apple, and orange, pawpaw have a higher protein and fat content. Banana exceeds pawpaw in food energy and carbohydrate content. There is little difference among these fruits in dietary fiber content. Pawpaw is most similar to banana in overall composition. Apple is especially low in protein, orange is low in fat, and both are lower than pawpaw or banana in food energy [8]. Pawpaw has three times as much vitamin C as apple, twice as much as banana, and one third as much as orange. Pawpaw has six times as much riboflavin as apple and twice as much as orange. Niacin content of pawpaw is twice as high as banana, fourteen times as high as apple and four times as high as orange. Pawpaw and banana are both high in potassium, having about twice as much as orange and three times as much as apple [8]. Pawpaw has one and a half times as much calcium as orange and about ten times as much as banana or apple. Pawpaw has two to seven times as much phosphorus, four to twenty times as much magnesium, twenty to seventy times as much iron, five to twenty times as much

zinc, five to twelve times as much copper and sixteen to one hundred times as much manganese, as do banana, apple, or orange [8].

The protein in pawpaw contains all of the essential amino acids. Pawpaw exceeds apple in all of the essential amino acids and it exceeds or equals banana and orange in most of them. The profile of fatty acids in pawpaw is preferable to that in banana. Pawpaw has 32% saturated, 40% monounsaturated, and 28% polyunsaturated fatty acids. Banana has 52% saturated, 15% monounsaturated, and 34% polyunsaturated fatty acids [8].

Table 7. Nutritional comparisons of pawpaw with banana, apple and orange

	Units	Pawpaw[a]	Banana[a]	Apple[a]	Orange[a]
Composition					
Food Energy	Calories	80	**92**	59	47
Protein	Grams	**1.2**	1.03	0.19	0.94
Total Fat	Grams	**1.2**	0.48	0.36	0.12
Carbohydrate	Grams	18.8	**23.4**	15.25	11.75
Dietary Fiber	Grams	2.6	2.4	**2.7**	2.4
Vitamins					
Vitamin A	Re[b]	8.6	8	5	**21**
Vitamin A	IU[c]	87	81	53	**205**
Vitamin C	milligrams	18.3	9.1	5.7	**53.2**
Thiamin	milligrams	0.01	0.045	0.017	**0.087**
Riboflavin	milligrams	0.09	**0.1**	0.014	0.04
Niacin	Milligrams	**1.1**	0.54	0.077	0.282
Minerals					
Potassium	milligrams	345	**396**	115	181
Calcium	milligrams	**63**	6	7	40
Phosphorus	milligrams	**47**	20	7	14
Magnesium	milligrams	**113**	29	5	10
Iron	milligrams	**7**	0.31	0.18	0.1
Zinc	milligrams	**0.9**	0.16	0.04	0.07
Copper	milligrams	**0.5**	0.104	0.041	0.045
Manganese	Milligrams	**2.6**	0.152	0.045	0.025
Essential amino acids					
Histidine	milligrams	21	**81**	3	18
Isoleucine	milligrams	**70**	33	8	25
Leucine	milligrams	**81**	71	12	23
Lysine	milligrams	**60**	48	12	47
Methionine	milligrams	15	11	2	**20**
Cystine	milligrams	4	**17**	3	10
Phenylalanine	milligrams	**51**	38	5	31
Tyrosine	milligrams	**25**	24	4	16
Threonine	milligrams	**46**	34	7	15
Tryptophan	milligrams	9	**12**	2	9
Valine	Milligrams	**58**	47	9	40

Source: [8,47]

Key: 1. (Mean value per 100 grams edible portion)

2. b- (Retinol Equivalents-these units are used in the most National Research Council Recommended Dietary Allowances table)

c- (International Units-these units are still seen on many labels).

Number in bold face represents the highest value for each component).

Note: Pawpaw analysis was done on pulp with skin, although the skin is not considered edible. Probably much of the dietary fiber, and possibly some of the fat, would be thrown away with the skin

Table 8. Portion of daily needs provided by pawpaw in comparison with banana, apple and orange

	Pawpaw[a]	Banana[a]	Apple[a]	Orange[a]
Composition				
Food Energy [b]	4.0	**4.6**	3.0	2.4
Protein [b]	**2.4**	2.1	0.4	1.9
Total Fat [b]	**1.8**	0.7	0.6	0.2
Carbohydrate [b]	6.3	**7.8**	5.1	3.9
Dietary Fiber [b]	10.4	9.6	**10.8**	9.6
Vitamins				
Vitamin A [c]	1.0	0.9	0.6	**2.3**
Vitamin C [c]	30.5	1 5.2	9.5	**88.7**
Thiamin [c]	0.8	3.5	1.3	**6.7**
Riboflavin [c]	6.0	**6.7**	0.9	2.7
Niacin [c]	**6.5**	3.2	0.5	1.7
Minerals				
Potassium [b]	9.9	**11.3**	3.3	5.2
Calcium [c]	**7.9**	0.8	0.9	5.0
Phosphorus [c]	**5.9**	2.5	0.9	1.8
Magnesium [c]	**35.9**	9.2	1.6	3.2
Iron [c]	**56**	2.5	1.4	0.8
Zinc [c]	**6.7**	1.2	0.3	0.5
Copper [d]	**22.2**	4.6	1.8	2.0
Manganese [d]	**74.3**	4.3	1.3	0.7
Essential amino acids				
Histidine [e]	3.5	**13.5**	0.5	3.0
Isoleucine [e]	**11.6**	5.5	1.3	4.2
Leucine [e]	**9.6**	8.5	1.4	2.7
Lysine [e]	**8.4**	6.7	1.7	6.5
Methionine + Cystine [e]	2.4	3.6	0.6	**3.8**
Phenylalanine + Tyrosine [e]	**9**	7.4	1.1	5.6
Threonine [e]	**10.8**	8.1	1.7	3.6
Tryptophan [e]	4.3	**5.7**	1.0	4.3
Valine [e]	**9.7**	7.8	1.5	6.7

Source: [8,47]

Key: a – percentage of daily nutritional need per 100 gram serving

b- Percentage of Daily Reference Value, based on a diet of 2,000 Calories a day for adults.

c- Percentage of the 1989 NAS-NRC Recommended Dietary Allowance average valve for women and men of ages 25-50.

d- Percentage of the Estimated Safe and Adequate Daily Dietary Intake, average value for adults.

e- Percentage of the estimated amino acid requirement for a 60 kg (130 lb) adult.

Number in bold face represents highest value for each component.

7. USES AND ECONOMIC IMPORTANCE OF PAWPAW FRUIT

Practically, every part of *Carica papaya* is of economic value. Its uses ranges from domestic to industrial uses in short, the benefits of pawpaw are enormous both the natural fruit and natural pawpaw supplements.

The unripe papaya fruit has a high latex content that may make it unsuitable for raw consumption although raw shredded green papaya is often used in Asia for salads preparation, the unripe green pawpaw if peeled, seeded and chocked is used in a variety of savoury Asian dishes including pickles and chutneys and for canning in sugar syrup [5,48]. The Green fruit leaves and flowers can also be used as a cooked vegetable [49]. The TIV ethnic group from Benue State Nigeria processes the unripe fruit into thin dry shreds and uses them as vegetables in soup preparation especially during the dry season when regular vegetables become scares. Soups have been known add variety to foods such as improve eye appeal, taste, flavour and aroma they by creating diet diversity [50]. Papaya seeds

have a peppery taste and can be dried in a dehydrator then grounded in a mortar and pestle and used as pepper [33,43]. The seeds are also medically important in the treatment of sickle cell condition and poisoning related disorder [51]. Chewing the seeds of the ripe pawpaw fruit also helps to clear nasal congestion [52]. The seeds are used in some countries as a vermifuge, counter-irritant and abortifacient [33].

Carica papaya is the most important species within the Caricaceae, being cultivated widely for domestic consumption for its fresh fruit which could be eaten raw, in dessert and fruit salads and are used industrially for making other edible products such as soft drinks, juice, jam candies, wines, ice cream flavouring and crystallized fruit canned in syrup drinks [53]. The unripe fruits are cooked as a substitute for mango and for apple sauce [24]. Kolawole et al. [54] Used ripe pawpaw fruits in the preparation of ogi (a Nigerian traditional infant complementary food) where it was co-fermented with sorghum to produce sorghum-ogi. Pawpaw leaves and fruit produces several proteins and alkaloids with a lot of important pharmaceutical and other industrial applications [55]. Due to its antioxidant and fiber contents pawpaw is used in the treatments of digestion and other ailments such as chronic indigestion, overweight, obesity, arteriosclerosis, fibroid, tuberculosis, malaria, high blood pressure(HBP) and weakening of the heart [56, 57,58]. Pawpaw stems, leaves and unripe fruits contains milky latex that is harvested by scarifying the green skin to induce latex flow and the latex collated is allowed to dry before taken for industrial processing [6]. Papain a major component of the milky latex have various industrial uses in the food, beverage and pharmaceutical industries these includes its use in the production of chewing gums, chill-proofing beer, meat tenderizers as such traditionally meat becomes tenderized by wrapping it in pawpaw leaves for some hours before cooking [59]. Papain also aids in general digestion with emphasis on proteins since it is a proteolytic enzyme [60]. Medically papain has been used to produce drugs useful in the treatment of less serious digestive disorders like bloating and other conditions such as arthritis, intestinal worms, chronic indigestion and treatment of gangrenous wounds [61]. The Phytochemicals in papain when extracted and used invitro may increase immune system strength and may also promote the release of natural chemicals that attack tumor cell there by making it useful in cancer prevention and treatment [62,63]. In the tanning industry papain is used for bating hides, for degumming silk and wool softening in the textile industry while in the cosmetics industry it is used for the production of skin and hair care products such as creams, soaps and shampoos. Countries with the highest papain imports globally are United States, Japan, United Kingdom, Belgium and France with United States as the Chief importer [24,64] While major exporters are D. R. Congo, Tanzania, Uganda and Sri-Lanka [64].

The fresh unripe green pawpaw fruits and pawpaw leaves tea have antiseptic properties where it cleans the intestines from bacteria allowing for proper absorption of vitamin and minerals, especially vitamin B12, [58] while the brown dried pawpaw leaves are best served as a blood tonic and purifier [51]. Over all the leaf tea or extract has a reputation as a tumor destroying agent [5].

Some constituents of *Carica papaya* exhibit an alkaline pH thus when combined with borax or potassium carbonate and they have showed good results in treatment of warts, corns, sinuses, eczema, coetaneous tuberculosis and other hardness of the skin [9]. Green fruits of papaya are used to stimulate reproductive organs there by boosting male fertility. It contains an enzyme called arginine which is known in the medically community to boost blood flow around the man-hood where it boosts nitric acid in the body to relax the muscles surrounding the blood vessels that supply the man-hood with blood. These blood vessels then dilate and increase blood flow, a more concentrated form of arginine is used to treat erectile dysfunction [9]. Both papain and chymopapain can help lower inflammation and improve healing from burns [9]. Carpaine which is also found in pawpaw is an alkaloid which slows heart rate in humans and thus reduces blood pressure its action is similar to digitalis the drug prescribed for heart patients, it is also reported to be able to kill worms and amoebas [65]. Papaya has an abundance of cancer fighting lycopene which is a key intermediate in the biosynthesis of many important carotenoids, such as beta-carotene and xanthophylls and thus another useful compound not readily found in the plant kingdom but found in pawpaw is Fibrin. Fibrin reduces the risk of blood clots and improves the quality of blood cells, optimizing the ability of blood to flow through the circulatory system and also important

in stroke prevention [9]. Pawpaw fruits, leaves and peels are also useful in making as livestock and fish feeds production [9, 60, 61].

A large portion of the annual harvest of pawpaw fruits in the tropics is consumed locally, as it is difficult to transport them over long distances. Pawpaw fruit storage requires special conditions which are based on temperature control thus extending the shelf life of fresh fruits but sometimes the temperature control may in turn expose them to microbial spoilage and deterioration from water loss, bleaching, surface burning, shriveling, excessive softening and desiccation thus leading to loss of quality (softening, flaccidity, limpness, loss of crispness and juiciness) and nutritional quality [29,32,66, 67,68]. Inadequate storage of fresh pawpaw fruits results in fading of colour by oxidation and enzymatic activity which affects the commercial value of fresh fruits when stored at room temperature [69]. Studies have also shown that chilling temperatures are not appropriate for many tropical crops such as pawpaw due to their susceptibility to chilling damage resulting in pitting, discoloration, poor sensory appeal and even loss of some nutrients [70]. However fresh pawpaw fruits are exported by air and in cold storage by sea from Hawaii to the United States, but only a little of the fresh fruits reach other temperature countries. Pawpaw fruits are now being canned and with this the market will probably increase [67].

Currently India has become the leading producer of pawpaw fruits in the world, with production of about 5.5 millions tons per annum [41]. The production in Nigeria is quite high but still does not meet even domestic demands in the big cities as most of the harvest is lost to microbial decay, these microorganisms under the influence of favorable environmental factors, pose a serious threat to pawpaw fruits production [68].

The main actors in the international trade market for pawpaw are presented in the Table 9.

8. ALLERGIES, SIDE EFFECTS AND TOXICITY

Papaya extract is frequently used as an important ingredient in the production of hair and skin care products; however it should be used in small amounts to avoid irritation and allergic reaction in some people [9]. The latex concentration of unripe pawpaw fruits is speculated to cause uterine contractions which can induce abortion or may lead to a miscarriage hence it is advised to avoid eating plenty of unripe pawpaw fruits salad if pregnant. [71,72] reported that papaya seed extracts in large doses had a contraceptive effect on rats and monkeys, but in small doses have no effect on the unborn animals while [33,57,73] also reported that green pawpaw and pawpaw seeds extract have shown contraceptive effects in adult male langur monkeys and human adults.

Excessive consumption of ripe papaya can cause carotenemia a harmless condition associated with the yellowing of soles of the feet and palms. However, a very large dose would need to be consumed for this condition to occur as ripe pawpaw fruits contains about 6% of the level of beta carotene found in carrots the most common cause of Carotenemia [26]. Papaya latex is an irritant to human skin and if ingested it can causes severe gastritis [74]. Some people are allergic to the fruit as well as the enzyme papain because of its negative properties however all parts of the plant contain latex and so care must be taken when harvesting pawpaw fruits as fresh latex is a skin irritant and can

Table 9. International market for pawpaw

Exporting countries	MT	Importing countries	MT
Mexico	59,638	USA	47,908
Malaysia	34,312	Singapore	21,219
Brazil	9,878	Hong Kong	13,210
USA	6,024	China	4,919
Jamaica	4,000	Japan	4,670
Belice	3,557	UK	3,606
Holland	2,051	Canada	3,291
Costa Rica	1,000	Germany	2,546
Ghana	1,000	Portugal	1,486
		France	1,269
		Spain	1, 132

Source: FAO STAT [75]

cause blisters and also conjunctivitis [76]. Pawpaw flower pollen and papain can also induce respiratory discomfort in sensitive individuals [74].

Symptoms of pawpaw allergy includes dizziness, trouble breathing, itching, rashes and swelling and in some people stomach upset or nausea may also occur therefore it is not advised to consume pawpaw if you have recently had surgery or are on blood thinners [9,26].

9. CONCLUSION AND RECOMMENDATION

Pawpaw trees with an average life span of 20 years are well adapted to both tropical and sub-tropical regions in the world. Pawpaw fruits and others parts of the plant have both food and non food uses. The fruits both ripe and unripe are cheap and rich in several micronutrients thus consuming them often will help reduce micronutrient malnutrition. They can also be processed into various forms domestically and on industrial scale for juices, soups, meat-tenderizers etc and can also be used to complement other foods to improve both nutrient and sensory attribute. Thus consuming them will reduce over dependence on other fruits with similar nutritional potentials.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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