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Nutritional quality of raw and processed unripe *Carica papaya* fruit pulp and its contribution to dietary diversity and food security in some peasant communities in Nigeria

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ABSTRACT

Processed unripe *Carica papaya* fruit pulp is used as soup ingredient in some Nigerian communities but the nutritional value of the variously processed forms is largely unknown. The thrust of this study was to determine the nutritional quality of traditionally processed unripe *C. papaya* fruit pulp using AOAC methods. The proximate evaluation of the raw, dried-uncooked and dried-cooked samples revealed variation in nutrient contents (g/100 g): moisture (7.84 ± 0.15 - 26.07 ± 0.04), carbohydrate (55.82 ± 0.18 - 63.00 ± 0.58), protein (12.49 ± 0.01 - 16.50 ± 0.29), fat (0.94 ± 0.04 - 3.30 ± 0.06), ash (3.45 ± 0.08 - 5.60 ± 0.06) and crude fibre (1.89 ± 0.01 - 3.53 ± 0.12). The dried-uncooked sample was found to have the highest mineral content ($p < 0.05$) compared with the raw and dried-cooked samples. Aside potassium, iron and selenium which were significantly higher ($p < 0.05$) in the raw (199.33 ± 12.25 mg/100 g, 0.28 ± 0.03 mg/100 g and 1.62 ± 0.09 mg/100 g respectively) than dried-cooked (94.67 ± 1.76 mg/100 g, 0.17 ± 0.02 mg/100 g and 1.37 ± 0.12 mg/100 g respectively), the composition of other minerals was similar in the two samples. In the same vein, the vitamin content of the raw fruit pulp was significantly reduced ($p < 0.05$) by the sun-drying and cooking. There were notable decreases in the values of non-nutrients except for the levels of flavonoids and cardenoloids which did not differ in the three samples. Overall, unripe *C. papaya* fruit pulp was found to be rich in nutrients; traditional processing may not adversely affect its proximate composition. However, the appreciable leach in vitamins and minerals can be supplemented with other good sources via complementary nutrition.

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Keywords: Proximate, mineral, vitamin, non-nutrient, processing, pawpaw.

INTRODUCTION

The current global food crisis marked by soaring food prices has continued to raise serious concerns about food security. Food is vital for human lives, being an essential ingredient for growth and a major factor in sustainable development. Food availability

and accessibility will have to increase to meet demands as the world population increases. The topmost millennium development goal (MDG) to eradicate extreme hunger and poverty has led to a global reduction in food insecurity (Luchuo et al., 2013; GFSI, 2015). Nevertheless, many countries, especially in

the developing economies, have not been able to meet development targets. According to FAO (2015), an unacceptably large number of people still lack the food they need for an active and healthy life.

Recent information shows that the sub-Saharan Africa harbours the highest prevalence of undernourishment in the world (Adegbola et al., 2015; UN, 2015). For Africa as a whole, prevalence of undernourishment decreased from 27.6% in 1990-1992 to 20.0% in 2014-2016 whereas in sub-Saharan Africa, undernourishment prevalence reduced from 33.2% to 23.2% for the same period (FAO, 2015; PRB, 2016). Although substantial progress has been achieved, yet, the pace is somewhat slow considering the high population growth rate for many countries in the sub region. For instance, Nigeria with a current population of 177 million has an annual population growth rate of 2.9% (PRB, 2015).

Nigeria has made a modest progress in achieving the international hunger target (MDG 1C) by reducing undernourishment prevalence from 21.3% in 1990-1992 to 7.0% in 2014-2016 (FAO, 2015). Nonetheless, socio-political factors including political instability, armed conflicts, civil unrest, displacement of refugees and other emergencies have often frustrated efforts to fight hunger in Nigeria. Also, poor postharvest practices, seasonal variation and low dietary diversity contribute immensely to unavailability of many food varieties in the country (Hart et al., 2005; Adegbola et al., 2011). Thus, household food insecurity, undernutrition and micronutrient deficiency are still prevalent in Nigeria (Ubesie and Ibeziakor, 2012; Ngozi, 2013).

In discussing the problem of food insecurity in Nigeria, Adegbola et al. (2011)

posited that adequate food preservation and storage would promote food security through reduction in wastage and seasonal scarcity. In another study, Johns (2003) advocated for dietary diversity as a key factor for enhanced food security and health promotion. According to FAO (2011), about one-third of the world food produced for human consumption is wasted annually due primarily to food spoilage. Also, half of fruits and vegetables harvested in the tropics are lost to fungal spoilage (Pitt and Hocking, 2009). Yet, these are mostly plant foods which represent the largest segment of dietary diversity (Johns, 2003). It, therefore, means that if plant foods are well processed and stored, dietary diversity would be enhanced and food insecurity would be minimized.

Pawpaw (*Carica papaya*) is a tropical and subtropical food plant gaining popularity worldwide not just for the delicious fruit but also for medicinal properties of the whole plant parts, leaf, fruit, root, bark, peel, seed and pulp (Aravind et al., 2013). Its fast growth in nature, high yields and diverse range of varieties offer papaya for development of many economically viable products. Pawpaw ranks fourth as major tropical fruit after banana, orange, and mango and Nigeria is among the top global producers with India, Brazil, Indonesia and Mexico (FAOSTAT, 2013). The fruit is fleshy, juicy and usually green but turns yellow or orange when ripe. Ripe pawpaw is usually consumed raw while the unripe or green fruit is added into fresh salads (Boshra and Tajul, 2013). In many parts of the world including Nigeria, green pawpaw fruit is also cooked as vegetable (Ahmed et al., 2002; Matsuura et al., 2004; OECD, 2005). The unripe fruit is also valuable as a source of the proteolytic enzyme papain which has many economic and

industrial applications (Boshra and Tajul, 2013). The preservation of pawpaw fruit is very minimal in Nigeria (Awoite et al., 2013). Refrigeration and mechanical drying methods are associated with high cost of equipment and irregular power supply (Ojike et al., 2011). Sun-drying is a cheap method to preserve foods to maintain food security all year round. Studies by Eme-Okafor (2012) and Chitsa et al. (2014) showed that the advantages of sun-drying as domestic food processing technique outweigh the disadvantages. The proteolytic enzyme papain is destroyed when exposed to high temperature, but sun-drying; a much slower process does not destroy the enzyme. Another enzyme in pawpaw chymopapain that digests fats, starches and proteins is also not destroyed by sun-drying (Tietze, 2002).

Studies by Chukwuka et al. (2013) showed that unripe *C. papaya* fruit has higher amounts of nutrients and beneficial non-nutrients such as saponins, flavonoids, alkaloids and phenols compared to the hard-ripe or very-ripe fruit. In another study, Tietze (2002) reported that the enzyme papain is at its peak concentration in the green, unripe papaya fruit. In some parts of Nigeria, unripe *C. papaya* pulp harvested in the wet season is dried and stored for future use as vegetable during the dry season when leafy green vegetables are scarce. This study was therefore designed to investigate the changes in nutrient and non-nutrient contents of the unripe *C. papaya* fruit pulp following drying and dry-boiling with the aim to ascertain if these methods adversely affect its nutritional value and food use.

MATERIALS AND METHODS

Fruit collection

Eight medium size (about 500 g each) unripe *C. papaya* fruits were harvested from home garden in Cross River University of Technology (CRUTECH) staff quarters in February 2014 and transported to the Department of Botany, University of Calabar (UNICAL) where they were properly identified. Subsequently, the fruits were taken to the research laboratory in the Department of Biochemistry, UNICAL for processing.

Sample preparation

The fruits were washed, peeled, deseeded and the pulps were shredded into small pieces and mixed thoroughly. From this bulk, 1 kg portion was homogenized, stored in sealed bottle, labelled as raw sample and stored in the refrigerator at 4 °C pending analysis within 24 hours, while the remainder was sun-dried for 3 days into flakes. The dried flakes were divided into two parts: one portion was ground into powder and labelled as dried-uncooked sample; the other portion (about 300 g) was boiled in water in a clean pot for 3 minutes, homogenized and labelled as dried-cooked sample. The two samples were kept in sealed sample bottles and stored in the refrigerator at 4 °C prior to analysis within 24 hours.

Proximate analysis

The moisture, fat, crude protein, ash and fibre contents of the three labelled samples were determined using the standard methods of the Association of Official Analytical Chemists (AOAC, 2005). In brief, moisture content was determined by drying a 50 g portion of each sample to constant weight, using a vacuum oven (Astell-Hearson) at 70 °C for about 24 hours. The

moisture content was taken as the difference in weight between the initial sample and the completely dried sample. Fat content was determined by exhaustively extracting 50 g of the sample with petroleum ether (B.P. 40 °C – 60 °C) using a Soxhlet apparatus (Corning, England). The crude protein content was determined by the micro-Kjeldahl digestion apparatus. The method estimated the amount of nitrogen in the sample which was subsequently used to calculate the protein content by multiplying with the factor of 6.25. The crude fibre content was estimated by boiling 50 g of the sample in 1.25% (w/v) sulphuric acid and afterwards with 1.25% (w/v) sodium hydroxide. The residue was then incinerated completely at 550 °C. The loss in weight represented the crude fibre content of the sample. Total ash was determined from the residue left after incinerating a 50 g portion of the sample in a muffle furnace at 550 °C, whereas carbohydrate content was obtained by difference i.e. by subtracting the protein, fat, ash and moisture contents from the total dry matter and expressed in percentage.

Determination of minerals

The minerals were determined using a sample digest prepared by digesting completely 5 g of the sample in perchloric and concentrated nitric acids diluted with deionized water in a 50 ml volumetric flask. Sodium (Na) and potassium (K) in the digest were measured using the flame photometric method; calcium (Ca), phosphorus (P), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and selenium (Se) were measured by the Perkin Elmer Atomic absorption spectrophotometer (Model 306, UK).

Vitamin assay

Vitamins A, E, K and C in the samples were determined according to the methods of Kirk and Sawyer (1998). The quantification of the B vitamins was done following the method of Mohsin et al. (2008).

Determination of non-nutrients

Non-nutrients in the *C. papaya* samples were quantified using standard procedures variously described by Harbone (1998), Onwuka (2005) and Sofowara (2006).

Statistical analysis

Data generated from the study was subjected to statistical analysis using the SPSS version 17. One-way analysis of variance (ANOVA) was used to compare the levels of nutrients and non-nutrients in each vegetable sample. All the results were expressed as mean ± 3 determinations and statistical significance was accepted at 5% probability level or less.

RESULTS

As shown in Table 1, the raw, dried-uncooked and dried-cooked *C. papaya* samples had appreciable amounts of crude protein (12.49 \pm 0.01 g/ 100 g, 16.50 \pm 0.29 g/ 100 g and 15.73 \pm 0.15 g/ 100 g respectively). Similarly, carbohydrate content was high in the three samples (55.82 \pm 0.18 g/ 100 g, 63.00 \pm 0.58g/ 100 g and 60.67 \pm 0.33g/ 100 g respectively) analysed. Except for moisture content which was lower ($p < 0.05$) in the dried-uncooked (7.84 \pm 0.15 g/100 g) than raw and dried-cooked (26.07 \pm 0.04 g/ 100 g and 14.71 \pm 0.20 g/ 100 g respectively) samples, all the other proximate nutrients were higher ($p < 0.05$) in the dried-uncooked than the raw and dried-cooked samples.

For the mineral content shown in Table 2, potassium was the most predominant in the raw (199.33 ± 12.25 mg/100 g), dried-uncooked (511.67 ± 33.52 mg/100 g) and dried-cooked (94.67 ± 1.76) samples, followed by magnesium (22.33 ± 0.88 mg/100 g, 80.00 ± 6.56 mg/100 g and 17.67 ± 0.33 mg/100 g respectively) and calcium (22.00 ± 1.53 mg/100 g, 40.67 ± 7.36 mg/100 g and 20.87 ± 0.70 mg/100 g respectively). Copper showed the least concentration being undetectable in the raw and dried-cooked samples, and only 0.16 ± 0.01 μ g/100 g in the dried-uncooked sample ($p < 0.05$).

Vitamin A content was similar ($p > 0.05$) in the raw, dried-uncooked and dried-cooked (4.92 ± 0.13 μ g/100 g, 4.38 ± 0.02 μ g/100 g and 4.40 ± 0.02 μ g/100 g respectively) samples. All the other vitamins were higher in the raw than in dried-uncooked and dried-cooked samples; vitamin B₁₂ was completely absent in the three samples. The raw sample had high content of vitamin C

(60.33 ± 1.20 mg/100 g) which was significantly ($p < 0.05$) decreased in the dried-uncooked and dried-cooked (30.00 ± 2.08 mg/100 g and 33.67 ± 2.40 mg/100 g respectively) samples (Table 3).

Table 4 shows the non-nutrient composition (mg/100 g) of the three papaya pulp samples: flavonoids were predominant with similar ($p > 0.05$) levels in the raw, dried-uncooked and dried-cooked (5.97 ± 0.32 , 5.08 ± 0.15 and 5.93 ± 0.09 respectively) samples. Next in concentration were the polyphenols with significantly lower ($p < 0.05$) concentration in the dried-uncooked (3.43 ± 0.12) and dried-cooked (3.83 ± 0.18) samples than the raw (4.13 ± 0.23) sample. Oxalates, cyanates and phytates showed very low levels in the raw (0.98 ± 0.07 , 0.05 ± 0.00 and 0.93 ± 0.02 respectively), which were almost completely removed in the dried-cooked (0.01 ± 0.00 , 0.00 ± 0.00 and 0.02 ± 0.01 respectively) sample.

Table 1: Proximate composition of the unripe *C. papaya* samples (g/ 100 g).

Samples	Moisture	Protein	Fat	Ash	Carbohydrate	Crude fibre
Raw	26.07 ± 0.04	12.49 ± 0.01	1.11 ± 0.01	3.45 ± 0.08	55.82 ± 0.18	1.89 ± 0.01
Dried-uncooked	$7.84 \pm 0.15^*$	$16.50 \pm 0.29^*$	$3.30 \pm 0.06^*$	$4.95 \pm 0.31^*$	$63.00 \pm 0.58^*$	$3.53 \pm 0.12^*$
Dried-cooked	$14.71 \pm 0.20^{*,a}$	15.73 ± 0.15	$0.94 \pm 0.04^{*,a}$	$5.60 \pm 0.06^{*,a}$	$60.67 \pm 0.33^{*,a}$	$2.36 \pm 0.06^{*,a}$

Values are expressed as mean \pm SEM of 3 samples.

* = significantly different from raw *C. papaya* at $p < 0.05$

a = significantly different from dried-uncooked *C. papaya* at $p < 0.05$

Table 2: Mineral composition of the unripe *C. papaya* samples (per 100 g).

Minerals	Raw	Dried-uncooked	Dried-cooked
Ca (mg)	22.00±1.53	40.67±7.36*	20.87±0.70 ^a
P (mg)	11.17± 0.73	33.67± 2.60*	11.33± 0.33 ^a
Na (mg)	4.23± 0.12	32.33± 2.73*	3.07± 0.22 ^a
Mg (mg)	22.33± 0.88	80.00± 6.56*	17.67± 0.33 ^a
K (mg)	199.33±12.25	511.67±33.52*	94.67± 1.76 ^{*,a}
Fe (mg)	0.28±0.03	0.82±0.05*	0.17±0.02 ^{*,a}
Se (mg)	1.62±0.09	2.23±0.09*	1.37±0.12 ^{*,a}
Zn (µg)	0.07±0.01	0.62±0.01*	0.05±0.00
Cu (µg)	0.00±0.00	0.16± 0.01*	0.00± 0.00 ^a
Mn (µg)	0.03±0.01	0.23±0.01*	0.02±0.01 ^a

Values are expressed as mean ± SEM of 3 samples.

* = significantly different from raw *C. papaya* at p<0.05

a = significantly different from dried-uncooked *C. papaya* at p<0.05.

Table 3: Vitamin composition of the unripe *C. papaya* samples (per 100 g).

Vitamins	Raw	Dried-uncooked	Dried-cooked
Vit. A (µg)	4.92 ± 0.13	4.38 ± 0.02	4.40± 0.02
Vit. E (µg)	0.37±0.03	0.27±0.01*	0.30±0.00*
Vit. K (mg)	2.70±0.06	2.00±0.06*	2.20±0.06
Vit. B1 (mg)	0.03±0.00	0.01±0.00*	0.01±0.00*
Vit. B2 (mg)	0.03±0.00	0.01±0.00*	0.01±0.00*
Vit. B3 (mg)	0.38±0.02	0.30±0.01*	0.29±0.00*
Vit. B6 (mg)	0.04±0.01	0.02±0.01*	0.02±0.00*
Folic acid (µg)	27.67±0.33	22.00±0.58*	20.67±0.88 ^{*,a}
Vit. B12 (mg)	0.00±0.00	0.00±0.00	0.00±0.00
Vit. C (mg)	60.33±1.20	30.00±2.08*	33.67±2.40*

Values are expressed as mean ± SEM of 3 samples.

* = significantly different from raw *C. papaya* at p<0.05

a = significantly different from dried-uncooked *C. papaya* at p<0.05.

Table 4: Non-nutrient composition of the unripe *C. papaya* samples (mg/100 g).

Non-nutrients	Raw	Dried-uncooked	Dried-cooked
Saponins	2.91 ± 0.17	2.64 ± 0.09	3.11 ± 0.06 ^a
Flavonoids	5.97 ± 0.32	5.08 ± 0.15	5.93 ± 0.09
Cardenoloids	1.50 ± 0.15	1.47 ± 0.07	1.63 ± 0.03
Polyphenols	4.13 ± 0.23	3.43 ± 0.12 [*]	3.83 ± 0.18 ^a
Phenols	1.60 ± 0.06	1.20 ± 0.00 [*]	1.47 ± 0.04 ^{*,a}
Oxalates	0.98±0.07	0.03±0.00 [*]	0.01±0.00 [*]
Cyanates	0.05±0.00	0.01±0.00 [*]	0.00±0.00 ^{*,a}
Phytates	0.93±0.02	0.11±0.01 [*]	0.02±0.01 ^{*,a}

Values are expressed as mean ± SEM of 3 samples.

* = significantly different from raw *C. papaya* at p<0.05

a = significantly different from dried-uncooked *C. papaya* at p<0.05

DISCUSSION

In this study, raw, dried-uncooked and dried-cooked unripe *Carica papaya* pulp were analysed for nutritional quality. Proximate analysis revealed that the raw unripe fruit pulp was high in moisture and carbohydrate, moderate in protein and ash, but low in crude fat and crude fibre contents. These findings corroborate those of other studies (Nwofia et al., 2012) that *C. papaya* pulp is high in moisture which indicates that the raw fruit pulp may not be preserved for a long period of time without spoilage, as the high moisture makes it susceptible to microbial attack. However, as shown in the results, the moisture content reduced significantly when sun-dried showing that the dried pulp can keep longer without spoilage. Hence, the customary treatment of *C. papaya* pulp by some Nigerian consumers can help to substantially increase its shelf life and reduce its susceptibility to microbial attack. Also, sun-drying of the pulp was found to cause increase in the other proximate constituents. That is, apart from

improved storage, the traditional sun-drying of unripe *C. papaya* fruit pulp helps to increase the levels of protein, fat, carbohydrate, ash and crude fibre. This confers a unique nutritional advantage, as drying from previous study (Awogbemi and Ogunleye, 2009) was reported to cause a general decrease in the protein, carbohydrate and fat contents of leafy vegetables, and appreciable increase in total ash, while their fibre contents remained unchanged.

The results also indicate that the unripe *C. papaya* pulp is not a good source of fat, crude fibre and inorganic mineral elements. Slavin and Lloyd (2012) had reported that fruits are generally low in protein and mineral constituents, but could serve as a reliable source of these nutrients when taken in adequate quantities. The low fat content agrees with other studies (Champagne et al., 2011; Slavin and Lloyd, 2012) that fruits are generally low in fat content and hence are usually recommended in weight-reducing diets. Cooking further increased the crude

fibre and ash contents showing that the usual processing of the fruit pulp by some consumers does not adversely affect its proximate nutrient content.

However, the levels of all the water soluble vitamins reduced following processing showing an adverse effect of both sun-drying and cooking on these nutrients, while the fat soluble vitamins analysed were less affected. Also less affected were the minerals except iron, selenium and potassium whose levels reduced significantly following processing. A similar reduction in iron and calcium contents of green cowpea pods were reported by Deol and Bains (2010) following boiling. However, in this study, the loss in calcium content was not significant. It is important to note that unripe *C. papaya* contains a high level of vitamin C and although sun-drying and subsequent cooking reduced its level significantly, these processing methods still left a substantial amount of the vitamin in the papaya pulp.

A number of secondary plant products including oxalates, phytates, cyanates, saponins, flavonoids, cardenoloides and phenols were generally found to occur in appreciable quantities. Cyanates are known to inhibit the respiratory chain at the cytochrome oxidase level. However, the level of this anti-nutrient was reduced substantially by sun-drying, and removed totally following cooking of the sun-dried pulp. This shows an advantageous effect of the customary processing of unripe *C. papaya* pulp by some consumers during preservation and soup preparation. A similar loss of cyanide due to some traditional processing methods was reported in cassava (Montagnac et al., 2008). Phytates and oxalates in foods react with metals to form insoluble complexes thereby reducing their bioavailability. Dietary oxalate has been known to complex with calcium, magnesium and iron leading to the formation of insoluble oxalate salts, resulting in oxalate

stones. It has been reported that simple processing techniques such as soaking, cooking, germination and fermentation can significantly reduce the content of anti-nutritional factors in plant foods. Our study is in agreement with this finding as drying and subsequent cooking caused substantial reduction in the levels of the anti-nutrients assayed.

A number of plant foods are generally taken for treatment of certain diseases when their consumption is not as food or snacks (Agbankpé et al., 2014; Adjakpa et al., 2016). *C. papaya* is used traditionally in the treatment of ailments, including malaria, diabetes, stomach ulcer, external ulcer, pile and impotence (Aravind et al., 2013; Boshra and Tajul, 2013). The medicinal value of *C. papaya* is possibly contributed by the presence of significant levels of saponins, flavonoid and cardenoloids. Cardenoloids is known for its usefulness in the treatment of congestive heart failure (Schneider and Wolfling, 2004). According to Schneider and Wolfling (2004), saponin may also function in a similar capacity. However, these compounds are known to cause adverse effect on health when consumed in excessive amounts. For instance, saponins are reported to cause blood haemolysis when consumed in high concentrations (Bala et al., 2012). However, it was observed that though sun-drying increased the level of saponins substantially, subsequent cooking reduced them to bearable level.

Conclusion

Unripe pawpaw fruit pulp is a rich source of important nutrients; the usual sun-drying and sun-drying with subsequent cooking used by some consumers during preservation and soup preparation do not adversely affect its proximate composition. Also, these traditional processing methods offer some nutritional and health benefits to

the consumers with respect to the non-nutrients such as oxalates, phytates and cyanates which were substantially reduced to negligible levels. Additionally, the biologically and medicinally functional non-nutrients such as flavonoids, saponins, cardenoloids and polyphenols were substantially retained. Nevertheless, there were significant losses of some vitamins and minerals; these should be substituted with other good locally available sources such as legumes, crayfish, prawn, crab, fish and bush meat.

COMPETING INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

AUTHORS' CONTRIBUTIONS

The authors WIO, GOI and IJA contributed to the supervision of the Master's Degree Thesis carried out by the author AIO. The four authors also contributed to the manuscript preparation and correction.

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