

Evaluation of the Nutritive Values of *Carica Papaya* Fruit peels as A Potential Ingredient in Livestock Nutrition

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Abstract. The nutritive values of the peels of ripe and unripe fruits of *Carica papaya* were assessed for their potential in livestock production. Proximate and phytochemical analyses, as well as vitamins and mineral contents of the ingredients, were determined. Data were subjected to a t-test for statistical analysis. The crude protein (CP) of ripe and unripe *Carica papaya* peels were 3.50% and 10.30%. The ripe *Carica papaya* peels had 26.20%, 3.05%, 15.03%, 3.71%, 52.22%, 2.44%, and 1,060.09Kcal/Kg of crude fiber, crude fat, ash content, moisture, carbohydrate, fatty acid, and energy respectively while the unripe *Carica papaya* peels contained 27.10%, 22.30%, 13.30%, 4.15%, 27.00%, 17.84% and 1,459.20Kcal/Kg of crude fiber, crude fat, ash content, carbohydrate, fatty acid, and energy respectively. The ripe *Carica papaya* peels had significantly higher ($p < 0.05$) values for calcium (0.39%), potassium (0.40%) and iron (570mg/Kg). The ripe *Carica papaya* peels had significantly higher ($p < 0.05$) values of saponin (9.69mg/100g) while the unripe peels had significantly higher values ($p < 0.05$) for alkaloid (6.44mg/100g), hydrogen cyanide (0.57mg/100g) and tannin (86.90mg/100g). Ripe *Carica papaya* peels having significantly higher ($p < 0.05$) values for vitamin B1 (1.67mg/100g) and vitamin B6 (1.80mg/100g) while the unripe *Carica papaya* peels had significantly higher ($p < 0.05$) values for vitamin A (3360IU/Kg), vitamins B2 (0.45mg/100g), B3 (3.25mg/100g), B12 (0.92mg/100g) and C (9.78mg/100g). It is concluded that these products offer a good source of basic vitamins and minerals and hold potential for therapeutic use in livestock nutrition. Therefore, the inclusion of these ingredients should be encouraged in livestock production, especially in the industry of monogastric animals.

Keywords: livestock, minerals, phytochemicals, proximate, vitamins

Introduction

Tropical Africa is home to the important plant species *carica papaya*. The third-largest producer in the world is Nigeria, according to estimates (FAO, 2004). It has become a popular fruit and vegetable due to the plant's economic and nutritional potential. A top-notch supplier of vitamins A and C is *Carica papaya*. Thiamine, riboflavin, calcium, iron, potassium, magnesium, and sodium are all present in trace amounts (Bari et al., 2006). In addition to its cheap price, *Carica papaya* is rich in nutritive value, vitamins, and minerals (Krishna et al., 2008). *Carica papaya* is potentially beneficial for poultry because it contains abundant amount of papain and

chymopapain and other antioxidant compounds (Unigwe et al., 2014). Previous studies claim that papaya fruits contain antibacterial activity (Ukaegbu-Obi et al., 2018) and cholesterolemic activities (Vij and Prashar, 2015), and hence feasible as phyto-additives for poultry feed. Further, antimicrobial and antioxidant activities in the extracts of papaya leaf and fruit are attributed to phenols, vitamins, and enzymes (Addai et al., 2013; Maisarah et al., 2013; Zuhair et al., 2013).

According to Kamaruzzaman et al. (2005), feeding papaya peel meal to broilers at a rate of 120 g/kg had no negative effects on their growth. El-Neney et al. have also reported that

papaya peel meal has a positive impact on egg production (2015). Papaya peels may be given value by being used as a feed supplement. Utilization of papaya peel meals by poultry may vary depending on a number of variables, including as the fruit's level of ripeness, the processing methods used, the age of the birds, and the food the birds are eating (Gueye, 2002; Diarra, 2018). However, no study has attempted a comprehensive evaluation of the nutrient values of the ripe pawpaw peels using different processing methods.

Large amounts of papaya peels are wasted during processing (Diarra, 2018), even though they might be added to the feed of animals and poultry. In the tropical Africa, there are many fruits sellers who just sell the *Carica papaya* fruits thus accounting for much of the peels being wasted on an annual basis.

Fresh papaya pulp is made from ripe fruits, but unripe papaya can also be peeled and added to curries. Unripe papaya fruits also naturally fall from the trees in the area and are wasted in large numbers. We evaluate the nutritive potentials of ripe and unripe *Carica papaya* peels as an alternative feed ingredient in livestock production in order to convert the waste to wealth since *Carica papaya* fruits are available all year round in West Africa.

Materials and Methods

Experimental Site

The study was carried out at Babcock University in Ilishan-Remo, Ogun State, Nigeria, in the Animal Science Laboratory of the Department of Agriculture and Industrial Technology. The study location is situated in the south-western rain forest vegetation zone of Nigeria at a latitude of 6°54'N and a longitude of 3°42'E from the Greenwich Meridian, with an average annual temperature of about 27°C. The climate is humid with an average annual rainfall of about 2400mm and peak rainfall occurs in the period of June to September (Google Earth, 2018).

Processing of papaya peel and diet formulation

Ripe *Carica papaya* fruits were purchased from the Farm Shop of the Department of Agriculture and Industrial Technology in Ilishan-Remo, Ogun, State, Nigeria while the unripe fruits were harvested within the campus of Babcock University, Ilishan-Remo, Ogun State, Nigeria. The ripe and unripe fruits were appropriately washed with clean running water from the tap and the peels were removed from the fruits. The peels were then chopped into small pieces. The peels were sun dried for 72 hours.

Proximate analysis

The samples' cyanide, crude fiber, protein, and moisture contents were all determined using the AOAC's (Association of Official Analytical Chemists, 2000) methodology. Every determination was made twice. Percentages were used to report the approximate numbers.

The moisture content of samples of ripe *Carica papaya* peels that had previously been sun- and oven-dried (5 grams each) in duplicate was determined by weighing in a crucible and drying in an oven at 105°C until a constant weight was attained. Ash content was measured by ashing at 550°C for roughly three hours. The protein content was calculated using the Kjeldah technique (AOAC, 2000) by multiplying the nitrogen amount by a conversion factor (6.25). The samples' crude fiber content was assessed using the digestion method, and the lipid was assessed using the Soxhlet extraction method (AOAC, 2000). The total soluble carbohydrate was calculated as the sum of all the proximate compositions divided by 100%. In the techniques used by Akinyeye et al. (2010) and Akinyeye et al. (2011), the calorific (energy) value was calculated. To achieve this, the values of carbohydrate, protein, and crude fat were multiplied by the corresponding Atwater factors of 17, 17, and 37. (Akinyeye et al, 2011; Niye et al., 2019). According to Akinyeye et al. (2010), Akinyeye et al. (2011), Greenfield and

Southgate's (2010) and Greenfield and Southgate's (2011) descriptions, crude fat was transformed into fatty acid by multiplying with a conversion factor of 0.80.

Mineral Analysis

According to the procedures outlined by the Association of Official Analytical Chemists, the mineral contents (elements) of *Carica papaya* fruit peels were measured using an atomic absorption spectrophotometer (AAS-Buck 205). These minerals included calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) (AOAC, 2000). The AOAC-recommended colorimetric method was used to measure phosphorus. Every determination was made in pairs of two. Sodium, iron, zinc, phosphorus, manganese, and copper readings were stated in parts per million, whereas calcium, magnesium, and potassium values were provided as percentages (ppm).

Phytochemical Analysis and Anti-Nutrients

We determined the quantitative phytochemical analyses of anti-nutrients using the methods of Iwuozor (2019). All determinations were done with four replicates.

Statistical Analysis

All data generated were analyzed using descriptive statistic. Data were further subjected to t-test and level of significance was accessed. All data were analyzed using SPSS Version 22 (SPSS 2012)

Results and Discussion

Proximate and Mineral Composition of Ripe *Carica Papaya* Fruits Peels

Table 1 showed that the results of proximate analysis of the peels of ripe *Carica papaya* fruits. The results revealed that the ripe and unripe peels of *Carica papaya* fruits contained appreciable amounts of 3.50% and 10.30% crude protein, 26.20 and 27.10% crude fiber, 3.05%

and 22.30% crude fat, 15.03% and 13.30% ash and 3.71% and 4.15% moisture.

The crude protein contents of ripe and unripe peels of *Carica papaya* obtained from this study was in contrast with the report of Seshamamba et al. (2018) but the results obtained on unripe papaya peels was in proximity with the crude protein values of 11.67% on papaya peel flour reported by Martial-Didier et al. (2017), 8.90% reported for unripe papaya seeds reported by Akintunde et al. (2021), 8.63% reported for sun-dried ripe papaya seeds reported by Kolu et al. (2021) and 13.1% reported on papaya leaves by Nath and Dutta (2016).

The results obtained on crude fiber for the ripe and unripe peels (26.20% and 27.10% respectively) was in agreement with 32.51% reported by Martial-Didier et al (2017) but at variance with the values obtained on leaves (1.95%) and seeds (18.83%) of papaya as reported by Nath and Dutta (2016) and Seshamamba et al. (2018) respectively.

The results obtained on crude fat for the ripe *Carica papaya* peel was in agreement with the report of Martial-Didier et al. (2017) and Nath and Dutta (2016). However, the crude fat value of 22.30% obtained for the unripe *Carica papaya* peel was significantly higher and this implies that the unripe peel of papaya is a good source of oil and higher fatty acid which might be a potential replacement to vegetable oil or palm oil in poultry nutrition.

The values obtained in this present study for ash for both the ripe and unripe *Carica papaya* peel was close to 18.3% reported by Nath and Dutta (2016) but at variance with 5.98% reported for papaya peel flour by Martial-Didier et al (2017) and 9% reported for papaya seed powder by Seshamamba et al. (2018).

The 52.22% reported for carbohydrates for the ripe *Carica papaya* peel was in agreement with 47.33% reported for papaya peel flour reported by Martial-Didier et al. (2017) but in contrast with 63.1% reported for papaya leaves by Nath and Dutta (2016).

Table 1. Proximate analysis of *Carica papaya* peels

Parameter	Ripe <i>Carica papaya</i> Peels	Unripe <i>Carica papaya</i> Peels	Level of significance (P<0.05)
Crude protein (%)	3.50	10.30	*
Crude fibre (%)	26.20	27.10	ns
Crude fat (lipid) (%)	3.05	22.30	*
Ash content (%)	15.03	13.30	*
Moisture (%)	3.71	4.15	*
Carbohydrate (%)	52.22	27.00	*
Fatty acid	2.44	17.84	*
Dry matter (%)	96.29	95.85	ns
Energy (Kcal/100kg)	1,060.09	1,459.2	*

Table 2. Mineral composition of ripe and unripe peels of *Carica papaya* fruits

Parameter	Ripe peels	Unripe peels	Level of significance (p<0.05)
% Ca	0.39±0.19	0.32±1.12	*
% Mg	0.17±0.00	0.17±0.00	*
% K	0.40±0.01	0.23±0.16	NS
% Na	0.03±0.02	0.09±0.03	*
mg/kg P	8.35±2.95	18.56±3.28	*
mg/kgMn	19.34±3.42	23.32±3.41	*
mg/kgFe	570.93±67.28	566.94±66.81	*

Legend: Ca – Calcium, Mg – Magnesium, K – Potassium, Na – Sodium, P – Phosphorus, Mn – Manganese, Fe - Iron

The 27% carbohydrates reported for the unripe *Carica papaya* peel is however in contrast with the report of Martial-Didier et al. (2017) and Nath and Dutta (2016) but in agreement with the 21.3% value reported for papaya seed powder by Seshamamba et al. (2018). This however suggests that the ripe *Carica papaya* peels will be a better source of carbohydrate for livestock utilization when compared to the unripe peel of *Carica papaya*.

Table 2 showed that the ripe and unripe peels of *Carica papaya* fruits contained essential minerals, calcium (0.39% and 0.32%), magnesium (0.17% and 0.17%), potassium (0.40% and 0.23%), sodium (0.03% and 0.09%), phosphorus (8.35mg/Kg and 18.56mg/Kg), manganese (19.34mg/Kg and 23.32mg/Kg) and iron (570.93mg/Kg and 566.94mg/Kg). The minerals present in the ripe and unripe peels of *Carica papaya* fruits were however significantly different (p<0.05) from each other. Calcium and potassium were significantly higher (p<0.05) in the ripe peels while magnesium was significantly higher (p<0.05) in the unripe peels. The presence

of these essential nutrients and minerals implies that the peels from the ripe and unripe fruits of *Carica papaya* could be utilized as a nutritionally valuable and healthy ingredient for poultry.

The mineral contents of ripe and unripe peels of *Carica papaya* obtained from this study was in contrast with the report of Parni and Verma (2014) who observed lower values of 1.033mg/g and 1.9µg/g of phosphorus and iron respectively for the peels of *Carica papaya*. Also, the values obtained in this study were also in contrast with the report of Chukwuka et al. (2013). They reported extremely lower values for calcium, sodium and potassium for the ripe and unripe pawpaw peels while slightly higher values were reported for phosphorus. However, their values for magnesium were similar to the values obtained in this study for the ripe and unripe peels of *Carica papaya*. Also, lower values were reported for magnesium for the ripe papaya peels.

According to NRC (2000), the calcium levels (0.12 to 0.14 percent of the dry matter of the feed) were appropriate for nearly normal growth

but insufficient for gestation when given until first calving. Converse came to the conclusion that 0.14 percent of the total dry matter in the diet looked to be needed for calcium to support growth, and 0.16 percent was needed for gestation and lactation. Also, Hale and Olson (2001) reported that non-lactating pregnant cows require calci at a level of 0.18% of total dry matter intake, 0.27% for lactating cows and 0.31% for optimal growth for growing and finishing cattle. These results indicate that dairy cattle make efficient use of calcium and the results showed that both ripe and unripe peels are sufficient to meet the daily calcium needs of cattle. On the other hand, Bai et al. (2022) and Poultry Hub (2022) reported 0.59% and 1% as the required calcium need for broiler chickens, hence other calcium sources have to be considered for poultry in addition to the peels of *Carica papaya*.

Also, Herdt (2015) concluded that the range of dietary phosphorus concentration requirements for most dairy diets are 0.35%–0.4%, and for dry cows, 0.3%–0.35%. This suggests that the peels will not be sufficient to meet the phosphorus requirements of cattle. However, the results obtained was in contrast with the reports of Daagema et al. (2020) who observed 47g for pawpaw fruits, Leite et al. (2021) who observed 0.48% for *Carica papaya* seed and 221.54mg/100g for *Carica papaya* peels

Explicitly, in line with the requirements for poultry as reported by NRC (2000) and Poultry Hub (2022), the calcium contents of the peels of *Carica papaya* fruits will not be sufficient to meet the calcium needs of poultry, however, calcium is often considered specially while formulating diets or rations for poultry (even in addition to the formulated commercial mineral premix) in the form of bone meal, limestone or dicalcium phosphate (DCP).

Also, according to the NRC (2000) nutrient charts for poultry cattle, the sodium content of the peels will also not be sufficient but the daily

sodium needs will be met through the addition of common salt in the diet of poultry and salt lick for feedlot cattle. However, the unripe peels of *Carica papaya* with sodium content of 0.09% will be sufficient for cattle based on the reports of NRC (2000), Hale and Olson (2001) and Wright and Grings (2020) that the maximum advisable level for sodium in the diet is 0.008% of the dry matter for dry cows, 0.06-0.08% for growing, finishing and gestation cattle and 0.10 for lactating cows while Poultry Hub (2022) reported sodium need of 0.18% for poultry. The values obtained for the unripe peels was in proximity to the value of 9.61mg/100g reported by Martial-Didier et al. (2017) for *Carica papaya* peels but at variance with the value reported for ripe *Carica papaya* peel observed in the present study. The variations might be on the stage of ripeness of the peels used in the various studies.

Also, the magnesium contents of the peels will not be sufficient to meet the daily need of poultry but magnesium needs of poultry (NRC, 2005) are always met even in abundance through nuts, grains and many plant products hence magnesium is often not critical in poultry nutrition. Hale and Olson (2001) reported that cattle need about 0.04 to 0.10% of magnesium in the dry matter of their ration. This further confirms that the peels of *Carica papaya* (ripe and unripe) as presented in this study are sufficient to meet the magnesium need of cattle. The results are in contrast with the observations of Martial-Didier et al. (2017) who reported 19.11 mg/100g for the ripe peels of *Carica papaya* and 22.33 mg/100g reported for the unripe fruits of *Carica papaya* by Okon et al. (2017).

The iron and potassium contents are however sufficient to meet the daily requirements of poultry and cattle. The unripe peels of *Carica papaya* supplies the daily manganese requirements for poultry but the ripe peels of *Carica papaya* is not sufficient to meet the daily needs (NRC, 2005).

Table 3. Phytochemical composition of ripe and unripe peels *Carica papaya* fruits

Parameter	Ripe peels	Unripe peels	Level of significance
Saponin (mg/100g)	9.69±1.14	8.15±0.96	*
Alkaloid (mg/100g)	6.44±0.76	6.90±0.81	*
HCN (mg/100g)	0.45±0.05	0.57±0.07	*
Tannin (mg/100g)	76.89±9.06	86.90±10.24	*

The values obtained for iron were in variance with the values obtained for ripe *Carica papaya* peel (0.65 mg/100g) and sun-dried *Carica papaya* seeds (486.97 mg/Kg) by Martial-Didier et al. (2017) and Kolu et al. (2021). The values obtained for potassium and manganese in this present study were in contrast with the values of 0.15% (potassium) and 31.21 mg/Kg (manganese) reported by Kolu et al. (2021) for *Carica papaya* seeds. The variations might be due to different parts of *Carica papaya* and the stage of ripening.

Minerals are necessary for healthy development, muscle function, and skeletal development (such as calcium), as well as for cellular function, oxygen transport, chemical reactions in the body, intestinal absorption, fluid balance, nerve transmission, and the control of acid-base balance (phosphorus). The use of iron can help avoid anemia and other related disorders (Oluyemi et al., 2006). The immune system and energy generation are both supported by manganese (Muhammad et al., 2011). Additionally, it functions in conjunction with vitamin K to assist blood clotting and with B complex vitamins to reduce the negative effects of stress (Muhammad et al., 2011). Zinc aids in protein synthesis, healthy body development, and sickness healing (Muhammad et al., 2011). Poultry performance and health can potentially be affected by lack of these nutrients and minerals (Merck, 2005).

Phytochemical Composition and Anti-nutrients

Table 3 showed that ripe and unripe peels of *Carica papaya* fruits contained saponin (9.69mg/100g and 8.15mg/100g; respectively), alkaloid (6.44mg/100g and 6.90mg/100g),

hydrogen cyanide (0.45mg/100g and 0.57mg/100g) and tannin (76.89mg/100g and 86.90mg/100g). There was significant difference ($p < 0.05$) between ripe and unripe peels. The saponin and tannin contents were significantly higher ($p < 0.05$) than that in ripe peels while the alkaloid and hydrogen cyanide contents of the unripe peels were significantly higher ($p < 0.05$) than the ripe peels.

Plant polyphenols called tannins can form complexes with macromolecules like proteins and polysaccharides as well as metal ions (Dei et al., 2007; Bourvellec and Renard) (2019). Dietary tannins may decrease the effectiveness of feed and weight increase in chicks (Dei et al., 2007; Hidayat et al., 2021). Steroid saponins and triterpenoid saponins are examples of the glycosides known as saponins (Dei et al., 2007). High amounts of saponins in feed have an impact on chicken development rate and feed intake (Dei et al., 2007; Hassan, 2013). The harsh taste of saponins has been blamed for the decrease in feed intake (Das et al., 2012; Gemede & Ratta, 2014). Saponins (in excess), which bind cholesterol and prevent its absorption, produce hypocholestaemia (Soetan and Oyewole, 2009). Saponins also have haemolytic activity against RBC (Lorent et al., 2014).

Samtiya et al. (2020) assert that anti-nutritional elements have the power to regulate the nutritive value and food attributes of leguminous plants. It has been demonstrated by Dijkstra et al. (2013) and Grosse Brinkhaus et al. (2016) that protein digestibility by tannins has negative effects because complexes develop. According to Ebrahim et al., consuming more tannins may potentially be harmful to one's health (2015).

Table 4. Vitamins composition of ripe and unripe *Carica papaya* fruits peel

Parameter	Ripe peels	Unripe peels	Level of significance
Vitamin A (IU/Kg)	1795.00±211.54	3360.00±395.98	*
Vitamin B1 (mg/100g)	1.67±0.20	1.08±0.13	*
Vitamin B2 (mg/100g)	0.41±0.05	0.45±0.05	ns
Vitamin B3 (mg/100g)	2.91±0.34	3.25±0.38	*
Vitamin B6 (mg/100g)	1.80±0.30	1.63±0.27	*
Vitamin B12 (mg/100g)	0.71±0.12	0.92±0.15	*
Vitamin C (mg/100g)	6.69±1.11	9.78±1.63	*

There has been research that suggests that goats and wild browsers may reject forage above a tannin threshold of 5%. Dietary amounts of 2 and 5 percent, respectively, have also been observed to have negative impacts on digestibility in sheep and cattle (Washaya et al. 2018).

According to a report by Mkhize et al., the maximum permitted tannin levels for ruminant animals shouldn't be more than 100g/kgDM (2018). Tannins have deleterious effects above this point, such as reducing live weight gain. Growing saponin amount strongly influences poultry feed intake and growth rate (Sim et al., 1984; Potter et al., 1993; Dei et al, 2007). Saponins are the cause of the disease hypocholestaemia. When it binds with cholesterol in order to lessen its absorption, hypocholestaemia is the result (Soetan and Oyewole 2009).

On animals, several alkaloids exhibit extremely hazardous consequences. Alkaloids have the potential to disrupt fetal development in sheep, sometimes even resulting in fetal mortality. The teratogenic alkaloids are mostly to blame for the anomalies in embryonic development (Guo et al., 2013; Li et al., 2018). Alkaloids can hurt a person's health as well. In humans, glycoalkaloids cause hemolysis. It also demonstrates human toxicity (Dahlin et al., 2017).

Anti-nutrients have a significant impact on how animals consume and use nutrients. It has been noted that animals with monogastric stomachs are poisoned by significant amounts of cyanide. The poisonous effects of cyanide are reduced using a variety of techniques. The toxic

effects of anti-nutrients are further lessened by soaking and boiling plant components in water, which also encourages animal eating and usage of anti-nutrients. Utilizing these techniques also improves protein digestibility. (Dei et al., 2007; Adeleke et al., 2017). In 1991 however, FAO/WHO recommended that HCN levels in mammals should be 10mg/kg dry weight (10ppm) (Ekpa and Sani, 2018) or 1mg/100g which was much than what was obtained in this study thus making the peels safe for livestock.

In this investigation, very little anti-nutrient material was found in either ripe or unripe *Carica papaya* peels. The peels of both mature and unripe *Carica papaya* fruits contain vital nutrients and minerals, suggesting they could be used to boost the health and growth of poultry. Some bioactive chemical substances, or secondary metabolites, of plants, such as saponins, tannins, and other phytochemicals, are thought to have pharmacologically active agents (Soetan and Oyewole, 2009). They have antibacterial and anti-parasitic effects, making them potentially useful for therapeutic purposes in livestock, particularly poultry.

Vitamins Composition

Table 4 showed that the ripe and unripe peels of *Carica papaya* fruits contained Vitamin A (1795IU/Kg and 3360IU/Kg), Vitamin B₁ (1.67mg/100g and 1.08mg/100g), Vitamin B₂ (0.41mg/100g and 0.45mg/Kg), Vitamin B₃ (2.91mg/100g and 3.25mg/100g), Vitamin B₆ (1.80mg/100g and 1.63mg/100g), Vitamin B₁₂ (0.71mg/100g and 0.92mg/100g) and Vitamin C (6.69mg/100g and 9.78mg/100g). The unripe

peels had significantly higher ($p < 0.05$) vitamins A, B1, B3, B12 and Vitamin C.

All the vitamins analyzed in this study showed that the peels of both ripe and unripe *Carica papaya* fruits will be sufficient to meet the daily vitamins A, B1, B2, B3, B6, B12 and C needs of broiler chickens thus making it an excellent replacement for commercial broiler vitamin premix. However, the required Vitamin A of 3750IU for layers could only be met by the unripe peels of *Carica papaya* (NRC 1994). The results showed that the ripe and unripe peels of *Carica papaya* could sufficiently meet the vitamins B and C needs of layers chickens.

Conclusions

The ripe and unripe peel of the *Carica papaya* could be used as a potential source for functional feed ingredients in livestock nutrition. In addition, it could be further processed into therapeutic functional feed products taking into account the phytochemical contents. Based on our study, oil has the potential to be produced and further studied because it can be a valuable source of energy, particularly for the nutrition of poultry.

References

- Addai, ZR, A Abdullah, SA Mutalib, KH Musa, and EMA Douqan. 2013. Antioxidant activity and physicochemical properties of mature papaya fruit (*Carica papaya* L. cv. Eksotika). *Advance Journal of Food Science and Technology*. 5:859-865, 10.19026/ajfst.5.3173.
- Adeleke, OR, OQ Adiamo, OS Fawale and G Olamiti. 2017. Effect of soaking and boiling on anti-nutritional factors, oligosaccharide contents and protein digestibility of newly developed bambara groundnut cultivars. *Turkish Journal of Agriculture - Food Science and Technology*. 5(9): 1006-1014. <https://doi.org/10.24925/turjaf.v5i9.1006-1014.949>
- Akintunde, AO, P Kolu, LC Ndubuisi-Ogbonna, OE Akinboye, IA Akintunde and SA Adewole. 2021. Nutritive and phytochemical values of unripe seeds of *Carica papaya* and prospects in animal nutrition. *Nigerian Research Journal of Chemical Sciences*. 9(2):278-287.
- Akinyeye, RO, A Oluwadunsin and A Omoyeni. 2010. Proximate, mineral, anti-nutrients and phytochemical screening and amino acid composition of the leaves of *Pterocarpus mildbraedi* Harms. *Electronic Journal of Environmental, Agricultural and Food Chemistry (EJEAFCh)*. 9(8):1322-1333.
- Akinyeye, RO, A Oluwadunsin and A Omoyeni. 2011. Proximate, mineral, anti-nutrients and phytochemical screening and amino acid composition of the leaves of *Pterocarpus mildbraedi* Harms. *Electronic Journal of Environmental, Agricultural and Food Chemistry (EJEAFCh)*, 10(1):1848-1857.
- Association of Official Analytical Chemists (AOAC) 2000. *Official Methods of Analysis of AOAC International*, 17th ed., AOAC International: Gaithersburg, MD, USA.
- Bai, S, Y Yang, X Ma, X Liao, R Wang, L Zhang, S Li, X Luo and L Lu. 2022. Dietary calcium requirements of broilers fed a conventional corn-soybean meal diet from 1 to 21 days of age. *Journal of Animal Science and Biotechnology*. 13(1):11. doi: 10.1186/s40104-021-00652-5.
- Bari, L, P Hassan, N Absar, ME Haque and MIIE Khuda. 2006. Nutritional analysis of two varieties of papaya (*Carica papaya*) at different maturation stages. *Pakistan Journal of Biological Science*. 9:137-140.
- Bourvellec CL and CMGC Renard 2019. Interactions between polyphenols and macromolecules: effect of tannin structure, In *Encyclopedia of Food Chemistry*. L Melton, F Shahidi and P Varelis (Eds). Academic Press. Pp 515-521. <https://doi.org/10.1016/B978-0-08-100596-5.21486-8>.
- Chukwuka, KS, M Iwuagwu and UN Uka. 2013. Evaluation of nutritional components of *Carica papaya* L. at different stages of ripening. *IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)*. 6(4)13-16.
- Daagema, AA, PN Orafa and FZ Igbua 2020. Nutritional potentials and uses of pawpaw (*Carica papaya*): A review. *European Journal of Nutrition and Food Safety*. 12(3): 52-66.
- Das, TK, D Banerjee, D Chakraborty, MC Pakhira, B Shrivastava and RC Kuhad. 2012. Saponin: Role in animal system. *Veterinary World*. 5(4), 248-254. <https://doi.org/10.5455/vetworld.2012.248-254>
- Dei, HK, SP Rose and AM Mackenzie. 2007. Shea nut (*Vitellaria paradoxa*) meal as a feed ingredient for poultry. *World's Poultry Science Journal*. 63(4):611-624.
- Diarra, SS. 2018. Peel meals as feed ingredients in poultry diets: Chemical composition, dietary recommendations and prospects. *Journal of*

- Animal Physiology and Animal Nutrition. 102: 1284-1295.
- Dijkstra, J, O Oenema, JW van Groenigen, JW Spek, AM van Vuuren and A Bannink. 2013. Diet effects on urine composition of cattle and N₂O emissions. *Animal*. 7:292–302. doi: 10.1017/S1751731113000578.
- Ebrahim, R, JB Liang, MF Jahromi, P Shokryazdan, M Ebrahimi, CW Li and YM Goh. 2015. Effects of tannic acid on performance and fatty acid composition of breast muscle in broiler chickens under heat stress. *Italian Journal of Animal Science*. 14(4):3956. DOI: 10.4081/ijas.2015.3956
- Ekpa, E and D Sani. 2018. Phytochemical and anti-nutritional studies on some commonly consumed fruits in Lokoja, Kogi state of Nigeria. *General Medicine Open*. 2(3):2-5. DOI: 10.15761/GMO.1000135
- El-Neney, BAM, NB Awadien and TA Ebeid. 2015. The productive performance and immunological traits of local chicken strain by using natural enzymes (plant papain) and remnants of plant papaya 1-effect of papaya latex on laying period. *Egyptian Poultry Science*. 35(1):1-24.
- Food and Agriculture Organization (2004). United Nations Statistics. <http://faostat.fao.org>
- Gemedede HF and N Ratta 2014. Antinutritional factors in plant foods: Potential health benefits and adverse effects. *International Journal of Nutrition and Food Sciences*. 3(4):284–289. <https://doi.org/10.11648/j.ijnfs.20140304.18>
- Greenfield, H and DA Southgate. 2003. *Food Composition Data. Production Management and Use*, 2nd ed., Rome, FAO.
- Grosse, BA, G Bee, P Silacci, M Kreuzer and F Dohme-Meier 2016. Effect of exchanging *Onobrychis viciifolia* and *Lotus corniculatus* for *Medicago sativa* on ruminal fermentation and nitrogen turnover in dairy cows. *Journal of Dairy Science*. 99:4384–4397. doi: 10.3168/jds.2015-9911.
- Gueye, EF. 2002. Employment and income generation through family poultry in low income food deficit countries. *Worlds Poultry Journal*. 58: 546.
- Guo, Y, Z Ma, H Kou, R Sun, H Yang, CV Smith, J Zheng and H Wang. 2013. Synergistic effects of pyrrolizidine alkaloids and lipopolysaccharide on preterm delivery and intrauterine fetal death in mice. *Toxicology Letters*, 221(3): 212-218.
- Hale, C and KC Olson. 2001. Mineral supplements for beef cattle. University MO Ext. G2081
- Hassan, SM. 2013. Effects of Guar meal, Guar gum and saponin rich Guar meal extract on productive performance of starter broiler chicks. *African Journal of Agricultural Research*, 8(21): 2464-2469. DOI: 10.5897/AJAR2013.6875
- Herd, TH. 2015. *Nutritional Requirements of Dairy Cattle*. MSD Veterinary Manual, Merck & Co., Inc., Rahway, NJ, USA
- Hidayat, C, A Irawan, A Jayanegara, MM Sholikin, TR Prihambodo, YR Yanza, E Wina, S Sadarman, R Krisnan and I Isbandi. 2021. Effect of dietary tannins on the performance, lymphoid organ weight, and amino acid ileal digestibility of broiler chickens: A meta-analysis. *Veterinary world*. 14(6):1405–1411. <https://doi.org/10.14202/vetworld.2021.1405-1411>
- Iwuozor, KO. 2019. Qualitative and Quantitative Determination of Anti-Nutritional Factors of Five Wine Samples. *Advanced Journal of Chemistry-Section A*, 2(2): 136-146
- Kamaruzzaman, M, SD Chowdhury, CK Podder and MA Pramanil. 2005. Dried papaya skin as a dietary ingredient for broiler chickens. *British Poultry Science*. 46(3): 390-393.
- Kolu, P, MD Olumide and AO Akintunde. 2021. Potentials of ripe *Carica papaya* seed meal using different processing methods as alternative feed ingredients in monogastric animal nutrition. *Nigerian Journal of Animal Science*. 23 (3): 177-184.
- Krishna, KL, M Paridhavi and JA Patel. 2008. Review on nutritional and medicinal and pharmacological properties of papaya (*Carica papaya* Linn.). *Natural Product Radiance*, 7(4):364-373.
- Leite, PRSC, TH de Oliveira, HB de Oliveira, VBL de Souza, TA Oliveira and TA Carvalho. 2021. Anticoccidial and performance effects of adding papaya seed to broiler diet. *Revista Portuguesa De Ciencias Veterinarias*. 116(620):25-30.
- Li, X, X Yang, E Xiang, J Luo, S Qiu, Y Fang, L Zhang, Y Guo, J Zheng and H Wang. 2018. Maternal-fetal disposition and metabolism of retrorsine in pregnant rats. *Drug Metabolism and Disposition*. 46(4):422-428. <https://doi.org/10.1124/dmd.117.079186>.
- Lorent, JH, J Quetin-Leclercq and MM Marie-Paule 2014. The amphiphilic nature of saponins and their effects on artificial and biological membranes and potential consequences for red blood and cancer cells. *Organic and Biomolecular Chemistry*. 12, 8803 – 8822.
- Maisarah, AM, B Nurul Amira, R Asmah and O Fauziah. 2013. Antioxidant analysis of different parts of *Carica papaya*. *International Food Resource Journal* 20: 1043-1048.
- Martial-Didier, AK, KK Hubert, KEJ Parfait and T Kablan. 2017. Phytochemical properties and proximate composition of papaya (*Carica papaya* L. var solo 8) Peels. *Turkish Journal of Agriculture - Food Science and Technology*. 5(6): 676-680.

- Merck. 2005. Mineral deficiencies. The Merck Veterinary Manual, 9th ed. Merck and Co. Inc., Whitehouse Station, N.J., USA. Pp. 2320-2330.
- Mkhize, NR, IMA Heitkonig, PF Scongings, LE Dziba, HHT Prins and WF de Boer. 2018. Effects of condensed tannins on live weight, faecal nitrogen and blood metabolites of free-ranging female goats in a semi-arid African savanna. *Small Ruminants Research*. 166:28–34. doi: 10.1016/j.smallrumres.2018.07.010.
- Muhammad, A, SM Dangoggo, AI Tsafe, AU Itodo and FA Atiku. 2011. Proximate, minerals and anti-nutritional factors of *Gardenia aqualla* (*Gauden dutse*) fruit pulp. *Pakistan Journal of Nutrition*. 10(6):577-581.
- Nath, R and M Dutta. 2016. Phytochemical and Proximate Analysis of Papaya (*Carica papaya*) Leaves. *Scholar Journal of Agriculture and Veterinary Science*. 3(2):85–87.
- Niyi, OH, AA Jonathan and AO Ibukun. 2019. Comparative Assessment of the Proximate, Mineral Composition and Mineral Safety Index of Peel, Pulp and Seeds of Cucumber (*Cucumis sativus*). *Open Journal of Applied Sciences*. 9(9).
- NRC. 2000. Nutrient Requirements for Beef Cattle 7th Rev. ed. Update 2000. Natl. Acad. Press, Washington, DC.
- NRC. 2005. Mineral Tolerance of Animals. 2nd Rev. ed. Natl. Acad. Press, Washington, D.C.
- Okon, WI, AI Ogri, GO Igile and IJ Atangwho. 2017. 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. *International Journal of Biological and Chemical Science*. 11(3): 1000-1011
- Oluyemi, EA, AA Akilua, AA Adenuya and MB Adebayo. 2006. Mineral contents of some commonly consumed Nigerian foods. *Science Focus*. 11:153-157.
- Parni, B and Y Verma. 2014. Biochemical properties in peel, pulp and seeds of *Carica Papaya*. *Plant Archives*. 14(1):565-568.
- Poultry Hub 2022. Nutrient Requirements of Egg Laying Chickens. PoultryHub Australia CJ Hawkins Homestead, University of New England, Armidale NSW 2351
- Samtiya, M, RE Aluko and T Dhewa. 2020. Plant food anti-nutritional factors and their reduction strategies: An overview. *Food Production, Processing and Nutrition*. 2:6. <https://doi.org/10.1186/s43014-020-0020-5>
- Seshamamba, BSV, P Malati, ANG Ruth, AS Mallika and V Sharma. 2018. Studies on physicochemical properties & proximate analysis of *Carica papaya* seed. *Journal of Pharmacognosy and Phytochemistry*. 7(6): 1514-1519.
- Soetan, KO and OE Oyewole. 2009. The need for adequate processing to reduce the anti-nutritional factors in animal feeds: A review. *African Journal of Food Science*. 3(9):223-232.
- SPSS 2012. User's Guide: Statistics. IBM Version 22. SPSS Inc., Chicago, IL, USA.
- Unigwe CR, UP Okorafor, UM Ogbu and OC Nwufoh. 2014. The nutritive profile of sun-dried paw-paw (*Carica papaya*) leaf meal and its effect on the growth performance of broiler chickens. *International Journal of Pure and Applied Science and Technology*. 20(2): 72-78.
- Vij, T and Y Prashar. 2015. A review on medicinal properties of *Carica papaya* Linn. *Asian Pacific Journal of Tropical Disease*. 5(1): 1-6.
- Washaya, S, J Mupangwa and V Muchenje. 2018. Chemical composition of *Lablab purpureus* and *Vigna unguiculata* and their subsequent effects on methane production in Xhosa lop-eared goats. *South African Journal of Animal Science*. 48:445-458. doi:10.4314/sajas.v48i3.5.
- Wright, CL and EE Grings. 2020. Mineral Nutrition for Beef Cattle. SDSU Extension. South Dakota Board of Regents.
- Zuhair, RA, A Aminah, AM Sahilah and D Eqbal. 2013. Antioxidant activity and physicochemical properties changes of papaya (*Carica papaya* L. cv. Hongkong) during different ripening stage. *International Food Research Journal*. 20: 1653-1659