LAUTECH Journal of Engineering and Technology 19 (3) 2025: 142-154

10.36108/laujet/5202.91.0331

Nutritional And Antinutritional Evaluation of Gluten-Free Pasta from Cocoyam Starch and Lima Beans Flour

Amanyunose, A. A., Olanipekun, B. F. and Adelakun, O. E.

Department of Food Science, Ladoke Akintola University of Technology, Ogbomoso.

Article Info

Article history:

Received: May 15, 2025
Revised: July 6, 2025
Accepted: July 10, 2025

Keywords:

Cocoyam,
Gluten-free,
Lima beans,
Pasta

Corresponding Author:
bfolanipekun@lautech.edu.ng

ABSTRACT

Pasta is a wheat-based food product which has gained universal popularity in recent years due to its versatility, low cost, ease of preparation and nutritional quality. It is traditionally produced from wheat that is largely imported in Nigeria, placing a heavy burden on the dwindling financial resources of the nation. Wheat also contains gluten, which triggers a multi-system autoimmune disorder called celiac disease in genetically predisposed individuals. Treatment for celiac disease is complete exclusion of dietary gluten. Efforts are currently being made to develop gluten-free pasta from indigenous crops in order to reduce wheat importation and provide alternatives to consumers affected by celiac disease. Cocoyam and lima beans are gluten-free, underutilised indigenous tropical crops with a rich nutritional profile, which can be used to replace wheat flour in pasta production. This study, therefore, aims to develop gluten-free pasta from lima bean flour and cocoyam starch. Composite blends of pregelatinized cocoyam starch, germinated lima beans flour and xanthum gum (binder) were formulated in the following ratios: (100:0, 87.5:12:5, 75:25, 62.5:37.5 and 50:50) and used to produce pasta. The protein, moisture and carbohydrate contents of the gluten-free pasta ranged from 6.54 -18.82%, 9.06-10.56% and 59.29-74.30% respectively. Mineral content of gluten-free pasta ranged from 61.54-108.20 mg/100g for calcium and 0.94-6.09 mg/100g for iron. Lysine values increased from 2.63 (100% Wheat Flour Pasta) to 3.85 g/100 g protein (50% PCS, 50% GLBF & xanthum gum) while total amino acids ranged from 53.66-83.11 g/100 g protein. The antinutritional factors cyanide, oxalate and phytic acid ranged from 0.191-1.199mg/100g, 10.251-85.064 mg/100g and 0.01-1.66% respectively. The study concluded that pregelatinized cocoyam starch and germinated lima beans flour blends are effective in developing nutritious gluten-free pasta.

INTRODUCTION

Pasta is a popular and widely consumed food all over the world (IPO, 2021). It is traditionally produced from durum wheat semolina or soft wheat flour and water, kneaded until the final texture is obtained (Arcangelis *et al*., 2020). In recent years, a lot of research efforts have been targeted at improving the nutritional composition of pasta by using unconventional and indigenous crops rather than the conventional wheat, which is imported (Bresciani *et al*., 2022**)**. Non-wheat flours are gaining ground as a substitute for wheat flour in pasta production as a means of increasing local indigenous crop utilisation and reducing wheat importation (Makhuvha *et al*., 2024).

Cocoyam is an important underutilised indigenous tropical crop commonly grown by low-income earners in Nigeria (Amanyunose *et al.,* 2021). It is mainly a starchy food, even though there are reports that it has nutritional advantages over other roots and tubers because of its greater protein content and amino acid (Obiegbuna *et al*., 2014). Starch, which is the major nutritional component of cocoyam, can be extracted and used for varying food formulations, thus extending the utilisation of cocoyam (Okunade and Arinola, 2021). Cocoyam starch, unlike cassava and corn starches, has not found wide application in food and nonfood industries (Arinola, 2019). In its native form, starch is unusable for many applications. The undesirable properties of native starch can be reduced or eliminated through modifications; by reorganising the structural arrangement of the starch granules, resulting in enhanced physicochemical properties (Oladebeye *et al*., 2013).

Lima beans are leguminous plants that are important sources of protein (which compares favorably with other legumes) and dietary fibre. It has good potential as a cheap and alternative source of protein (Seidu *et al*., 2018). The high protein content, as well as the presence of the amino acid lysine makes them a suitable, cheap source for fortification of diets in most developing countries (Kaur *et al*., 2009). Lima beans contain some antinutrients, which can be completely removed or reduced to a minimal level by common processing and household cooking methods. Some researchers have attempted to use various indigenous crops such as millet, sorghum, pearl millet, prosso millet, rice flour and banana starch and the likes in the production of gluten free pasta (Palavecino *et al*., 2017; Fradinho *et al*., 2020) There is however no information available on the use of pregelatinized cocoyam starch fortified with germinated lima beans flour in the production of gluten free pasta**.** This research was carried out to evaluate the proximate, mineral, antinutritional components and amino acid profile of gluten-free pasta made from pregelatinized cocoyam starch, germinated lima beans flour, using xanthum gum as a binder.

MATERIALS AND METHODS

Materials

Cocoyam (*Xanthosoma* sp) and lima beans (*Phaseolus lunatus*) used for this study were obtained from the International Institute of Tropical Agriculture, Moniya, Ibadan.

Methods

Cocoyam starch extraction

Starch was extracted from cocoyam using a method described by Arawande and Ashogbon (2019). Cocoyam corms were washed, peeled, cut into small slices and ground in a milling machine and the resulting slurry mixed with distilled water (1:4). The mixture was then sieved through a muslin bag, and the starch suspension left overnight at refrigerated temperature (4ºC) to settle. The supernatant was decanted and the white starch sediment was washed 3 to 4 times by resuspending in distilled water. It was allowed to settle and decant when the supernatant became transparent. The isolated starch was dried in an oven at 40ºC and milled using a conventional blender. It was sieved and packaged in ziplock bags and stored at ambient temperature (26 ± 2 ºC) until required for use.

Pregelatinization of cocoyam starch

This was carried out according to the method described by Okunade and Arinola (2021). A known weight (100g) of starch sample was mixed with 150 ml of distilled water and heated in a water bath at 80 ºC for 15 min with slow intermittent manual mixing using a stirring rod. A thin film of the pregelatinized starch was spread on a stainless steel tray in the oven at 40 ºC for 24 h. to dry. This was cooled, milled, sieved and packaged in ziplock bags and stored at ambient temperature (26 ± 2 ºC) until required for use.

Lima beans flour processing

Germinated Lima beans flour was processed from wholesome lima beans using a method described by Farinde *et al*. (2018).

Formulation of composite blends

Composite blends of pregelatinized cocoyam starch (PCS) and germinated lima bean flour (GLBF) were formulated in the following ratios: 100:0, 87.5:12.5, 75:25, 62.5:37.5 and 50:50. Xanthum gum was added to the composite flour at 2.5%. Control (100% wheat flour) was included. The composite blends were thoroughly mixed using a Kenwood blender until an homogeneous blend was obtained.

Pasta production

Pasta dough was formulated using a method described by Bolarinwa and Oyesiji, (2021). Composite flour (100g) composed of pregelatinized cocoyam starch, lima beans flour and xanthum gum were mixed with water to form a uniform dough. The dough was kneaded and extruded using a pasta extruder. Control pasta was prepared using 100% wheat flour(WF) with no xanthum. The pasta samples were dried at 60ºC for 3h, allowed to cool and packed in ziplock bags until further use.

Analysis

Proximate and Mineral analysis

Composite blends and pasta samples were analysed for proximate composition based on the method of analysis of the Association of Official Analytical Chemists (AOAC, 2006). The analysis for essential mineral elements was carried out by Atomic Absorption Spectrophotometer (AOAC, 2005)

Amino acid profile determination

This was determined according to the method of Obreshkova, *et al.* (2012).

Determination of anti-nutritional factors

Tannin was determined using the method of AOAC (2005), and cyanide content of the samples was determined using the method described by Bradbury *et al*. (1991). Phytate content was evaluated using the process described by Haugh and Lantzsch, (1992), while oxalate content was analysed using the protocol described by N'zi *et al.* (2021)

Statistical analysis

Analysis was carried out in triplicate. The means and standard deviations of the analyses were thus calculated, and the results were subjected to analysis of variance using the statistical package for social science (SPSS), while means were separated using Duncan Multiple Range Test (DMRT) at $p < 0.05$ (Arise *et al*., 2022).

RESULTS AND DISCUSSION

Proximate Composition of the Composite Blends from Pregelatinized Cocoyam Starch (PCS) and Germinated Lima Bean Flour (GLBF)

The proximate composition of blends from pregelatinized cocoyam starch and germinated lima bean flour are presented in Table 1. The moisture content of blends ranged between 7.36 and 9.81%. The moisture values were significantly different (p<0.05) with the exception of samples D (75% PCS & 25% GLBF) and E (62.5% PCS & 37.5 GLBF). The highest moisture content (9.81%) observed was for sample A (100%WF). The moisture content of 100% wheat flour obtained in this work is similar to the value reported by Radhika *et al.* (2019) for wheat flour, but lower than the range 11.28 - 15.00% reported by Vellore *et al*. (2023) for sorghum and pearl millet flour blend. Moisture content of flour is important as it predicts the stability of the flour during storage (Bolarinwa and Oyesiji, 2021). All moisture content values obtained in this work fall below the recommended moisture level (≤13), indicating the shelf stability of the samples**.** The protein content of the blend ranged between 2.82 and 15.02%. The values were observed to be significantly different (p<0.05) with sample B (100% PCS) having the lowest value and sample F (50% PCS & 50% GLBF) having the highest value. Protein content increased with the increase in germinated lima bean flour addition. A similar increase in protein content was reported by Fiorda *et al*. (2013), who used cassava starch, cassava bagasse and amaranth flour in gluten-free pasta production. Tharise *et al*. (2014) also reported an increase in protein content of flour blend from potato starch, cassava flour and soybeans flour as an alternative to wheat flour.

The fat content ranged between 2.10 and 2.92% with sample A (100%WF) having the lowest. The fat content observed for the sample B (100% PCS) is higher than 0.08% reported by Ashogbon, (2017) for 100% cocoyam starch. There was an increase in the fat content of the blend with increasing addition of lima bean flour. The fat content values reported in this work are lower than the values reported by Awolu *et al*. (2017) for composite flour made from maize flour, soyflour and tigernut flour. High fat content is undesirable in pasta products to prevent oxidative rancidity that can negatively impact its shelf life. The ash content of the blend ranged from 1.56 to 3.94%. The values were significantly different (p<0.05) from the control. Sample A (100% WF) had the lowest ash content, while sample F (50% PCS & 50% GLBF) had the highest value. The ash content of the blend samples increased with increasing addition of germinated lima bean flour. Tharise *et al*. (2014) reported lower ash content values in the range 0.75-1.12% for composite flour from potato starch, rice flour, cassava flour and soybean flour. They also reported an increase in ash content as levels of cassava flour and soybean flour increased.

Table 1 Proximate Composition (%) of Composite Blends from Pregelatinized Cocoyam Starch and Germinated Lima Beans Flour

Sample	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
A	9.81±0.02^{e}	1.38±0.10^{a}	11.23±0.25^{d}	0.67±0.00^{b}	1.66±0.03^{a}	75.25±0.17^{d}
B	9.07±0.02^{d}	2.10±0.10^{b}	2.82±0.25^{a}	1.10±0.00^{a}	1.56±0.03^{a}	83.35±0.17^{e}
C	8.75±0.06^{c}	2.42±0.06^{b}	9.10±0.00^{b}	3.19±0.00^{c}	2.98±0.01^{b}	73.56±0.01^{c}
D	8.16±0.02^{b}	2.61±0.15^{b}	10.12±0.32^{c}	3.22±0.00^{c}	3.17±0.02^{c}	72.72 ±0.14^{c}
E	8.16±0.03^{b}	2.87±0.06^{c}	12.00±0.22^{e}	3.79±0.01^{d}	3.61±0.01^{d}	69.57±0.25^{b}
F	7.36±0.03^{a}	2.92±0.12^{c}	15.02±0.13^{f}	3.88±0.00^{d}	3.94±0.01^{d}	66.88±0.11^{a}

Mean values with different superscripts within the same column are significantly different at 5% level. Keys A = 100% Wheat Flour, B = 100% Pregelatinized Cocoyam Starch., C = 87.5% Pregelatinized Cocoyam Starch and 12.5% Germinated Lima Beans Flour, D = 75% Pregelatinized Cocoyam Starch and 25% Germinated Lima Beans Flour, E= 62.5% Pregelatinized Cocoyam Starch and 37.5% Germinated Lima Beans Flour and F= 50% Pregelatinized Cocoyam Starch and 50% Germinated Lima Beans Flour

Crude fibre content of the blend ranged from 0.67 to 3.88%. The values were significantly different (p<0.05) from one another. Sample A (100%WF) had the lowest value, while sample F (50% PCS & 50% GLBF) had the highest value. Awolu et al. (2017) observed the same increase in crude fibre content of composite flour from toasted maize, soybean and tigernut flour. The crude fibre value of 100% WF obtained in this work is lower than 2.5% obtained by Vellore et al. (2023) and higher than 0.54% reported by Bala *et al*. (2015), both for wheat flour. The carbohydrate content of the pregelatinized cocoyam starch and germinated lima beans flour blend ranged from 66.88 – 83.95%. The values were significantly different (p<0.05), with sample B (100% PCS) having the highest value and Sample F (50% PCS & 50% GLBF) having the lowest carbohydrate content. The carbohydrate content decreased with a decrease in levels of PCS and an increase in levels of GLBF. James et al. (2017) reported a similar carbohydrate value for 100% wheat flour, while Vellore et al. (2023) reported a much lower value.

Proximate Composition (%) of Gluten Free Pasta Produced from Blends of Pregelatinized Cocoyam Starch, Germinated Lima Beans Flour and Xanthum Gum

The proximate composition of gluten-free pasta is presented in Table 2. The moisture content of gluten-free pasta ranged between 9.04 and 10.56% with sample D (75% PCS & 25 GLBF Pasta) having the highest value and sample E (62.5% PCS & 37.5% GLBF Pasta) having the lowest value. These values are similar to the range 10.44 – 11.22% obtained by Ikujenlola (2016) for sorghum pasta and higher than the range (0.57 – 2.89%) obtained by James *et al.* (2017). The low moisture content values obtained in this work will promote the keeping quality of the pasta, as the moisture content of pasta and similar products should be equal to or less than 12.5% after drying in order to avoid microbial contamination (Radhika et al., 2019). The moisture content of a food is indicative of the dry matter in that food. Also, low residual moisture content in pasta is beneficial because microbial proliferation will be reduced, and storage life may be prolonged if stored inside appropriate packaging material under standard environmental conditions.

The protein content of gluten-free pasta ranged between 6.54 and 18.82%. The protein content of pasta was significantly different ($p<0.05$) from one another. The pasta from blends of PCS and GLBF had higher protein and the protein content increased as the percentage level of GLBF increased. James *et al*. (2016) reported an increase in protein content of pasta as levels of African breadfruit and soybean increased. A similar increase was also reported by Ikujenlola (2016) for gluten-free pasta produced from quality protein maize, sorghum and watermelon seed flour. Protein is important for good development and growth as it replaces worn-out tissues.

Table 2 Proximate Composition (%) of Gluten Free Pasta Produced from Pregelatinized Cocoyam Starch, Germinated Lima Beans Flour and Xanthum Gum

Sample	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
A	10.29±0.05^{c}	1.70±0.06^{a}	10.15±0.05^{b}	2.20±0.02^{a}	1.51±0.02^{a}	74.15±0.04^{d}
B	9.92±0.02^{b}	4.20±0.00^{c}	6.54±0.02^{a}	2.48±0.02^{a}	2.56±0.03^{b}	74.30±0.04^{d}
C	10.37±0.03^{c}	5.57±0.06^{e}	10.82±0.02^{c}	2.41±0.02^{a}	2.88±0.02^{c}	67.95±0.14^{b}
D	10.56±0.04^{c}	4.91±0.02^{c}	11.32±0.05^{d}	5.98±0.03^{d}	2.22±0.00^{b}	65.01±0.07^{b}
E	9.06±0.02^{a}	2.96±0.05^{b}	12.53±0.12^{e}	4.10±0.01^{c}	2.31±0.01^{b}	71.04±1.48^{c}
F	10.53±0.03^{c}	5.42±0.02^{d}	18.82±0.00^{f}	3.48±0.02^{b}	2.46±0.03^{b}	59.29±0.05 ^{a}

Mean values with different superscripts within the same column are significantly different at 5% level. Keys A = 100% Wheat Flour Pasta, B = 100% Pregelatinized Cocoyam Starch Pasta, C = 87.5% Pregelatinized Cocoyam Starch and 12.5% Germinated Lima Beans Flour Pasta, D = 75% Pregelatinized Cocoyam Starch and 25% Germinated Lima Beans Flour Pasta, E= 62.5% Pregelatinized Cocoyam Starch and 37.5% Germinated Lima Beans Flour Pasta and F= 50% Pregelatinized Cocoyam Starch and 50% Germinated Lima Beans Flour Pasta

Increased protein content of the gluten-free pasta suggests that they could be used as a solution to the increased rate of protein malnutrition in less developed countries. The fat content of gluten-free pasta ranged from 1.70-5.57%. The highest fat content was recorded for sample C (87.5% PCS & 12.5 GLBF Pasta), while sample A (100% WF Pasta) had the lowest fat content. The fat content of the blends was significantly different ($p<0.05$), and there was an increase in the fat content of pasta as levels of GLBF increased. This is in agreement with the work of Sule et al., (2019) who reported increased levels of fat (1.38-1.48%) in pasta as the levels of carrot powder increased. Bolarinwa and Oyesiji, (2021) also reported fat content in the range of 3.51-5.77% for rice soy pasta. Thatsanasuwan et al., (2023) equally reported increased fat content for gluten free pasta produced from jackfruit seeds. Fat is an important nutrient, containing fat soluble vitamins (A, D, E and K), a high fat content in pasta and other dried food product is undesirable as it can cause off-flavour and rancidity, resulting in short shelf life (Ikujenlola, 2016).

The ash content of the pasta sample ranged between 1.51 and 2.88% and the values are significantly different ($p<0.05$) from sample A (100% WF Pasta), which also had the lowest ash content, while sample C (87.5% PCS & 12.5 GLBF Pasta) had the highest ash content. Radhika et al. (2019) reported a similar trend where the ash content of composite pasta was significantly increased compared to the control sample of 100% wheat flour. The ash content of a food is related to its mineral content (Edet et al., 2017). It indicates the presence of inorganic matter in food

Crude fibre content for pasta ranged between 2.20 and 5.98% with sample A (100% WF Pasta) having the lowest value and sample D (75% PCS & 25 GLBF Pasta) having the highest value. The samples were significantly different from the control except for samples B (100% PCS Pasta) and C (87.5% PCS & 12.5 GLBF Pasta). Consumption of dietary fibre is important as it helps in lowering serum cholesterol level, reducing the onset of coronary heart disease, the development of colon cancer and hypertension. Dietary fibre promotes glucose tolerance and increases insulin sensitivity (Hassan and Umar, 2004). The carbohydrate content of gluten-free pasta ranged between 59.29 and 74.30% showing a decrease in carbohydrate content as levels of pregelatinized cocoyam starch decreased and levels of germinated lima bean flour increased. There was no significant difference ($p>0.05$) in carbohydrate content of samples A (100% WF Pasta) and B (100% PCS Pasta), while sample F (50% PCS & 50% GLBF Pasta) had the lowest carbohydrate content. James *et al.* (2016) reported similar carbohydrate content for pasta obtained from blends of wheat, Bambara groundnut and cassava flour. Carbohydrate evaluation based on differences is highly affected by the protein, ash and fat content and an increase in the content of these nutrients can reduce or elevate total carbohydrates (Putri et al., 2023).

Mineral Composition of Gluten-Free Pasta Produced from Pregelatinized Cocoyam Starch, Germinated Lima Beans Flour and Xanthum Gum

The mineral content of gluten-free pasta is presented in Table 3. The calcium content of pasta samples ranged between 61.54 and 108.20 mg/100g, with sample B (100% PCS Pasta) having the lowest value and sample F (50% PCS & 50% GLBF Pasta) having the highest value. The samples were all significantly different ($p<0.05$) from one another. Calcium content increased with the addition of germinated lima bean flour. Jalgaonkar et al. (2018) reported lower values (21.66mg/100g) for 100% wheat flour, while Ikujenlola, (2016) observed a similar increase in calcium content as the incorporation of watermelon seed into quality protein maize increased. Calcium is important in the formation of strong, healthy bones and teeth. Calcium is also needed for normal cell regulation of the nerves, heart and proper functioning of the enzymes. Lack of calcium in the diet can result in rickets in children and osteoporosis in premenopausal and post-menopausal women (Ibitoye *et al.,* 2013).

Sodium content of pasta ranged between 25.31 and 257.10mg/100g, with the samples significantly different ($p<0.05$) from each other. Sample A (100% WF Pasta) had the highest sodium content, while sample B (100% PCS Pasta) had the lowest sodium content. James *et al.* (2017) reported similar sodium content for 100% wheat flour pasta but far lower sodium values for blends of wheat, cassava and bambara groundnut pasta. The increase in sodium content with increased addition of lima bean flour observed in this research is corroborated by the findings of Yadaf *et al.* (2014), who also observed an increase in sodium content with the incorporation of selected vegetables in pasta.

Magnesium content of pasta ranged between 102.607 and 146.83mg/100g, with sample A (100% WF Pasta) having the highest magnesium content and sample B (100% PCS Pasta) having the lowest value. There was an increase in the magnesium content of pasta samples as levels of germinated lima bean flour increased. The composite pasta was also significantly different ($p<0.05$) from the 100%WF pasta. Sule *et al.* (2019) observed a different trend with a decrease in magnesium content of carrot-incorporated pasta as levels of carrot powder increased. The magnesium values observed in this work are higher than the values reported by James *et al.* (2017), who reported magnesium content in the range 10.0-14.0mg/100g. Magnesium is essential for over 300 enzymes in the body. It is needed in the formation of ATP, storing of carbohydrates, fats and proteins, in nerves and muscle activities. Humans have a unique ability to conserve magnesium. Its deficiency leads to growth abnormalities and defective central nervous systems (Ikujenlola, 2016). The zinc and iron content of composite pasta ranged between 1.30 and 3.75mg/100g and 0.94-6.09mg/100g. The zinc and iron content were all significantly different ($p<0.05$), and the values improved with the addition of lima bean flour. Sample B (100% PCS Pasta) recorded the lowest zinc and iron content, while sample F (50% PCS & 50% GLBF Pasta) recorded the highest value. This shows improved zinc and iron content compared to that of pasta from100%wheat flour. Jalgaonkar *et al.* (2018) reported a similar range for zinc content (2.93-4.88mg/100g) of composite pasta. The iron content reported for 100% wheat flour pasta in this work is higher than 1.30mg/100g reported by James *et al.* (2017) for 100% wheat flour pasta. Iron is essential for blood formation, and it helps in transporting oxygen throughout the body (Ikujenlola, 2016).

Amino Acid Composition of Gluten-Free Pasta Produced from Pregelatinized Cocoyam Starch, Germinated Lima Beans Flour and Xanthum Gum

The amino acid content of pasta made from pregelatinized cocoyam starch and germinated lima beans flour is presented in Table 4. The total amino acid composition of gluten free pasta samples ranged between 53.66 and 83.11 g/100 g protein with sample B (100% PCS Pasta) having the lowest amino acid values and sample F (50% PCS & 50% GLBF Pasta) having the highest values.

Table 3. Mineral Composition (mg/100g) of Gluten Free Pasta Produced from Pregelatinized Cocoyam Starch and Germinated Lima Beans Flour and Xanthum Gum

Sample	Calcium (mg/100g)	Sodium (mg/100g)	Magnesium (mg/100g)	Zinc (mg/100g)	Iron (mg/100g)
A	101.02 ± 0.02^{d}	257.10 ± 0.01^{f}	146.83 ± 0.03^{f}	2.17 ± 0.04^{b}	3.21 ± 0.03^{b}
B	61.54 ± 0.03^{a}	25.31 ± 0.00^{a}	102.607 ± 0.01^{a}	1.31 ± 0.00^{a}	0.94 ± 0.02^{a}
C	97.78 ± 0.09^{b}	146.38 ± 0.04^{b}	104.078 ± 0.01^{b}	2.30 ± 0.06^{c}	4.29 ± 0.01^{c}
D	99.66 ± 0.55^{c}	163.45 ± 0.36^{c}	114.187 ± 0.02^{c}	2.77 ± 0.01^{c}	4.54 ± 0.06^{c}
E	104.62 ± 0.01^{e}	167.57 ± 0.09^{d}	120.432 ± 0.00^{d}	3.54 ± 0.03^{d}	5.02 ± 0.04^{d}
F	108.20 ± 0.04^{f}	175.21 ± 0.02^{e}	121.619 ± 0.03^{e}	3.75 ± 0.03^{d}	6.09 ± 0.01^{e}

Mean values with different superscripts within the same column are significantly different at 5% level. Keys A = 100% Wheat Flour Pasta, B = 100% Pregelatinized Cocoyam Starch Pasta, C = 87.5% Pregelatinized Cocoyam Starch and 12.5% Germinated Lima Beans Flour Pasta, D = 75% Pregelatinized Cocoyam Starch and 25% Germinated Lima Beans Flour Pasta, E= 62.5% Pregelatinized Cocoyam Starch and 37.5% Germinated Lima Beans Flour Pasta and F= 50% Pregelatinized Cocoyam Starch and 50% Germinated Lima Beans Flour Pasta

Pasta samples containing germinated lima bean flour showed an increase in lysine content compared to the 100% wheat flour pasta. This is similar to the findings of Filip and Vidrih, (2015), who produced pasta using plant protein extract and spinach powder and Gopalakrishnan *et al.* (2011), who produced pasta using sweet potato flour and defatted soy flour. The lysine content of pasta with added germinated lima bean flour showed an improvement compared to the 100% WF pasta; this is similar to the report of Filip and Vidrih, (2015). Lysine is one of the essential amino acids that is necessary for cell growth and repair (Matthews, 2020). The lysine content of 100% WF pasta (2.63 g/100g protein) obtained in this work is lower than that obtained (3.1 g/100g protein) for 100% WF pasta by Veena et al. (2022), while the tryptophan levels were higher. Recommended dietary intake for tryptophan is 1.1g/day (Cavada et al., 2011), indicating that pasta samples with ≥ 25% germinated lima bean flour will be suitable to fulfil this minimum requirement. The biological value of proteins is determined by their essential amino acid, which are dependent on varying raw materials and their formulations (Messia et al., 2023).

Table 4 Amino Acid Composition (g/100 g protein) of Gluten-Free Pasta Produced from Pregelatinized Cocoyam Starch and Germinated Lima Beans Flour.

Amino Acid	A	B	C	D	E	F
Leucine	7.62	5.02	5.51	6.91	7.44	7.77
Lysine	2.63	2.57	2.94	3.08	3.74	3.85
Isoleucine	4.03	2.42	2.81	3.11	3.70	3.83
Phenylalanine	4.52	3.10	3.01	3.28	3.99	4.26
Tryptophan	1.29	0.74	0.87	1.05	1.26	1.28
Valine	4.27	2.81	3.10	3.07	3.97	4.15
Methionine	1.76	0.80	0.91	1.07	1.55	1.55
Threonine	3.41	2.30	2.33	2.72	3.25	3.61
Total Essential	29.53	19.76	21.48	24.29	28.90	30.30
Non-Essential						
Proline	3.45	2.54	2.44	2.94	3.25	3.45
Arginine	5.85	3.87	4.04	4.39	5.59	5.64
Tyrosine	3.61	2.75	2.58	2.75	3.27	3.40
Histidine	2.81	2.08	2.27	2.62	3.03	3.68
Cystine	1.82	1.21	1.39	1.76	2.06	2.82
Alanine	4.25	3.00	3.30	3.60	4.17	4.55
Glutamic acid	11.28	8.17	9.23	9.61	11.58	12.12
Glycine	3.97	2.61	3.02	3.30	4.37	4.61
Serine	4.16	2.62	3.00	3.24	3.81	4.32
Aspartic acid	8.38	5.05	5.46	7.01	8.03	8.22
Total Non-Essential	49.58	33.9	36.73	41.22	49.16	52.81
Total Amino acid	79.11	53.66	58.21	65.51	78.06	83.11

Keys A = 100% Wheat Flour Pasta, B = 100% Pregelatinized Cocoyam Starch Pasta., C = 87.5% Pregelatinized Cocoyam Starch and 12.5% Germinated Lima Beans Flour Pasta, D = 75% Pregelatinized Cocoyam Starch and 25% Germinated Lima Beans Flour Pasta, E= 62.5% Pregelatinized Cocoyam Starch and 37.5% Germinated Lima Beans Flour Pasta and F= 50% Pregelatinized Cocoyam Starch and 50% Germinated Lima Beans Flour Pasta

Pasta samples obtained from 50%GCS and 50%GLBF had higher total amino acid composition (83.11 g/100g protein) than the 100%WF pasta (79.11 g/ 100g protein), with higher levels of leucine, lysine, threonine (essential amino acid), histidine, cystine, alanine, glutamic acid, glycine and serine (non essential amino acid). The essential amino acids are important from a nutritional point of view since the body cannot synthesise them and should therefore be supplemented in the diet.

Table 5 Anti-nutrient Factors of Gluten Free Pasta Produced from Pregelatinized Cocoyam Starch, Germinated Lima Beans Flour and Xanthum Gum

Sample	Cyanide (mg/100g)	Oxalate (mg/100g)	Phytic Acid %	Tannin mg GAE/100g
A	0.191±0.002[a]	10.251±0.003[a]	0.01±0.06[a]	0.002±0.001[a]
B	0.465±0.062[a]	27.015±0.003[b]	0.21±0.10[b]	0.007±0.001[b]
C	1.176±0.000[b]	55.527±2.599[c]	1.66±0.01[c]	0.442±0.004[c]
D	1.105±0.031[b]	78.201±0.201[d]	1.51±0.19[c]	0.598±0.000[d]
E	1.199±0.031[b]	85.064±0.006[e]	1.44±0.95[c]	0.641±0.002[e]
F	1.034±0.001[b]	85.037±0.032[e]	1.32±0.00[c]	1.016±0.004[f]

Mean values with different superscripts within the same column are significantly different at 5% level. Keys A = 100% Wheat Flour Pasta, B = 100% Pregelatinized Cocoyam Starch. Pasta, C = 87.5% Pregelatinized Cocoyam Starch and 12.5% Germinated Lima Beans Flour Pasta, D = 75% Pregelatinized Cocoyam Starch and 25% Germinated Lima Beans Flour Pasta, E=62.5% Pregelatinized Cocoyam Starch and 37.5% Germinated Lima Beans Flour Pasta and F= 50% Pregelatinized Cocoyam Starch and 50% Germinated Lima Beans Flour Pasta

Anti-nutrient Factors of Gluten-Free Pasta Produced from Pregelatinized Cocoyam Starch and Germinated Lima Beans Flour.

The antinutrient factors of gluten-free pasta produced from pregelatinized cocoyam starch and germinated lima bean flour are presented in Table 5.

The cyanide content of gluten free pasta ranged from 0.191-1.199mg/100g with the samples significantly different from sample A (100% WF Pasta) and sample B (100% PCS Pasta) All the pasta samples are safe for human consumption as they were very low in cyanide content and do not exceed the WHO safe limit of 10mg/kg (Puspitojati *et al*., 2019). Germination of lima bean flour drastically reduced the cyanide content of gluten-free pasta, coupled with drying of pasta samples after extrusion. This is similar to the observation of Adebowale *et al*. (2016), who reported a decrease in cyanide content after initial processing of raw materials followed by extrusion. Processing has been proven to reduce the cyanide content of food as evident in cassava processing to various products that are safe to consume. High cyanide content of food leads to toxicity, causing paralysis and death (Onyenweaku, 2021).

Oxalate content of gluten-free pasta ranged from 10.251-85.064 mg/100g, with sample A (100% WF Pasta) having the lowest level and sample E having the highest content. The samples were significantly different ($p<0.05$) in terms of oxalate composition, showing an increase as levels of germinated lima bean flour increased. The range of oxalate content observed in this work is higher than that reported by Liebman and Okombo (2009) and Veena *et al.* (2019), who reported a range between 12.7 and 15.6 mg/100g for different brands of pasta and a range of 21.5-76.0 mg/100g for vegetable pasta. Oxalates are known to form insoluble salts with minerals like zinc, calcium, magnesium and iron, thereby making such minerals unavailable for utilisation in the body (Olaoye and Obidegwe, 2018). Oxalates, when present in large quantities in foods, chelate some metal ions and render them insoluble and hence, the metal ions cannot be absorbed in the intestine (Sanni *et al*., 2018). A diet high in oxalate increases the risk factors of renal calcium absorption and can lead to kidney stones (Gwer *et al*., 2020).

The phytic acid content of gluten-free pasta ranged from 0.01 - 1.66% with a significant difference ($p<0.05$) existing between the 100% WF samples and other samples. The 100% WF pasta had the lowest phytic acid content, while sample C (87.5% PCS & 12.5 GLBF Pasta) had the highest content. The level of phytic acid decreased as the level of lima bean flour increased. The trend observed is contrary to the report of Olopade and Ogundeji (2019) for acha/bambara pasta. Kamble *et al.*

(2019) equally reported a minute increase in phytic acid content of multi-grain pasta as levels of sorghum and millet incorporation in pasta increased. The phytic acid content of 100% Wheat flour pasta obtained in this study is slightly higher than that obtained by Olopade and Ogundeji (2019) for 100% wheat flour pasta. The phytic acid content observed for all the samples is lower than the permissible level of 250-500mg/100g dry mass, showing that the gluten-free pasta is safe for consumption (Ndidi *et al*., 2014). Phytic acid (phytates), are compounds that occur naturally and can be found in several grains and seeds. Phytates prevent the absorption of minerals such as iron, zinc, and calcium and the hydrolysis of starch (Bethapudi *et al*., 2023). Phytic acid can also bind with protein to configure a protein–mineral compound which inhibits the enzymatic degradation of protein (Jalgaonkar *et al*., 2018).

Tannin content of gluten-free pasta ranged from 0.002 - 1.016 mgGAE/100g, with sample A(100% WF Pasta) having the lowest content and sample F (50% PCS & 50% GLBF Pasta) having the highest content. The samples are significantly different ($p<0.05$) from each other. The tannin content observed in this work is lower compared to the values observed by Kamble *et al*. (2018) for wheat and multi-grain pasta, but it's similar to the values observed by Olapade and Ogundeji, (2019) for acha/bambara pasta. The tannin content observed for all the samples was lower than the permissible level of 20 mg/g dry mass, showing that the gluten-free pasta is safe for consumption (Ndidi *et al*., 2014). Tannins are soluble astringent, complex and phenolic compounds from plants that greatly influence the reduction of dietary protein digestibility (Olapade and Ogundeji, 2019). Tannins are known to have acerbic characteristics that can quicken the healing of wounds and prevent decay (Adebowale *et al*., 2017).

CONCLUSIONS

The study concluded that gluten-free pasta with good nutritional attributes can be developed using underutilised locally available food materials.

REFERENCES

Adebowale, A. A., Kareem, S. T., Sobukola, O. P., Adebisi, M. A., Obadina, A. O., Kajihausa, O. E., Adegunwa, M. O., Sanni, L. O. and Keith, T. (2017). Mineral and Antinutrient Content of High Quality Cassava -Tigernut Composite Flour Extruded Snack. *Journal of Food Processing and Preservation*. 41(5): 1-9

Amanyunose, A. A., Abiose, S. H., Adeniran, H. A. and Ikujenlola, A. V. (2021). Amino Acid Profiles and Chemical Constituents of Wheat-Cocoyam- Groundnut Biscuits. *Annals. Food Science and Technology,* 22 (2): 210-217

Arawande, J. O. and Ashogbon, A. O. (2019). Isolation and Characterization of Starch obtained from Cocoyam Cultivated at Akungba Akoko, Ondo State, Nigeria. *Nutritional Food Science International Journal*, 8(2):1-9

Arinola, S. O. (2019). Physicochemical Properties of Pregelatinized and Microwave Radiated White and Red Cocoyam (*Colocasia esculenta*) Starches. *Croatian Journal of Food Science and Technology,* 11(2):251-258

Arise A. K., Oriade, K. F, Asogwa, T. N. and Nwachukwu, I. (2022). Amino acid Profile, Physicochemical and Sensory Properties of Noodles Produced from Wheat-Bambara Protein Isolate. *Measurement:Food* https://doi.org/10.1016/j.meafoo.2021.100020

Ashogbon, A. O. (2017). Evaluation of Compositional and Some Physicochemical Properties of Bambara Groundnut and Cocoyam Starch Blends for Potential Industrial Applications. *American Journal of Food and Nutrition,* 5(2):62-68

Awolu, O. O., Omoba, O. S., Olawoye, O. and Dairo, M. (2017). Optimization of Production and Quality Evaluation of Maize-Based Snack Supplemented with Soybean and Tiger-Nut (*Cyperus esculenta)* Flour. *Food Science and Nutrition,* 5(1):3–13

Bala, A., Gul, K. and Riar, C. S. (2015). Functional and Sensory Properties of Cookies Prepared from Wheat Flour Supplemented with Cassava and Water Chestnut Flours. *Cogent Food and Agriculture*, 1:1019815

Bethapudi, S. S., Kaur, N., Khatri, B., Sharma, K., Thazhathethil, A. K., Saini, A., Bana, H. and Darlong, L. L. (2023). Effect of Various Pretreatments on Anti-Nutrients of Mango Seed Kernel and Its Utilization in Preparation of Pasta. *Journal of Food Chemistry and Nanotechnology,* 9(1):398-407

Bolarinwa, I. F., Oyesiji, O. O. (2021). Gluten Free Rice-Soy Pasta: Proximate Composition, Textural Properties and Sensory Attributes. *Heliyon*, 7:1-7

Bradbury, J. H. (1988). Chemical Composition of Tropical Root Crops *ASEAN Food Journal*, 4:3-13.

Bresciani, A., Pagani, M. A., & Marti, A. (2022). Pasta-Making Process: A Narrative Review on the Relation between Process Variables and Pasta Quality. *Foods*, 11(3), 256.

Cavada, E. S. R., Drago, R. J., González, R., Juan, J. E., Alaiz, M. and Vioque, J. (2011). Effects of the Addition of Wild Legumes (*Lathyrus annuus and Lathyrus clymenum*) on the Physical and Nutritional Properties of Extruded Products Based on Whole Corn and Brown Rice. *Food Chemistry*, 128:961-967.

Edet, E. A., Onwuka, G. I., Orieke, C. O. M. (2017). Nutritonal Properties of Composite Flour (Blends of Rice (*Oryza sativa*), Acha(*Digitariaexilis*) and Soybeans (*Glycine max*) and Sensory Properties of Noodles Produced from the Flour. *Asian Journal of Advances in Agricultural Research,* 1(2):1-13.

Farinde, E. O., Olanipekun; O. T. and Olasupo, R. B. (2018). Nutritional Composition and Antinutrients Content of Raw and Processed Lima Bean (*Phaseolus lunatus*). *Annals. Food Science and Technology,* 19 (20):250-264

Filip, S. and Vidrih, R. (2015). Protein Enriched Pasta for Low-Carbohydrate Diet. *Food Technology Biotechnology*, 53(3):298–306.

Fiorda, F. A., Soares, M. S., Da Silva. F. A. (2013). Microstructure, texture, and Colour of Gluten Free Pasta Made with Amaranth Flour, cassava Starch and Cassava Bagasse. *LWT Food Science and Technology*, 54(1):122-138

Fradinho, P., Soares, R., Niccolai A., Sousa, I. and Raymundo, A. (2020). *Psyllium* Husk Gel to Reinforce Structure of Gluten-Free Pasta? *LWT - Food Science and Technology*

Gopalakrishnan, J., Menon, R., Padmaja, G., Sajeev, M. S. and Moorthy, S. N. (2011). Nutritional and Functional Characteristics of Protein-Fortified Pasta from Sweet Potato. *Food and Nutrition Sciences*, 2:944-955

Gwer, J. H., Igbabul, B. D., and Ubwa, S. T. (2020). Micronutrient and Antinutritional Content of Weaning Food Produced from Blends of Millet, Soya beans and Moringa Oleifera Leaf Flour. *European Journal of Agriculture and Food Sciences*, 2(5):1-7

Hassan, L. G., and K. J. Umar. (2004). Proximate and Mineral Composition of Seeds and Pulp of *Parkia biglobosa*. *Niger. Journal of Basic and Applied Science,* 13:15–27.

Ibitoye, W. O., Afolabi, M. O., Otegbayo, B. O. and Akintola, A. C. (2012). Preliminary Studies of the Chemical Composition and Sensory Properties of Sweet Potato Starch-Wheat Flour Blends Noodles. *Nigeria Food Journal*,31(2):48-51.

Ikujenlola, A. V. (2016). High Nutrient Dense Gluten Free Pasta from Quality Protein Maize, Sorghum and Water Melon Seed Flours: Chemical Composition, Invitro Protein Digestibility and Sensory Properties. *Ife Journal of Technology,* 24(1):46-51

IPO (2021). International Pasta Organization. Available at: https://internationalpasta.org/ Accessed: 16 February 2021.

Jalgaonkar , K., Sunil, K. J. and| Manoj, K. M. (2018). Influence of Incorporating Defatted Soy Flour, Carrot Powder, Mango Peel Powder, and Moringa Leaves Powder on Quality Characteristics of Wheat Semolina-Pearl Millet Pasta. *Journal of Food Processing and Preservation*, 1-11

James, S., Nwokocha, L., James, Y., Abdulsalam, R. A., Amuga, S. J., Ibrahim, I. B., and Yakubu, C. M. (2017). Chemical Composition and Sensory Acceptability of Partially Gelatinised Pasta Produced rom Blends of Wheat, Bambara nut and Cassava Flours. *Journal of Tropical Agriculture, Food, Environment and Extension*, 16 (1):26 - 30

Kamble, D. B., Singh, R., Rani, S., Pal Kaur, B., Upadhyay, A. and Kumar, N. (2019).Optimization and Characterization of Antioxidant Potential, Invitro Protein Digestion and Structural Attributes of Microwave Processed Multigrain Pasta. *Journal of Food Processing and Preservation*, 1-11

Kaur, S., Singh, N., Sodhi, N. S., and Rana, J. C. (2009). Diversity in Properties of Seed and Flour of Kidney Bean Germplasm. *Food Chemistry*, 117:282-289

Liebman, M. and Okombo, J. (2009). Oxalate Content of Selected Pasta Products. *Journal of Food Composition and Analysis*, 22:254–256

Messia, M. C., Cuomo, F., Quiquero, M., Verardo, V. and Marconi, E. (2023). Assessment of Nutritional Value and Maillard Reaction in Different Gluten-Free Pasta, *Foods*, 12:1221.

Matthews, D. E. (2020). Review of Lysine Metabolism with a Focus on Humans. *In The Journal of Nutrition*, 150:2548S-2555S

Makhuvha, M. C., Laurie, S. and Mosala, M. (2024) Effect of Orange-Fleshed Sweet Potato (*Ipomoea batatas*)–Bambara groundnut (*Vigna subterranea*) Composite Flour on Quality Properties of Pasta. *Journal of Food Science*, 89: 7348–7359

Ndidi, U., Unekwuojo Ndidi, C., Abbas, O., Muhammad, A., Graham Billy, F. and Oche, O. (2014). Proximate, Antinutrients and Mineral Composition of Raw and Processed (Boiled and Roasted) *Sphenostylis stenocarpa* Seeds from Southern Kaduna, Northwest Nigeria. *Nutrition,* 2- 12

N'zi, K. P., Martial-Didier, A. K., N'guessan, K. F., Attchelouwa, K. C. and Tano, K. (2021). Effect of Spontaneous Fermentation Time on Physicochemical, Nutrient, Anti-nutrient and Microbiological Composition of Lima Bean (*Phaseolus lunatus*) Flour. *Journal of Applied Biosciences*, 162:16707 – 16725

Obiegbuna, J. E., Ishiwu, C. N., Akubor, P.I. and Igwe, E.C. (2014). Effect of Processing and Storage Relative Humidity on Selected Functional Properties of Cocoyam (*Colocasia esculenta*) Corm Flour. *Food Science and Quality Management*, 28:19 – 28

Okunade, O. A. and Arinola, S. O. (2021). Physicochemical Properties of Native and Heat Moisture Treated Starches of White and Red Cocoyam (*Colocasia esculenta*) Varieties *Turkish Journal of Agriculture Food Science and Technology*, 9(6):1195-1200

Oladebeye, A. O., Oshodi, A. A., Amoo, I. A., Karim, A. A. (2013). Functional, Thermal and Molecular Behaviours of Ozone-Oxidised cocoyam and Yam Starches. *Food Chemistry*, 141:1416-1423.

Olaoye, O. A. and Obidegwe, F. (2018). Chemical Composition, Anti-nutrients and Functional Properties of Composite Flours Formulated from Wheat and Three Cultivars of Cocoyam Corms (*Xanthosoma sagittifolium*) Commonly found in Nigeria. *Journal of Food Science and Nutrition*, 4:1 1-6

Olapade, A. A. and Ogundeji, E. Y. (2019). Evaluation of Extruded Pasta (Spaghetti) Prepared from Acha (*Digitaria exilis*) Enriched with Germinated Bambara Groundnut (*Vigna subterranean*). *Elixir Food Science*, 127:52617-52624

Onyenweaku, E. O., Ebai, P. A., Okonkwo, C. O. and Fila, W. A. (2021). Comparative Evaluation of the Nutrient and Anti-nutrient Contents of Edible Flours Consumed in Nigeria. *African Journal of Food Agriculture and Nutritional Development*, 21(1):17254-17271

Palavecino, M. P., Bustos, M. C., Alabı, M. B., Nicolazzi, M. S., Penci, M. C.and Ribotta, P . D. (2017). Effect of Ingredients on the Quality of Gluten-Free Sorghum Pasta. *Journal of Food Science*, 0:1-9

Puspitojati, E., Indrati, R., Cahyanto, M. N. and Marsono, Y. (2019) Jack bean as Tempe Ingredients: The Safety Study and Fate of Protein Against Gastrointestinal Enzymes *IOP Conference. Series. Earth* and *Environmental. Science*, 346

Putri, R. D. A., Rohma, K. A. N., Lestari, I. P., Bahlawan, Z. A. S., Astuti, W., Kusumaningrum, M., Yanuar, T. R., Nurzulcha, F. and Purwanti, D. (2022). Physical Characteristics and Nutritional Value of Cassava Analogue Rice with Fortified Protein Tempeh and the Addition of Xanthan Gum for Healthy Dieters. *Earth and Environmental Science*, 969:1-10

Sanni, A. A., Fadimu J. F. and Adebowale, L. O. (2018). Effect of Drying Methods on the Chemical Composition, Colour, Functional and Pasting Properties of Plantain (*Musa parasidiaca*) Flour. *Croatian Journal of Food Technology, Biotechnology and Nutrition*, 13(1-2):38–43

Seidu, K.T., Osundahunsi, O.F. and Osamudiamen, P.M. (2018). Nutrients Assessment of Some Lima Bean Varieties Grown in South West Nigeria. *International Food Research Journal*, 25(2):848-853

Sule, S., Oneh, A. J. and Agba, I. M. (2019). Effect of Carrot Powder Incorporation on the Quality of Pasta. *MOJ Food Processing and Technology*, 7(3):99-103

Thatsanasuwan, N., Duangjai, A., Suttirak, P. and Phanthurat, N. (2023). Proximate Composition and Sensory Attributes of Gluten-Free Pasta Made from Jackfruit Seeds. *Functional Foods in Health and Disease*, 13(1):11-21

Veena, U. K, Shobha, D., Neena, J., Darshan, M. B. and Benherlal, P.S. (2022). Spirulina Enriched Gluten Free Quality Protein Maize (QPM) Pasta as Functional Food. *Emirates Journal of Food and Agriculture*, 34(4):279-288

Vellore, S. T., Jayaprakash, H. M., Sai Srinivas, K. and Venkatesh, M. (2023). Proximate Composition of Different Flours Used in the Formulation of Pasta. *International Research Journal of Modernization in Engineering Technology and Science*, 5(9):1486-1490

Yadav, D.N., Sharma, M., Chikara, N., Anand, T. and Bansal, S. (2014). Quality Characteristics of Vegetable-Blended Wheat Pearl Millet Composite Pasta. *Agric. Research*, 3:263-27.