The Annals of the University Dunarea de Jos of Galati
Fascicle VI – Food Technology (2024), 48(1), 131-146

ORIGINAL RESEARCH PAPER

QUALITY ATTRIBUTES OF PASTA PRODUCED FROM CASSAVA STARCH, EGG POWDER AND SPICED WITH GINGER FLOUR

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Received on 29 May 2024
Revised on 16 July 2024

Abstract

Protein malnutrition stands out as the most serious nutrition deficiency problem in infants and young children in developing countries. This study investigated the quality attributes of pasta produced from a blend of cassava starch, egg powder, and ginger flour. D-optimal mixture design approach was used for the formulation of the flour blends, resulting into fourteen experimental runs. Pasta was manufactured from this blend via cold extrusion process and was analyzed for proximate composition, colour, antioxidant, cooking and sensory properties using standard methods. The crude protein and total carbohydrate contents of the pasta ranged from 4.15-8.40% and 81.29-86.28%, respectively. Significant differences ($p<0.05$) were observed, from a statistical viewpoint, in the colour and antioxidant properties. The cooking properties ranged from 8.45-20.07min, 2.88-20.00%, 1.06-8.47% and 86.50-468.74% for cooking time, cooking loss, expansion ratio and water absorption capacity, respectively. However, pasta produced from cassava starch, egg powder and ginger flour were all preferred by the panelists in terms of aroma, colour, texture and appearance, but pasta from the control sample had the highest overall acceptability. The study showed that pasta from cassava starch, egg powder and ginger flour could be useful to combat malnutrition and nutritional deficiencies in developing countries.

Keywords: pasta, cassava starch, egg powder, ginger flour

Introduction

The main process of manufacturing pasta is making an unleavened dough with eggs, water, and durum wheat, then extruding it into different forms before boiling it

https://doi.org/10.35219/foodtechnology.2024.1.08

(Nilusha *et al*., 2019). Renowned globally for its convenience, adaptability, and nutritional value compared to other extruded products (Agbaeze *et al*., 2020), pasta has witnessed increased consumption in sub-Saharan countries like Nigeria, because of the propensity for quick food, population increase, and rapid urbanization. However, Nigeria has socioeconomic obstacles that make it difficult to cultivate wheat flour on a wide scale for the manufacturing of pasta. Wheat flour, the main ingredient in pasta, is not abundant in Nigeria due to the country's tropical climate conditions. Moreover, wheat is known to be deficient in lysine and threonine and is linked to the onset of celiac disease, which is caused by eating gluten from wheat grains (Serwaa *et al*., 2021; Oke *et al*., 2023). Several full or partial substitutes for wheat flour have been developed in an effort to lessen these issues. Reducing the amount of wheat imported and promoting the use of substitute ingredients such as egg powder, cassava starch, and ginger flour in place of wheat flour are the main objectives.

Cassava (*Manihot esculenta*) is classified within the *Euphorbiaceae* family (Agbaeze *et al*., 2020). Known for having a mild flavor, cassava flour is unlikely to change a product's flavor character. In regions susceptible to drought, famine, and civil unrest, cassava plays a vital role, serving as a primary source of dietary energy in lowland tropics and sub-humid regions (Burns *et al*., 2010; Kayode, 2015). Despite its widespread availability and affordability, cassava's usage is restricted due to its notably low protein content, which has implications for malnutrition. Cassava starch, obtained from the tuberous roots of the cassava plant, primarily consists of amylose and amylopectin, contributing to its thickening and gelling properties (Berski *et al.*, 2011; Ma'aruf and Abdul, 2020; Asare and Daufor, 2024). It is a viable option for individuals with gluten intolerance, offering the opportunity to develop gluten-free pasta variants with distinctive textures and properties. Moreover, its utilization contributes to the sustainability of the food industry by diversifying starch sources and reducing reliance on wheat.

Eggs, recognized for their abundant nutritional content and versatile culinary applications, have attracted considerable attention as a promising ingredient in a wide array of food formulations (Oso *et al*., 2023). With their rich protein content, essential vitamins (including vitamin A, D, and B-complex vitamins), minerals (including iron and zinc), and bioactive compounds (like choline and lutein), eggs present an appealing opportunity to amplify the nutritional quality of foods (Anton *et al.*, 2019). Additionally, their distinctive flavor profiles, ranging from savory to subtly sweet, contribute to a pleasurable taste experience when incorporated into culinary creations. Beyond their role as a source of high-quality protein, eggs also offer emulsification properties (Koç *et al*., 2012), making them a valuable ingredient in various food formulations, including pasta.

The fragrant taste characteristic of ginger, which comes from the rhizome of the Zingiber officinale plant, is well-known (Ozkur *et al*., 2022). Possessing a distinctive spicy flavor, ginger enhances the sensory experience of food products and is a popular digestive aid (Bijaya, 2018). Rich in bioactive compounds, ginger has been extensively researched for its antioxidant, anti-inflammatory, and antimicrobial properties (Ajanaku *et al.*, 2022), making it a widely utilized spice in various culinary traditions. Incorporating ginger into pasta not only introduces a new dimension of flavor that can appeal to consumers seeking innovative and enticing food options but also offers potential health benefits.

The extrusion process is extensively utilized in the food industry for the production of various products, including pasta. This process involves applying heat, pressure, and shear to starch-based dough, resulting in the creation of a distinct product with unique properties (Agbaeze *et al*., 2020). The quality benchmarks of pasta are crucial determinants of consumer acceptance and marketability. Therefore, it is imperative to explore the quality standards of pasta derived from cassava starch and egg powder, enhanced with ginger, to ensure its acceptability, and offer a new option for individuals with gluten intolerance. The preparation of pasta from cassava starch may yield products with low protein and antioxidant content. Consequently, augmenting it with ingredients rich in protein and antioxidants, such as egg powder and ginger flour, could enhance its nutritional profile and address nutrient deficiencies associated with pasta consumption. Therefore, the purpose of this research was to evaluate the qualitative characteristics of pasta made from mixes of egg powder and cassava starch that have been enhanced with ginger flour.

Materials and Methods

Materials

Cassava starch was acquired from Harvest Feed Limited, Ajura, Abeokuta. Fresh eggs and ginger were purchased from a retail supermarket at Eleweran Market, Abeokuta. Cold extruder machine was obtained from the Food Processing Laboratory, Federal University of Agriculture Abeokuta, Nigeria.

Processing of egg powder

The powdered egg was made using the modified procedure of Awoyale *et al*. (2010). The fresh eggs are washed to ensure cleanliness and remove any surface contaminants. Subsequently, the eggs are de-shelled to obtain liquid egg contents, separating the yolks and whites. The egg white was then homogenized to create a uniform mixture. A careful treatment with 2 drops of a 5% peroxide solution was applied to the homogenized egg white, serving various purposes such as sanitation or preservation. The treated egg white was dried at a controlled temperature of 50°C for 9 h to remove moisture and convert it into a powder form. Following the drying process, the egg powder undergoes cooling to reach room temperature. Subsequently, it undergoes milling to attain the desired particle size, followed by sieving using a mesh size of 600 micrometers, to achieve a finely powdered and uniformly textured egg product, suitable for immediate use or packaging.

Processing of ginger flour

The method described by Adegoke *et al*. (2000) for the preparation of ginger flour was followed. Initially, the ginger roots underwent careful sorting and washing to eliminate any soil and foreign particles. After peeling and slicing it thinly, the ginger was spread out evenly on trays and dried in an oven (GALLENKAMP SG3-08-169, Leicester, UK) at 70 °C for 48 h. After that, the ginger powder was ground up in a blender and the resulting flour was sieved through a 450-micrometer screen before being sealed in an airtight receptacle.

Blend formulation of pasta made from cassava starch, egg powder and ginger flour

D-optimal mixture design of Design expert version 6.0.8 (Stat Ease, Minneapolis, MN) was used to generate a total of fourteen experimental runs as illustrated in Table 1, while commercially sold pasta serve as control samples.

Table 1. Design outlay showing varying inclusion of cassava starch (CS), egg powder (EP) and ginger flour (GF)

Samples	CS	EP	GF
$CSEPGF_1$	63.33	30.83	5.83
$CSEPGF_2$	62.50	32.50	5.00
$CSEPGF_3$	65.00	30.00	5.00
$CSEPGF_4$	60.00	32.50	7.50
$CSEPGF_5$	60.00	35.00	5.00
$CSEPGF_6$	60.83	30.53	8.33
$CSEPGF_7$	60.00	30.00	10.00
$CSEPGF_8$	61.67	31.67	6.67
$CSEPGF_9$	60.00	32.50	7.50
$CSEPGF_{10}$	60.83	33.33	5.83
$CSEPGF_{11}$	65.00	30.00	5.00
$CSEPGF_{12}$	62.50	30.00	7.50
$CSEPGF_{13}$	60.00	30.00	10.00
$CSEPGF_{14}$	60.00	35.00	5.00

Pasta preparation

The pasta preparation method outlined by Nilusha *et al*. (2019) and Oke *et al*. (2023) was adhered to, utilizing the cold extrusion process. The flour blends consisting of cassava starch, egg powder, and ginger were thoroughly mixed with an addition of 60 ml of water to ensure uniformity. The mixture was compounded and allowed to rest before undergoing kneading and pressing to achieve a smooth texture. The dough was then inserted into a pasta maker's metal extruder attachment (LM-20, Stainless Steel Pressure Surface Machine, Jinan, China), which had an adjustable die, and cut, coming out in the form of thin strands. After that, the pasta was dried in a hot air oven (GALLENKAMP SG3-08-169, Leicester, UK) set at 50°C for 4-5 h, in order to achieve a moisture content of 5-7%. After being properly labeled and wrapped in an airtight container, the dry pasta was then kept in storage.

Proximate Analysis

The moisture, crude fat, total ash, crude fibre and crude protein contents were determined using the AOAC methods 950.46B, 920.39, 942.05B, 978.10 and 990.03, respectively (AOAC, 2003). The total carbohydrate content was calculated by subtracting the sum of % moisture content, % crude fat, % total ash, % crude fibre and % crude protein from 100%.

Physical and antioxidant properties of pasta

Colour properties

The pasta's colour properties were assessed using a Minolta chroma meter (CR- 410, Marunouchi, Chiyoda, Japan), in accordance with Feili *et al*. (2013). The Minolta chroma meter was calibrated by first covering a zero calibration mask, followed by a white calibration plate. Pasta samples were first placed on the Petri dish, and colour measurements were performed immediately. The colour properties such as lightness (L*), redness (a*) and yellowness (b*) were recorded.

Antioxidant properties

The 2,2-dipheny1-1-picrylhdrazyl (DPPH) radical scavenging activity was assessed using a technique outlined by Idowu *et al*. (2017). A volume of 1 ml of DPPH was added to each sample (4ml), followed by incubation at room temperature for 30 min. The absorbance was recorded at 520 nm using Spectrophotometer (Milton Spectronic 1201, Ontario, Canada). Percent inhibition was calculated using the following formula:

$$\text{Reduction of absorbance (\%)} = [(AB - AA) / AB] \times 100 \qquad (1)$$

$$AB = \text{Absorbance of blank sample } (t = 0 \text{ min}) \qquad (2)$$

$$AA = \text{Absorbance of tested extract solution } (t = 30 \text{ min}) \qquad (3)$$

Cooking properties of pasta

Cooking time

According to the standards set by the American Association of Clinical Chemists International (AACC 2010), the ideal cooking time for the pasta was as long as it took for the opaque center to vanish when it was gently pushed between two glass plates. An amount of 10g of pasta sample was added to a beaker containing 120 ml of boiling distilled water and timing started. The samples were removed from the boiling water at 30 s intervals and were placed inside water at a room temperature (26 ± 2 ºC). Five pieces of samples were squeezed between two pieces of glass until the white centre core of 3 pieces of samples disappeared; the timer was stopped and recorded as cooking time.

Cooking loss

The dry matter losses during cooking were computed using the techniques described by Oke *et al*. (2024). Pasta samples were cooked in distilled water in a beaker until they were tender. Afterward, they were drained and given a 30-second blast of cold water. The average weight of the residues in the glass beaker was calculated by measuring the volume gained after obtaining the cooking and rinse water. The weight of the residual was multiplied by 100 to get the percentage of cooking loss.

Expansion ratio

The expansion ratio was assessed in accordance with the technique explained by Alvarez-Martinez *et al*. (1988) and Fan *et al*. (1996). The ratio of the diameter of the pasta sample to the diameter of die was used to express the expansion of the pasta. Six replicates of pasta samples were randomly selected, and the average was taken.

$$\text{Expansion ratio} = \frac{\text{Diameter of pasta}}{\text{Diameter of the die hole}} \quad (4)$$

Water absorption capacity

The explanation stated by American Association of Clinical Chemists International (AACC 2010) was adopted. An amount of 20 g of pasta was cooked in 500 ml of boiling distilled water until the white core of the noodles disappeared, and a colander was used to separate the pasta from the water. The pasta was then transferred to a filter paper, drained for 5 min at room temperature and then weighed (AACC international approved method, 2010).

$$\text{Water } absorption\ capacity = \frac{weight\ of cooked\ pasta - weight\ of\ uncooked\ pasta}{weight\ of\ un\ cooked\ pasta} \times 100 \quad (5)$$

Sensory properties of pasta

Clearance was approved by the ethical committee of the Department of Food Science and Technology, Federal University of Agriculture, Abeokuta (FUNAAB) for sensory evaluation. Panelists were not coerced into participating, full information about the study requirements and risks were explained to the participants as a group, and the participants had the ability to pull out from the sensory evaluation at any time. Sensory evaluation was carried out immediately after the cold extrusion process of the pasta samples, using sixty semi-trained panelists consisting of Staff and Students of the Department of Food Science and Technology, FUNAAB. The panelists were asked to score the pasta samples using the procedure outlined by Iwe (2002). A 9-point hedonic scale, with 1 denoting dislike extremely, 5 denoting neither like nor dislike and 9 denoting like extremely. Pasta attributes such as aroma, colour, texture, appearance and overall acceptance were assessed.

Statistical analysis

Each experiment was carried out in triplicates, SPSS version 21.0 was used to ascertain the differences in the experimental data, and Duncan's multiple range test was employed to assess the differences between the mean values at $p<0.05$.

Results and Discussion

Composition of pasta ingredients

Table 2 shows the composition of flours used in this study. Significant ($p<0.05$) differences across the nutrients were observed. The moisture content of the ingredients (cassava starch, egg powder and ginger flour) was observed to have mean values of 14.30%, 8.77% and 5.08%, respectively. The crude fat content for cassava starch, egg powder and ginger flour was 0.61, 5.63, and 6.55%, respectively, while the total ash content ranged from 0.04 to 4.45%, with cassava starch having the lowest value. The crude fibre content for cassava starch and ginger flour was 0.06 and 5.80%, while crude fibre content was absent in egg powder. The crude protein content ranged from 0.21-68.29%, with cassava starch having the lowest. The total carbohydrate content ranged from 11.54-84.79% with cassava starch having the highest value.

Table 2. Proximate composition of flour ingredient

Composition	CS	EP	GF
Moisture content (%)	14.30±0.28[c]	8.77±0.03[b]	5.08±0.03[a]
Crude Fat (%)	0.61±0.04[a]	5.63±0.04[b]	6.55±0.35[c]
Total Ash (%)	0.04±0.01[a]	5.77±0.05[c]	4.45±0.21[b]
Crude Fibre (%)	0.06±0.01[a]	0.00±0.00[a]	5.08±0.04[b]
Crude Protein (%)	0.21±0.01[a]	68.29±0.05[c]	8.20±0.14[b]
Total Carbohydrate Content (%)	84.79±0.33[c]	11.54±0.16[a]	70.64±0.35[b]

Mean ± standard deviation with different superscripts along the column are significantly different at ($p<0.05$), CS - Cassava Starch, EP - Egg Powder and GL – Ginger Flour,

Proximate composition of pasta

Table 3 shows the approximate contents of the pasta made using egg powder, ginger, and cassava starch. There were notable variations ($p<0.05$) seen in the pasta's moisture content. Moisture levels in the pasta ranged from 4.16% to 8.86%. The pasta formulation comprising 60% cassava starch, 30% egg powder, and 10% ginger flour demonstrated the least moisture content, contrasting with the control sample, which exhibited the highest moisture content. It is noteworthy that maintaining the moisture content below 13% is pivotal for prolonging the shelf life of food products (Ojo *et al*., 2017). Hence, the observed low moisture content in the pasta formulated with cassava starch, egg powder, and ginger in this investigation is anticipated to bolster its storage stability by mitigating the risk of mold proliferation and other undesirable biochemical reactions (Nilusha *et al*., 2019).

The pasta's crude fat level varied from 0.30% to 1.14%. The control sample was the one with the least amount of fat, while the combination sample of 60% cassava starch, 30% egg powder, and 10% ginger flour had the greatest fat content. These discoveries aligned with the results of Lawal *et al*. (2021), who described yellow cassava pasta fortified with amaranth and low in fat content. The low-fat content (<2%) of cassava flour indicates a low propensity to create amylose- or starch-lipid complexes, which is crucial for a variety of foods. Moreover, the creation of low-fat food formulations could be aided by their low-fat ingredients. The crude fibre contents of the pasta are lower than 3% (Table 3). According to the results, the highest fibre contents were observed in the samples with the blend of 65% cassava starch, 30% egg powder and 5% ginger flour and lowest fiber content was observed in the control sample which had 0%. This result has similar observations to those of Fernandez *et al*. (2017) for cassava-based pasta. Fibre, as described by Marques *et al*. (2017), is composed of various polysaccharides including cellulose, hemicellulose, pectins, gums, mucilages, and lignins. These components are abundant in foods such as grains, cereals, roots, leaves, and fruits. In the colon, they undergo partial digestion by bacteria or are excreted unchanged in the feces. Regular consumption of dietary fiber sources is vital for maintaining overall health and preventing a range of chronic, non-communicable, degenerative diseases, as highlighted by Slavin (2005).

Table 3. Proximate composition of pasta produced from cassava starch egg powder and ginger flour

Samples	Moisture Content (%)	Crude Fat (%)	Total Ash (%)	Crude Fibre (%)	Crude Protein, (%)	Total Carbohydrate Content (%)
$CSEPGF_1$	7.36±0.05^d	0.74±0.03^e	0.74±0.02^e	0.17±0.01^{de}	6.08±0.04^f	84.58±0.74^d
$CSEPGF_2$	6.80±0.03^f	0.91±0.03^c	0.87±0.03^c	0.11±0.01^c	6.99±0.03^d	84.32±0.04^d
$CSEPGF_3$	7.11±0.05^e	0.83±0.02^d	0.81±0.02^d	0.09±0.01^{cd}	6.63±0.05^e	84.56±0.01^d
$CSEPGF_4$	5.20±0.04^g	1.01±0.03^b	0.93±0.02^c	0.16±0.02^b	7.25±0.05^c	85.47±0.08^{bc}
$CSEPGF_5$	4.20±0.05^h	1.12±0.01^a	1.03±0.03^b	0.20±0.02^a	7.63±0.07^b	85.83±0.08^{ab}
$CSEPGF_6$	8.31±0.04^b	0.64±0.02^f	0.59±0.03^f	0.03±0.01^{fg}	4.56±0.07^h	86.28±0.01^a
$CSEPGF_7$	7.75±0.16^c	0.69±0.03^{ef}	0.68±0.02^e	0.05±0.01^{ef}	5.95±0.03^g	84.89±0.18^{cd}
$CSEPGF_8$	7.36±0.05^d	0.74±0.03^e	0.74±0.02^e	0.07±0.01^{de}	6.08±0.04^f	84.58±0.74^d
$CSEPGF_9$	4.19±0.05^h	1.12±0.01^a	1.03±0.03^b	0.20±0.02^a	7.63±0.07^b	85.83±0.08^{ab}
$CSEPGF_{10}$	7.75±0.16^c	0.69±0.03^{ef}	0.68±0.02^e	0.22±0.01^{ef}	5.95±0.03^g	84.89±0.18^{cd}
$CSEPGF_{11}$	5.20±0.04^g	1.01±0.03^b	0.93±0.02^c	0.16±0.02^b	7.25±0.05^c	85.47±0.08^{bc}
$CSEPGF_{12}$	4.18±0.05^h	1.14±0.01^a	1.01±0.03^b	0.15±0.01^{ef}	5.85±0.03^g	85.73±0.08^{ab}
$CSEPGF_{13}$	5.20±0.04^g	0.62±0.02^f	0.55±0.03^f	0.04±0.01^{fg}	4.15±0.07^h	86.25±0.01^a
$CSEPGF_{14}$	4.16±0.05^h	1.10±0.01^a	1.02±0.03^b	0.16±0.01^{ef}	5.87±0.03^g	85.83±0.08^{ab}
Control	8.86±0.05^a	0.30±0.02^g	1.17±0.04^a	0.00±0.00^g	8.40±0.02^a	81.29±0.08^e

*Mean ± standard deviation with different superscripts along the column are significantly different at ($p<0.05$) CHO -Total Carbohydrate, CS - Cassava Starch, EP - Egg Powder and GL – Ginger Flour, Control: Commercial Pasta

The total ash content in the pasta samples reflects the inorganic mineral content. As illustrated in Table 2, the ash content varied from 0.55% in the sample containing 62.5% cassava starch, 30% egg powder, and 7.5% ginger flour to 1.17% in the reference sample. These findings align with similar observations by Aluyor and Okwundu, (2015) who reported ash contents of 1.0% for whole-cassava based pasta. Additionally, the total ash content of cassava starch is comparable to that of commercial wheat flour.

A vital macronutrient, protein, serves as a crucial component in food compositions. The sample with 62.50% cassava starch, 30% egg powder, and 7.5% ginger had the lowest protein level, while the control sample had the greatest protein content, with a range of 4.15 to 8.40%. Notably, an increase in the egg powder ratio correlated with higher protein content. This trend closely resembled the findings reported by Fernandez *et al*. (2017) for the production of cassava-based pasta. However, the protein content of the analyzed samples was notably lower than that of the reference one (commercially sold pasta). This could be due to the high level of protein content in the control sample. The total carbohydrate content in the samples ranged from 81.29 to 86.28%, illustrated in Table 3. The reference sample possessed the lowest carbohydrate content, while the pasta produced from a blend of 65% cassava starch, 30% egg powder, and 5% ginger had the highest carbohydrate composition. Carbohydrates are a notable feature of cassava, making up to 65–70% of its makeup (Ogungbemi *et al*., 2022). It was observed that the pasta exhibits high carbohydrate content, indicating that cassava starch significantly contributes to the energy content of the pasta.

Colour and antioxidant properties of pasta

The colour and antioxidant properties are presented in Table 4. Pasta quality is significantly influenced by its colour, which serves as an indicator of chemical reactions and cooking degradation (Shere *et al*., 2018). The lightness of the pasta ranged from 19.89 to 35.64. Notably, the pasta composed of 65% cassava starch, 30% egg powder, and 5% ginger flour exhibited the lowest lightness value, while the control sample displayed the highest lightness. The lightness values in this investigation were comparable to those published by Susanna *et al*. (2013) for gluten-free pasta manufactured from high-protein flours, but they were noticeably lower than the range of 52.7 to 76.4 reported by Shobha *et al*. (2021) for pasta supplemented with drumstick. It was observed that there was a decrease in the lightness of the pasta samples as the ginger flour and egg powder contents increase. This could be due to the denaturation of proteins, causing changes in pasta structure and opacity. As the pasta cooks, the starch absorbs water. Consequently, the pasta swells and becomes more translucent, reducing the overall lightness of the pasta (Purnima *et al*., 2012). The redness of the pasta made from cassava starch, egg powder, and ginger flour ranged from 3.81 to 4.81, with the control sample displaying the lowest redness value, while the pasta comprising of 61.67% cassava starch, 31.67% egg powder, and 6.67% ginger flour showed the highest redness. Notably, these redness values were significantly different from the range of 0.5 to 1.2 reported by Shobha *et al*. (2021) for pasta made with 100% wheat flour, but somewhat similar to the range of 2.1 to 5.51 reported by Petitot and Micard (2010) for pasta with split pea and faba bean flours.

The yellowness parameter in the pasta exhibited a ranged from 9.92 to 28.28. Notably, the pasta made from cassava starch, egg powder, and ginger flour displayed the lowest yellowness value, while the reference sample showed the highest yellowness value. The yellowness of the pasta produced from cassava starch, egg powder and ginger flour exhibited a slight similarity to the range of 15.6 to 18.8 reported by Acosta *et al*. (2018) for pasta with added cassava bran and hydrocolloid. The high yellowness value observed in this study may be attributed to the yellow colour of the egg yolk used in the formulations.

The DPPH assay is a widely acknowledged approach for evaluating antioxidant properties in food items (Baliyan *et al*., 2022). In this investigation, the DPPH values of the pasta ranged from 0.00 to 17.55%. Interestingly, the pasta consisting of 60.83% cassava starch, 30.53% egg powder and 8.33% ginger flour displayed the highest DPPH value, while the control sample exhibited no DPPH content. It was notable that the DPPH value of the pasta increased as the ratio of ginger in the formulation increased. The presence of DPPH content in the pasta produced from cassava starch, egg powder, and ginger flour could be attributed to the inclusion of ginger as an ingredient in the formulation.

Table 4. Colour and antioxidant properties of pasta produced from cassava starch, egg powder and ginger flour

Samples	L*	a*	b*	DPPH (%)
CSEPGF$_1$	24.09±0.48^{c}	4.75±0.03^{ab}	13.17±0.00^{b}	10.92±0.06^{e}
CSEPGF$_2$	22.04±0.08^{de}	4.81±0.04^{a}	11.67±0.05^{c}	13.68±0.02^{c}
CSEPGF$_3$	22.18±0.08^{de}	4.69±0.03^{bc}	11.52±0.07^{c}	11.18±0.05^{d}
CSEPGF$_4$	21.73±0.01^{e}	4.54±0.01^{ef}	11.11±0.01^{d}	17.55±0.10^{b}
CSEPGF$_5$	19.90±0.07^{f}	4.60±0.00^{de}	9.92±0.05^{e}	10.24±0.04^{a}
CSEPGF$_6$	26.67±0.14^{b}	4.64±0.01^{cd}	13.22±0.09^{b}	9.49±0.04^{g}
CSEPGF$_7$	22.38±0.01^{d}	4.52±0.03^{f}	11.61±0.09^{c}	10.23±0.03^{f}
CSEPGF$_8$	24.08±0.48^{c}	4.76±0.03^{ab}	13.15±0.00^{b}	10.90±0.06^{e}
CSEPGF$_9$	19.89±0.07^{f}	4.66±0.01^{cd}	11.59±0.09^{c}	10.23±0.03^{f}
CSEPGF$_{10}$	21.71±0.01^{e}	4.52±0.01^{ef}	11.12±0.01^{d}	11.20±0.05^{d}
CSEPGF$_{11}$	22.04±0.08^{de}	4.80±0.04^{a}	11.66±0.05^{c}	13.71±0.02^{c}
CSEPGF$_{12}$	19.90±0.07^{f}	4.60±0.00^{de}	11.61±0.09^{c}	10.23±0.03^{f}
CSEPGF$_{13}$	26.67±0.14^{b}	4.64±0.01^{cd}	13.22±0.09^{b}	17.55±0.10^{b}
CSEPGF$_{14}$	21.04±0.08^{de}	4.80±0.04^{a}	11.09±0.01^{d}	18.85±0.10^{b}
Control	35.64±0.16^{a}	3.81±0.06^{g}	28.28±0.06^{a}	0.00±0.00^{h}

Mean ± standard deviation with different superscripts along the column are significantly different at ($p<0.05$), L- Lightness, a*- Redness, b*- yellowness, DPPH- 2,2-Diphenyl-1-picrylhydrazyl, CS - Cassava Starch, EP - Egg Powder and GL – Ginger Flour, Control: Commercial Pasta

Cooking properties of pasta

The cooking properties are presented in Table 5. In this study, the cooking time of the pasta samples ranged from 8.45 to 20.07 min, with the control sample and the sample comprising 60% cassava starch, 35% egg powder and 5% ginger flour exhibiting the minimum and maximum values, respectively. The control sample and the other samples had significantly different ($p<0.05$) cooking times, according to the statistical analysis.

Notably, it was noticed that pasta prepared from cassava starch, egg powder and ginger flour required shorter cooking time compared to the control sample, which is commercially marketed pasta manufactured with wheat. Because there is less gluten in the mixture, the dough has weaker properties and takes less time to cook (Omeire *et al*., 2014).

These results are consistent with those reported by Adebayo *et al*. (2018), who observed a parallel reduction in cooking time in instant noodles upon substituting gluten-rich flour with non-gluten-rich flour in their *Musa spp*-wheat composite.

The cooking loss of the pasta samples in this investigation showed a significant difference ($p<0.05$) between the samples manufactured from egg powder, ginger flour and cassava starch and the control sample. Notably, the cooking loss values ranged from 2.88% to 20.00% (Table 5), with the control sample demonstrating the lowest cooking loss. However, it's important to note that the cooking loss obtained in this study is notably higher than the range of 5.51% to 7.65% reported by Adebayo *et al*. (2018) in their study on instant noodles produced from *Musa spp*-wheat composites. The higher cooking loss observed in our study can be attributed to several factors, such as the protein content and the absence of gluten in the starch. The high cooking loss value may be linked to the inadequate formation of protein complexes during cooking. This phenomenon could result from the protein content in the pasta formulation or from the lack of gluten, which typically plays a significant role in forming protein-starch complexes (Omeire *et al*., 2014). Higher cooking loss may have resulted from a poorer protein-starch interaction during cooking caused by the gluten-free cassava starch and egg powder-based pasta. This finding underscores the importance of ingredient composition, particularly the presence or absence of gluten, in affecting the cooking properties of pasta, and ultimately influencing its cooking loss.

The expansion ratio of the pasta prepared from the blend of cassava starch, egg powder, and ginger flour displayed a range from 1.06% to 8.47%. Specifically, the pasta comprised of 60% cassava starch, 30% egg powder and 10% ginger flour exhibited the highest expansion ratio, while the control sample showed the lowest expansion ratio value. The expansion ratio serves as a pivotal parameter extensively utilized in evaluating extruded snacks (Alam *et al*., 2016). Remarkably, the expansion ratio range observed in our investigation strongly differed from the values of 168.48-190.87% reported by Sholichah *et al*. (2021) for gluten-free pasta products derived from modified cassava, rice flour, and corn flour enriched with seaweed. Our study revealed an increase in expansion ratio with the inclusion of cassava starch, likely attributable to the unique starch properties of cassava and its gelatinization capability.

Table 5. Cooking properties of pasta made from cassava starch, egg powder and ginger flour

Samples	Cooking Time, (Mins)	Cooking loss, (g)	Expansion ratio, (%)	WAC, (%)
$CSEPGF_1$	16.10 ± 1.41^a	10.00 ± 1.41^c	5.18 ± 0.10^d	409.24 ± 0.06^e
$CSEPGF_2$	16.48 ± 1.41^a	15.00 ± 1.41^b	5.35 ± 0.07^{cd}	451.64 ± 0.04^c
$CSEPGF_3$	16.00 ± 1.41^a	10.67 ± 1.41^b	8.37 ± 0.57^a	426.39 ± 0.04^d
$CSEPGF_4$	10.67 ± 1.41^b	20.00 ± 1.41^a	6.22 ± 0.33^{bc}	468.74 ± 0.04^b
$CSEPGF_5$	12.42 ± 1.41^b	10.00 ± 1.41^c	4.58 ± 0.01^d	458.65 ± 0.01^d
$CSEPGF_6$	12.17 ± 1.41^b	5.00 ± 1.41^d	6.37 ± 0.79^b	391.35 ± 0.16^g
$CSEPGF_7$	11.17 ± 1.41^b	10.00 ± 1.41^c	8.47 ± 0.36^b	405.04 ± 0.04^f
$CSEPGF_8$	10.62 ± 1.41^b	10.67 ± 1.41^b	8.37 ± 0.57^a	454.74 ± 0.04^b
$CSEPGF_9$	12.42 ± 1.41^b	20.00 ± 1.41^a	4.58 ± 0.01^d	458.63 ± 0.01^d
$CSEPGF_{10}$	16.00 ± 1.41^a	10.67 ± 1.41^b	8.37 ± 0.57^a	426.39 ± 0.04^d
$CSEPGF_{11}$	10.67 ± 1.41^b	20.00 ± 1.41^a	6.22 ± 0.33^{bc}	468.74 ± 0.04^b
$CSEPGF_{12}$	10.62 ± 1.41^b	10.67 ± 1.41^b	8.37 ± 0.57^a	454.74 ± 0.04^b
$CSEPGF_{13}$	16.48 ± 1.41^a	15.00 ± 1.41^b	8.47 ± 0.07^{cd}	451.64 ± 0.04^c
$CSEPGF_{14}$	20.07 ± 1.41^b	5.00 ± 1.41^d	1.14 ± 0.01^e	134.07 ± 0.03^h
Control	8.45 ± 0.21^b	2.88 ± 0.04^d	1.06 ± 0.02^a	86.50 ± 0.12^a

*Mean ± standard deviation with different superscripts along the column are significantly different at ($p<0.05$); CS - Cassava Starch, EP - Egg Powder and GL – Ginger Flour, WAC – Water Absorption Capacity, Control: Commercial Pasta

Water absorption capacity (WAC) stands as a critical metric for measuring the volume that the extrudate starch occupies following its expansion in excess water, crucial for maintaining starch integrity in aqueous dispersion (Li *et al*., 2015). In this study, the WAC of the pasta samples ranged from 86.50% to 468.74% as observed in the control sample with the minimum WAC value, while the sample that composed of 60% cassava starch, 32.50% egg powder and 7.50% ginger flour had the highest WAC. Notably, the WAC values of the samples prepared with cassava starch, egg powder and ginger flour displayed relative similarities, but they were significantly different from the control sample. This discrepancy can be attributed to the presence of cassava, which is denser than wheat flour, leading to an increased capacity to absorb water (Eleazu *et al*., 2014).

Sensory score of pasta

The sensory scores for the pasta samples are presented in Table 6. The aroma sensory scores of the pasta exhibited a range from 6.08, for the sample containing 60% cassava starch, 35% egg powder, and 5% ginger, reflecting the lowest aroma sensory scores, to 7.94 for the control sample, which obtained the highest aroma sensory score. An interesting observation was the slight reduction in aroma sensory scores as the proportion of egg in the formulation increased. This score is somewhat similar to the average of 7.3 reported by Akonor *et al*. (2017) for Instant noodles made from root and tubers composite.

The colour of the pasta varied from 6.10 to 7.78 with the sample containing 60.83% cassava starch, 30.53% egg powder, and 8.33% ginger having the lowest colour attribute, while the control sample had the highest colour attribute. This score showed a slight deviation from the range of 4.62 to 5.30. The colour of the pasta made from the blend of cassava starch, egg powder and ginger, was rated as slightly liked, while the colour of the control sample was rated as moderately liked. This could be due to the better appearance and structure of the control sample.

The texture of the pasta displayed a range from 6.08 to 7.82. It was observed that the sample containing 65% cassava starch, 30% egg powder and 5% ginger had the lowest texture score, while the control sample had the highest one. Consequently, the texture scores showed some variation between the control sample and the samples made from the blend of cassava starch, egg powder and ginger flour. The texture score of pasta from blend of cassava starch, egg powder and ginger flour were slightly liked, while the control sample was moderately liked. This could be due to other ingredients such as stabilizers and emulsifiers, which could have been added to the control sample and could have enhanced the texture of the control sample. The results of this investigation on the texture of noodles made from blends of cassava and wheat flour were higher than those published by Sanni *et al*. (2004).

The appearance of the pasta products exhibited a range from 5.62 to 7.68, with the sample containing 60% cassava starch, 30% egg powder, and 10% ginger flour showing the lowest appearance value, and the control sample receiving the highest appearance rating. Notably, it was observed that samples with higher ginger content in their formulations tended to have lower appearance values, potentially influenced by the colour contribution of ginger. This finding corresponds to the observations made by Fernandez *et al*. (2017) in their study on cassava-based pasta, where they reported lower acceptance scores for appearance.

The overall acceptability of the pasta products exhibited a range from 6.18 to 7.80 on a nine-point hedonic scale, including the sample composed of 60% cassava starch, 35% egg powder and 5% ginger flour, as well as the control sample. The control sample was found to be moderately liked by the team of panelists, while the samples produced from the blend of cassava starch, egg powder, and ginger flour were rated slightly liked. The highest value observed for the overall acceptability of the reference sample could be due to their familiarity with the commercially sold pasta.

Table 6. Sensory score of pasta made from cassava starch, egg powder and ginger flour

Samples	Aroma	Colour	Texture	Appearance	Overall Acceptability
$CSEPGF_1$	$6.80{\pm}0.95^{b}$	$6.80{\pm}1.40^{b}$	$6.54{\pm}1.34^{bc}$	$6.40{\pm}1.36^{bc}$	$6.60{\pm}1.41^{b}$
$CSEPGF_2$	$6.58{\pm}1.03^{bc}$	$6.58{\pm}1.23^{bcd}$	$6.44{\pm}1.15^{bc}$	$6.16{\pm}1.40^{bc}$	$6.60{\pm}1.03^{b}$
$CSEPGF_3$	$6.30{\pm}1.37^{bc}$	$6.12{\pm}1.17^{d}$	$6.12{\pm}1.22^{c}$	$6.20{\pm}1.41^{bc}$	$6.40{\pm}0.90^{b}$
$CSEPGF_4$	$6.10{\pm}1.30^{c}$	$6.48{\pm}1.03^{bcd}$	$6.34{\pm}1.24^{bc}$	$6.16{\pm}1.22^{bc}$	$6.38{\pm}1.01^{b}$
$CSEPGF_5$	$6.08{\pm}1.34^{c}$	$6.26{\pm}1.34^{cd}$	$6.09{\pm}1.23^{c}$	$5.92{\pm}1.38^{c}$	$6.18{\pm}1.30^{b}$
$CSEPGF_6$	$6.38{\pm}1.54^{bc}$	$6.72{\pm}1.23^{bc}$	$6.66{\pm}1.24^{b}$	$6.60{\pm}1.36^{b}$	$6.62{\pm}1.21^{b}$
$CSEPGF_7$	$6.24{\pm}1.36^{c}$	$6.12{\pm}1.17^{d}$	$6.08{\pm}1.27^{c}$	$6.40{\pm}1.32^{bc}$	$6.40{\pm}1.56^{b}$
$CSEPGF_8$	$6.09{\pm}1.30^{c}$	$6.12{\pm}1.23^{bc}$	$6.20{\pm}1.27^{c}$	$5.63{\pm}1.38^{c}$	$6.40{\pm}0.90^{b}$
$CSEPGF_9$	$6.78{\pm}0.95^{b}$	$6.81{\pm}1.40^{b}$	$6.53{\pm}1.34^{bc}$	$6.40{\pm}1.36^{bc}$	$6.60{\pm}1.41^{b}$
$CSEPGF_{10}$	$6.11{\pm}1.30^{c}$	$6.49{\pm}1.03^{bcd}$	$6.32{\pm}1.24^{bc}$	$6.17{\pm}1.22^{bc}$	$6.39{\pm}1.01^{b}$
$CSEPGF_{11}$	$6.09{\pm}1.34^{c}$	$6.13{\pm}1.17^{d}$	$6.10{\pm}1.23^{c}$	$5.91{\pm}1.38^{c}$	$6.40{\pm}1.56^{b}$
$CSEPGF_{12}$	$6.37{\pm}1.53^{bc}$	$6.73{\pm}1.24$	$6.66{\pm}1.24^{b}$	$6.61{\pm}1.37^{b}$	$6.63{\pm}1.21^{b}$
$CSEPGF_{13}$	$6.08{\pm}1.34^{c}$	$6.26{\pm}1.34^{cd}$	$6.10{\pm}1.23^{c}$	$5.92{\pm}1.38^{c}$	$6.40{\pm}1.56^{b}$
$CSEPGF_{14}$	$6.09{\pm}1.30^{c}$	$6.12{\pm}1.23^{bc}$	$6.20{\pm}1.27^{c}$	$5.62{\pm}1.38^{c}$	$6.40{\pm}0.90^{b}$
Control	$7.94{\pm}0.89^{a}$	$7.78{\pm}1.06^{a}$	$7.82{\pm}1.16^{a}$	$7.68{\pm}1.15^{a}$	$7.80{\pm}1.11b^{a}$

*Mean ± standard deviation with different superscripts along the column are significantly different at ($p<0.05$); CS - Cassava Starch, EP - Egg Powder and GL – Ginger Flour, Control: Commercial Pasta

Conclusion

The study demonstrated that the use of egg powder and ginger flour for pasta has the advantage of improving the protein content and antioxidant properties (DPPH radical scavenging activity) of pasta. The colour properties, such as yellowness, of pasta increased with the addition of egg powder, while the lightness decreased with the addition of egg powder and ginger flour. However, the addition of egg powder and ginger flour leads to a shorter cooking time, but higher expansion ratio and water absorption capacity of pasta. Pasta prepared from the blend of cassava, egg powder and ginger flour were all preferred by the panelists, but the control sample had the highest overall acceptability. Thus, pasta from cassava starch enhanced with egg powder and ginger flour could be useful to combat malnutrition and nutritional deficiencies in developing countries. However, subsequent studies can be carried out on the textural properties and storage stability of pasta produced from blend of cassava, egg powder and ginger flour

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