ORIGINAL ARTICLE

Food Chemistry, Engineering, Processing and Packaging Food Microbiology, Safety and Toxicology

Effect of polysaccharide-coatings on the physicochemical properties and nutritional composition of deep-fried chicken breasts

Utibe Mfon Okon [1] **Emmanuel Nuamah** [2] **Precious Peter Jonathan** [1] **Comfort Abel Essien** [1] **Zahidul Hasan Tushar** [3,4] **Zahra Gardezi** [5]

[1] Akwa Ibom State University, Faculty of Agriculture, Department of Animal Science, Animal Products and Processing Laboratory, P. O. Box 1167, Mkpat Enin 532111, Nigeria. utibeokon@aksu.edu.ng / preciousjona1@gmail.com / comfortessien@aksu.edu.ng

[2] Jeonbuk National University, College of Agricultural and Life Sciences, Department of Animal Science, Ruminant Nutrition and Data Science Laboratory, 567 Baekje-daero, Jeonju, 54896, Republic of Korea. emmanuamah@jbnu.ac.kr

[3] Bangladesh Agricultural University, Faculty of Animal Husbandry, Department of Animal Science; Meat Science Laboratory, Z3033, Mymensingh 2202, Bangladesh. tushar.1803143@bau.edu.bd

[4] Auburn University, College of Agriculture, Department of Poultry Science; AL 36849, USA.

[5] University of Agriculture, Faculty of Food, Nutrition and Home Sciences/Department of Food Science and Technology, Meat Science Laboratory, Faisalabad 38000, Pakistan. zgardezi5@gmail.com

ABSTRACT

Background: The consumption of deep-fried foods has been a topic of considerable debate in nutritional science due to its potential adverse effects on health. In this context, the method of coating deep-fried chicken breasts has garnered increasing attention.
Aims: This study aimed to provide valuable insights into the effects of alternative plant-based coatings on the physicochemical and nutritional properties of deep-fried chicken breast, with the broader objective of promoting healthier food options for consumers.
Materials and Methods: Pre-weighed, marinated chicken breast chunks were immersed in treatment batter made from various edible flour coatings, including wheat, sweet potato, cassava, and cocoyam. The samples were refrigerated and subsequently deep-fried. The fried products were analyzed for proximate and mineral composition, while breaded samples were examined for physicochemical properties.
Results: While coating did not affect the coating yield, it significantly increased frying yield ($p < 0.0001$) and pH ($p = 0.0105$). However, edible coatings did not significantly influence the lightness ($p = 0.1481$), redness ($p = 0.3596$), or yellowness ($p = 0.6852$) of the meat. Among proximate components, crude fiber and energy levels remained unchanged, but other parameters varied significantly across treatments ($p < 0.05$). Likewise, most mineral parameters, except magnesium, exhibited significant differences among coatings ($p < 0.05$). Notably, sweet potato coatings enhanced the physicochemical and proximate attributes more effectively than the other coatings, while cocoyam coatings yielded superior mineral composition compared to wheat flour.
Conclusion: Alternative plant-based coatings significantly influenced the physicochemical properties, nutrient composition, and mineral content of deep-fried chicken breasts. These findings suggest that utilizing such coatings could result in healthier fried chicken products. Further research is necessary to optimize these coatings for enhanced consumer acceptability and to support their integration into healthier dietary options.

Keywords: Frying medium, frying yield, meat color, mineral content, wheat flour substitutes.

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Corresponding author: U. M. Okon
E-mail: utibeokon@aksu.edu.ng / utibeokon93@gmail.com

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1 INTRODUCTION

Skinless chicken breast, classified as white meat, is widely regarded as a healthier alternative to red meats such as beef steak and pork chop due to its lower fat content (Szendrő *et al.*, 2024). Additionally, chicken, being more manageable, is also subject to fewer religious dietary restrictions (Korver, 2023). These attributes have contributed to its growing demand, with the commercial broiler industry playing a pivotal role in its global production and distribution (Korver, 2023). The rising demand for chicken breasts has led to the development of a niche market, offering food technologists with opportunities to create a variety of processed chicken products, such as chicken tenders and sausages. The high preference for convenient and nutritious chicken-based products reflects the needs of consumers in today's fast-paced lifestyles (Eduardo *et al.*, 2024).

Deep-frying, is a widely favored cooking technique due to its simplicity, speed, and cost-effectiveness, particularly within the fast-food sector. The appeal of deep-fried foods lies in their distinctive flavor, golden-brown appearance, and crispy texture, all of which contribute to their high consumer enjoyment (Ananey-Obiri *et al.*, 2019). These foods are popular because of their affordability, convenience, and consistently appealing sensory characteristics. However, the high rate of fat absorption during the frying process, especially during the cooling phase, presents health concerns. Fat absorption can constitute 10 to 40 percent of the food's total weight and composition (Oyom *et al.*, 2024). Regular consumption of such high-fat foods has been associated with a range of health issues, including hypertension, weight gain, obesity, elevated cholesterol levels, and even certain cancers (Ananey-Obiri *et al.*, 2020). In response to these concerns, regulatory bodies and researchers have intensified efforts to minimize fat absorption by modifying fried products and developing innovative frying techniques (Liberty *et al.*, 2019). A range of approaches has been explored, including the application of edible coatings, battering, breading techniques, and alternative methods such as microwave heating, air frying, and vacuum frying (Korkmaz *et al.*, 2022). Among these strategies, the use of edible coatings has demonstrated considerable promise and is regarded as one of the most effective methods for reducing fat absorption in fried foods (Adrah *et al.*, 2022).

The study by Liberty *et al.* (2019) highlighted the crucial role of coatings in minimizing fat absorption during frying by providing a protective barrier against oil penetration and the intense heating effect of hot oil. Wheat flour, traditionally employed as a coating material, provides a desirable crispy texture, an appealing golden-brown hue, and a characteristic flavor to deep-fried foods. However, wheat flour presents both health and economic challenges. Its gluten content raises dietary concerns for individuals with gluten intolerance or celiac disease, and its cost and extensive use in various consumer products, such as confectionaries, contribute to economic constraints (Okon *et al.*, 2024).

In countries such as Nigeria, flours derived from alternative sources, including cassava, sweet potato, and cocoyam, have been widely adopted for producing various food products such as biscuits, chin-chin, spaghetti, and pies. These flours are also integral to traditional dishes including "*fufu*" and "*amala*," which are particularly popular among farming households in southern Nigeria (Akonor *et al.*, 2023). Despite their nutrient richness and bioactive compound content, these alternative flours face challenges related to their perishable nature, limiting their long-term utility and necessitating processing into shelf-stable forms. Additionally, fluctuations in global wheat prices exacerbate the economic burden on many Nigerian households, particularly those reliant on farming (Balana *et al.*, 2022).

Given these considerations, alternative plant-based coatings, such as those derived from cocoyam, sweet potato, and cassava, offer a promising solution. These materials are not only readily available and cost-effective but also nutritious and health-promoting. This study, therefore, sought to evaluate the efficacy of coatings made from cocoyam, sweet potato, and cassava in improving the physicochemical and nutritional properties of deep-fried chicken breasts.

2 Materials and Methods

2.1 Study area

The experiment was conducted at the Department of Animal Science Laboratory, Faculty of Agriculture, Akwa Ibom State University, Nigeria.

2.2 Acquisition and processing of coating materials

Fresh roots and tubers of cassava, cocoyam, and sweet potato were purchased from Abak market located in Oruk Anam Local Government Area in Akwa Ibom State, Nigeria. These raw materials were thoroughly washed with clean water to eliminate dirt or debris. Following this, the root and tubers were peeled and finely chopped into small pieces using a manual kitchen food processor. The prepared pieces were then dried in an oven (6553 Thermo Scientific) for 48 hours at a moderate temperature of 65 ºC to prevent nutrient loss, fermentation, and the development of off-flavor. Once dried, the materials were milled into fine flour and stored in airtight containers to prevent moisture re-absorption and deterioration of shelf-life. The flour used as treatment variables were labeled as WF (wheat flour), SPF (sweet potato flour), CF (cassava flour), and CYF (cocoyam flour). These treatments were incorporated into the a completely randomized experimental design.

2.3 Chicken sample processing and marination

A total of 24 broiler chickens, each eight (8) weeks old, were obtained from the Akwa Ibom State University Commercial Farm, located at Obio Akpa in Oruk Anam Local Government Area of Akwa Ibom State, Nigeria. The chickens were slaughtered by severing the neck and allowing bleeding to occur for approximately two minutes. The slaughtering process was immediately followed by scalding, de-feathering, and thorough cleaning of the carcasses.

Breast muscle samples weighing approximately 300 g were extracted from each bird. Using a clean and sharp kitchen knife, the breast muscles were initially cut into chunks measuring 14 cm in length and 5 cm in width, aligned with the direction of the muscle fibers. These chunks were further subdivided into sizeable portions measuring 7 cm x 5 cm for uniformity before undergoing the marination process.

A standardized marinade mixture was prepared for priming the meat. The marinade consisted of water (1000 mL), and blend of salt, ginger, garlic, pepper, nutmeg, and mixed spices, each constituting approximately 5 % of the chicken muscle's weight. The chicken portions were immersed in the marinade mixture and refrigerated at 4°C for 12 hours until further use (USDA, 2023).

2.4 Coating preparation and meat breading

Flour from the various treatments (1 kg) was mixed with deionized water (1000 mL) to prepare multiple batter formulations. Egg white was incorporated as binding agent to achieve a firm batter consistency, following the methodology outlined by Adegoke *et al.* (2022). The batter slurry was applied to the pre-weighed chicken breast slices for ten seconds, followed by a draining period of fifteen seconds. The immersion process was repeated until drainage ceased. Subsequently, the meat was evenly coated with the flour from each treatment to ensure uniform coverage, as described by Adegoke *et al.*, (2022).

2.5 Meat frying process

The breaded chicken breast slices were fried in a deep-frying pot containing vegetable oil, purchased from a local grocery store at a temperature range of 180–200°C. A gas cooker served as a heat source. During frying, the breaded chicken breast strips were turned at two-minute intervals to ensure uniform cooking. The oil temperature was monitored and regulated using a thermometer, adhering to the recommendations of Latif and Abdel-Aal (2011).

2.6 Coating yield and frying yield

The coating yield of the meat was calculated using the formula proposed by Labropoulos *et al.* (2013):

$$\text{Coating yield (\%)} = \frac{(\text{weight of meat after coatings} - \text{weight of raw meat})}{\text{weight after coating}} \times 100$$

The frying yield of the chicken breasts was determined as a percentage, based on the weight of the samples before and after frying, as reported by Adegoke *et al.* (2022).

2.7 Proximate and mineral analysis

The breaded meat samples were transported to the laboratory for proximate composition analysis. Parameters evaluated included crude protein, ash, moisture, and ether extract. Additionally, samples from each treatment were analyzed for mineral content including phosphorus, zinc, calcium, potassium, and iron following the standard procedures outlined by AOAC (1990).

2.8 Color measurements

Instrumental color values of the fried chicken breast samples—lightness (L*), redness (a*), and yellowness (b*)—were measured using a chroma meter (colorimeter) in accordance with the methods described by Bah *et al.* (2022).

2.9 pH measurement

A 10 g sample of fried chicken meat, including the coating from each treatment, was homogenized with 9 mL of distilled water to obtain a uniform mixture. The mixture was filtered using filter paper to obtain a clear solution, and the pH was measured using a calibrated pH meter, as detailed by Alakhrash *et al.*, (2016).

2.10 Statistical analysis

The data obtained were analyzed to assess differences attributable to the coating medium using the One-Way Analysis of Variance (ANOVA) technique in GraphPad Prism Software (Version 10.20.0, 392). Where significant differences were detected ($p \leq 0.05$), means were separated using Tukey's pairwise comparison test at a 95% confidence interval.

3 Results and Discussion

It has been suggested that coating the substrate can effectively reduce oil absorption in fried foods (Liberty *et al.*, 2019). The primary components of coating systems typically include starch, wheat flour, and maize flour, which can be used individually or in combinations to optimize product quality and processing efficiency. Among these, wheat flour remains the most widely utilized due to its functional properties, despite the availability of alternative sources with higher nutritional value, health-promoting bioactive compounds, and diverse dietary fiber structures (Wang & Jian, 2022). However, alternatives flours such as cocoyam, cassava, and sweet potato have demonstrated significant potential as coating materials. These alternatives are not only nutrient-rich but also deeply embedded in local culinary traditions, highlighting their versatility and adaptability (Akonor *et al.*, 2023).

3.1 Physicochemical characteristics of breaded chicken breast

3.1.1 Coating yield

The coating yield of deep-fried chicken using various edible coating materials is presented in Figure 1 (A). The results indicate that the type of coating material had a non-significant ($p > 0.05$) effect on coating yield. However, higher coating yields were observed for the CYF and SPF treatments compared to the WF control group, with the exception of the CF treatment. The enhanced coating yields observed for CYF and SPF may be attributed to the binding properties of the batter, which influence its ability to adhere more effectively to the product surface. Improved adhesion between the coating solution and the product surface likely contributed to the higher coating pickup observed for CYF and SPF flour (Feng *et al.*, 2025). This suggests that CYF and SPF could effectively minimize mass transfer during frying. The barrier properties of edible coating, which are critical for blocking moisture, oxygen, and carbon dioxide, depend on the characteristics of the product, storage conditions, and the chemical composition and structure of the polymers forming the coating (Patil *et al.*, 2023).

3.1.2 Frying yield

Mass heat transfer, a well-documented phenomenon, is responsible for the replacement of water with oil in food during frying. This process suggests that the extent of water loss is strongly correlated with oil absorption (Wang & Jian, 2022). Moisture loss, which occurs due to evaporation during cooking and oil dripping post-cooking, is inversely related to frying yield (Adrah *et al.*, 2021). As illustrated in Figure 1 (B), a significant ($p < 0.001$) difference was observed in the frying yield of deep-fried chicken samples coated with various materials. While higher frying yields were recorded in chicken samples coated with sweet potato and cocoyam flour, the frying yields for cassava and cocoyam were not significantly different from those of the control group coated with wheat flour. The substantially lower frying yield with wheat flour, compared to sweet potato flour, could be attributed to its high cooking and drip losses, which are influenced by the viscosity and protein composition of the coating material. As noted by Sothornvit (2011), coating pickup is closely related to the viscosity of the coating solution, as a more viscous coating solution exhibits better adherence and results in higher pickup. Similarly, Karimi and Kenari (2016) emphasized that water retention in food products is directly influenced by the formation of a protein-based film, a characteristic imparted by edible coatings. The findings of this study suggest that wheat flour may have formed fewer films and retained less water in the chicken samples, leading to higher cooking and drip losses and, consequently, a lower frying yield. Supporting this, Kulp (2016) demonstrated that increasing the protein content of the coating material significantly enhances adhesion and yield while reducing frying loss. The superior frying yield observed with SPF may also be attributed to its gelatinization and surface change properties when exposed to heat. In edible coatings, starch gelatinization, induced by heat exposure, acts as a barrier to minimize mass loss during frying (Adrah *et al.*, 2021). Given that oil uptake is closely associated with moisture loss (Bouchon, 2009), the findings of the current study suggest that SPF exhibits low oil uptake due to its ability to minimize moisture loss.

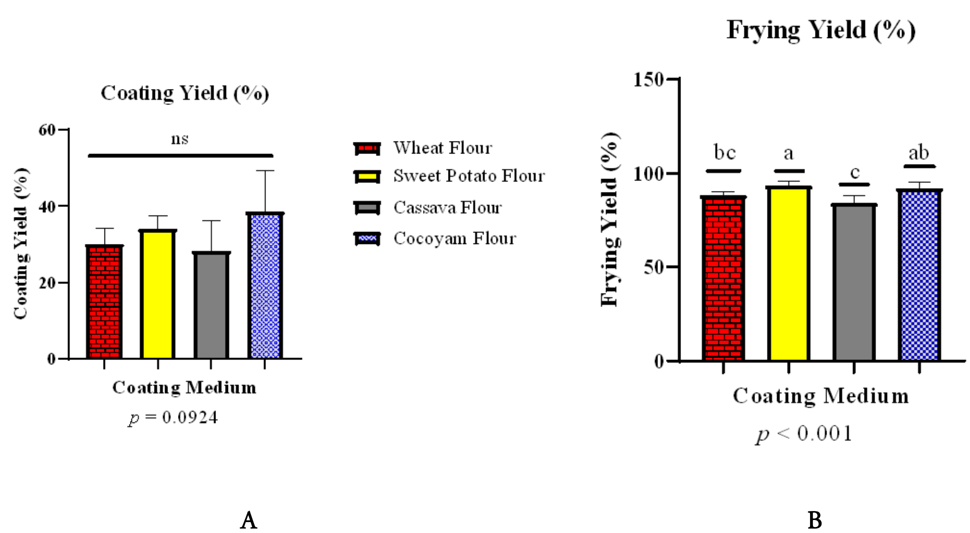

Figure 1. Coating (A) and frying (B) yields of deep-fried chicken breaded with alternative coatings
Different letters on the top of the data bars indicate significant differences ($p < 0.001$) between mean values

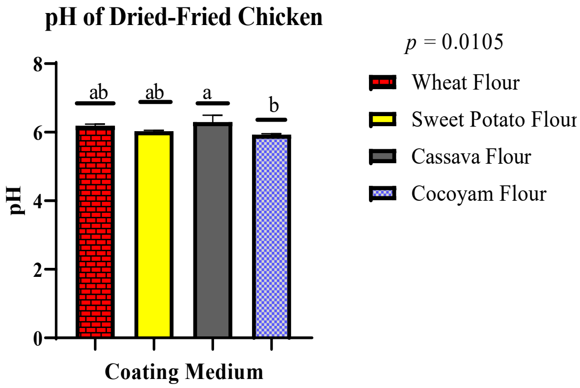

Figure 2. pH of deep-fried chicken breaded with alternative coatings
Different letters on the top of the data bars indicate significant differences ($p = 0.0105$) between mean values.

3.1.3 Meat pH

pH, a measure of acidity or alkalinity, is a critical factor influencing water-holding capacity and texture of meat products (Mena *et al.*, 2020). The pH values of deep-fried chicken coated with various materials are presented in Figure 2. Analysis of variance revealed that the coating material had a significant ($p = 0.0105$) effect on the pH of the fried chicken samples. Higher pH values are associated with larger pore structures, which can lead to increased oil absorption (Mah, 2008).

Despite the highest pH value recorded in fried chicken coated with SPF, the pH values of samples coated with alternative materials did not differ significantly from those of the control group (wheat flour). All pH values remained within the acceptable range for high-quality breaded chicken breast. While Wang *et al.* (2023) suggested that the addition of salt could counteract acidic pH levels, the pH values observed in the current study were slightly higher than the range (5.47 – 5.56) they reported. This observation aligns with the findings of Mena *et al.* (2020) who also noted that the addition of salt could lead to an increase in pH.

3.1.4 Meat Color

As illustrated in Figure 3, color analysis using the International Commission on Illumination (CIELAB) system indicated that none of the edible coatings significantly influenced the lightness ($p = 0.1481$), redness ($p = 0.3596$), and yellowness ($p = 0.6852$) of the deep-fried chicken breast. However, it was observed that alternative coating materials non-significantly increased the lightness and yellowness of the fried meat while reducing redness compared to the control group. These findings regarding the effect of alternative polysaccharide coatings on fried meat contrast the conclusions of Hashim *et al.* (2020), who reported that increased sugar reduction in cellulosic coatings decreased the lightness of fried cassava chips by enhancing the Maillard reaction. The discrepancy in results may be attributed to the relatively low cellulose concentration in the coating materials used in this study. However, the present results are consistent with the earlier findings of Adrah *et al.* (2022) who observed

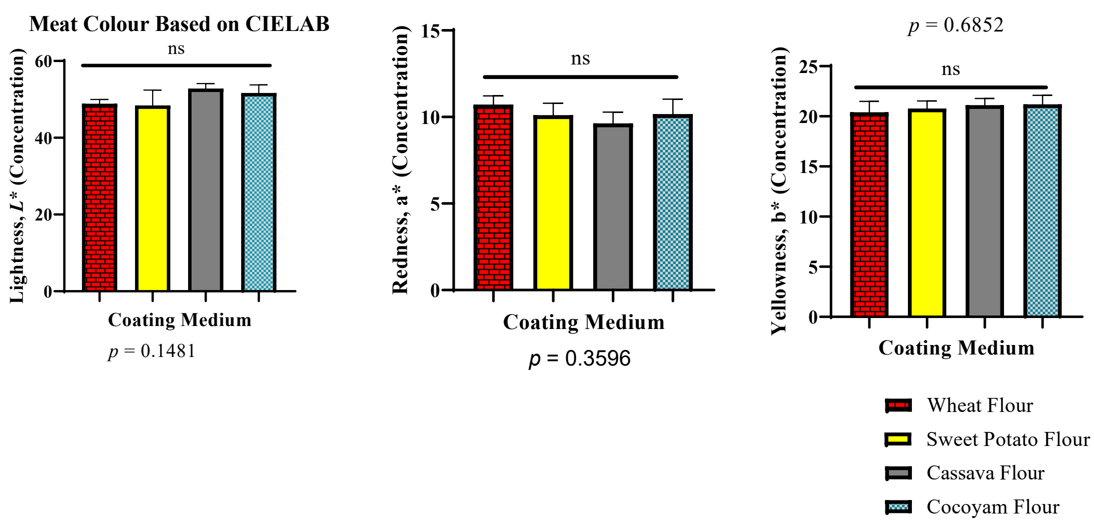

Figure 3. Instrumental color of alternatively breaded chicken breast
Different letters on the top of the data bars indicate significant differences ($p < 0.05$) between mean values

that the tristimulus color of coated samples was not significantly affected by the type of coating material, even when sweet potato starch-based batter was used. The color attributes of deep-fried chicken breast samples coated with alternate coating material suggest that these coatings do not adversely affect color. Consequently, such coatings are likely to enhance the visual appeal and consumer acceptance of the product compared to traditional wheat flour coatings.

3.2 Nutrient composition of breaded chicken breast

3.2.1 Proximate composition

In this study, coating materials were found to have a significant (p < 0.05) influence on the moisture content, crude protein, ash, crude fat, and carbohydrate content of the samples, with the exception of crude fiber and energy content. Moisture content is a critical determinant of the texture and consumable quality of deep-fried foods. Samples coated with SPF and CY generally recorded a lower moisture content compared to those coated with wheat and cocoyam. This suggests that SPF and CY coatings may have promoted higher moisture retention due to the formation of a more resistant crust, which likely acted as a barrier to water loss. The thickness of the crust, which impedes vapor movement, has been associated with enhanced moisture retention. The higher coating pickup observed in samples treated with alternative coatings (SPF and CYF) (Figure 1 A.) may have contributed to the increased crust thickness, thereby improving moisture retention after frying. The network formed by the edible coating on deep-fried foods effectively prevent moisture loss, retaining higher moisture levels in the sample and reducing fat absorption (Feng *et al.*, 2025; Patil *et al.*, 2023). These findings align with earlier research by Chayawat & Rumpagaporn (2020), who reported that chicken nuggets coated with defatted rice bran exhibited impressive moisture retention of 52% (Table 1).

Heat treatment, such as frying, can alter the protein composition of food by degrading certain amino acids and reducing overall protein concentration (Henry, 1998). However, frying, as a dehydrating operation, typically results in a higher protein content due to moisture loss (Bordin *et al.*, 2013). In this study, the results indicated a non-inverse relationship between moisture and protein contents, contrary to expectations for meat samples. The crude protein content of samples coated with alternative materials, with the exception of CYF, was generally lower than that of samples coated with wheat flour. This may be attributed to the nutritional composition of the respective coating materials. The lower crude protein content observed in SPF- and CF-coated samples further supports the hypothesis that film development, potentially influenced by the protein content of the edible coating, plays a role in these outcomes.

Ash content was measured for all coated chicken breast samples. Among the alternate coating materials, SPF and CYF exhibited significantly higher ash content compared to the standard control (wheat flour), with the exception of CF samples, which showed lower values. This indicates that edible coating can contribute to the mineral composition of processed meat products.

In addition, the results of this study indicated that the fat content of deep-fried chicken breasts coated with SPF was lower compared to the other treatments. This observation may be attributed to the low porosity of the crust formed and the reduced surface area of samples coated with SPF, both of which contribute to lower oil absorption. A decreased surface area facilitates faster heat transfers, thereby reducing moisture

Table 1. Proximate composition of breaded chicken breast.

Parameter	Coating Medium				
	WF[1]	SPF[1]	CF[1]	CYF[1]	p-value
Moisture (%	52.19 ± 0.51^{a}	51.85 ± 1.51^{ab}	48.117 ± 1.57^{b}	54.42 ± 2.15^{a}	0.007
Crude Protein (%	16.89± 0.12^{a}	16.29± 0.69^{ab}	15.26 ± 0.44^{b}	17.23 ± 0.79^{a}	0.013
Ash (%	3.40 ± 0.13^{c}	4.43 ± 0.03^{a}	2.75 ± 0.13^{d}	4.10 ± 0.10^{b}	0.000
Crude Fat (%	15.00 ± 0.13^{b}	14.92 ± 0.25^{c}	18.77 ± 0.03^{a}	15.30 ± 2.95^{b}	0.036
Crude Fiber (%	2.012 ± 0.10	1.93 ± 0.06	1.98 ± 0.08	2.00 ± 0.05	0.583
Carbohydrate	46.71 ± 0.89^{bc}	51.62 ± 0.95^{a}	50.44 ± 3.15^{ab}	43.61 ± 0.76^{c}	0.002
Energy (Kcal/Kg	451.00 ± 7.42	457.87 ± 0.58	451.97 ± 5.27	420.00 ± 58.6	0.443

Note. [1] WF: wheat flour; SPF: Sweet potato flour; CF: Cassava flour; CYF: Cocoyam flour. Mean ± SD ^{abc} Means ± SD within a row with different letters of superscript differ significantly loss. The combination of a low surface area and increased crust thickness accelerates heat transfer, minimizing contact between the oil and water vapor on the food surface, resulting in reduced oil absorption. These findings align with the work of Ziaiifar *et al.* (2008), who reported that heat transfer during cooking is closely related to the surface area characteristics of the food. This observation further supports the assertion that SPF exhibits low oil uptake due to its ability to minimize moisture loss. Conversely, the high fat uptake observed in cassava flour (CF)-coated samples may be attributed to the poor surface pore inhibition capacity of cassava, which likely facilitated oil migration. Oil absorption is a complex phenomenon influenced by multiple factors, including the initial structure of the product, interactions between the food and the heating medium, and variations in the properties of both the product and the oil (Ananey-Obiri *et al.*, 2018).

However, no significant differences ($p > 0.05$) were observed in crude fiber and energy content across the treatments. Samples coated with SPF and CF exhibited lower crude fiber content and higher energy levels compared to those coated with WF and CYF. The higher carbohydrate levels in SPF- and CF-coated meat samples may be attributed to the high energy content of these flours, which likely influenced the overall carbohydrate composition of the coated meat.

Table 2. Mineral Composition of breaded chicken breast

Parameter (mg/100	Coating Medium				
	WF[1]	SPF[1]	CF[1]	CYF[1]	*P*-value
Phosphorus (P	21.13 ± 0.002^{d}	27.64 ± 0.002^{c}	30.05 ± 0.002^{b}	39.13 ± 0.002^{a}	0.000
Potassium (K	40.50 ± 0.002^{b}	37.00 ± 0.002^{c}	41.00 ± 0.002^{a}	35.50 ± 0.002^{d}	0.000
Zinc (Zn	0.98 ± 0.003^{c}	0.97 ± 0.002^{d}	1.79 ± 0.002^{b}	1.84 ± 0.002^{a}	0.000
Iron (Fe	0.65 ± 0.004^{d}	0.85 ± 0.002^{c}	0.94 ± 0.001^{b}	0.96 ± 0.001^{a}	0.000
Magnesium (Mg	23.45 ± 1.051	24.30 ± 2.10	22.25 ± 1.025	25.85 ± 1.95	0.120

Note. [1] WF: wheat flour; SPF: Sweet potato flour; CF: Cassava flour; CYF: Cocoyam flour. Mean ± SD [abc] Means ± SD within a row with different letters of superscript differ significantly.

3.2.2 Mineral composition

Fried foods generally retain their mineral content effectively, as mineral loss during frying is not significant (Bordin *et al.*, 2013). Due to their water-soluble nature, mineral components are primarily affected during boiling rather than frying (Ghidurus *et al.*, 2010). Several studies have demonstrated that foods fried at high temperatures (between 165 and 185 °C) for short durations retain minerals well (Rani *et al.*, 2023).

The mineral composition of chicken breast-coated samples, as presented in Table 2, revealed significant differences ($p < 0.05$) in all analyzed parameters except magnesium. Notably, zinc and iron levels were higher in CF and CYF samples. In contrast, all alternative edible coatings in this study resulted in higher potassium and phosphorus levels in the chicken breast samples compared to those coated with wheat flour (WF). This suggests that the edible coating materials used may serve as a significant source of minerals.

Recent studies have emphasized the role of alternative coating materials in enhancing the nutritional quality of fried products. For instance, tuber-based flours, such as cassava and sweet potato, are recognized for their naturally high potassium content, which can be transferred to the coated product during frying (Akintayo *et al.*, 2023). Additionally, phosphorus, an essential mineral for metabolic functions, has been reported in significant quantities in coatings derived from plant-based flours, such as cocoyam, due to their dense mineral composition (Otekunrin *et al.*, 2021).

Moreover, the retention of minerals such as zinc and iron in CF and CYF coatings is consistent with finding indicating that batter formulations enriched with specific starches or alternative flours can enhance mineral retention during frying (Bhuiyan & Ngadi, 2024). However, the mineral content detected may also be influenced by the concentration effect in the battered and breaded samples prior to frying (Ersoy and Özeren, 2009).

3 Conclusion

The results of this study demonstrate that the physicochemical properties and nutrient composition of chicken breast can be significantly improved through the application of alternative coatings. Sweet potato flour was found to enhance the physicochemical and proximate attributes of the coated chicken breast, while cocoyam flour improved the mineral quality of the product. These findings suggest that alternative polysaccharide coatings can be effectively utilized in chicken processing to produce healthier, nutrient-rich food products for consumers.

However, further research is necessary to optimize the characteristics of these products to enhance consumer acceptability and promote wider adoption.

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Previous submissions: None.

Authors' Contribution: **Okon:** conceptualization, methodology, project administration, supervision, writing original draft, review and editing – original draft. **Nuamah:** data curation, formal analysis, software, validation, visualization, writing – review & editing. **Jonathan:** resources, investigation, data collection & methodology. **Essien:** methodology, writing – review & editing. **Tushar:** methodology, writing – review & editing. **Gardezi:** methodology, writing – review & editing.

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