Breadfruit (Artocarpus altilis) Pulp Flour as a Non-Conventional Filler in Comminuted Pork: Effect on Physicochemical, Sensory Attributes and Cost of Meatloaves

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ABSTRACT
This study explored the use of breadfruit (Artocarpus altilis) pulp flour (BFPF) as a filler in meatloaves, partially substituting comminuted pork. Four experimental treatments were formulated: T1 (control) with 0% BFPF, T2 with 5% BFPF, T3 with 10% BFPF, and T4 with 15% BFPF, baking them at 175 °C for 55 minutes. Data on chemical composition, cooking yield, pH, and sensory evaluation were collected. Increasing BFPF levels reduced protein and fat but increased moisture and ash in the meatloaves. Cooking yield significantly improved (p < 0.001), ranging from 751.7 g/kg DM (T1) to 835.3 g/kg DM (T5). The pH remained stable (p = 0.350), and taste preferences showed no significant differences (p = 0.283). The cost of meatloaf decreased linearly with higher BFPF inclusion. Replacing comminuted pork with up to 15% BFPF in meatloaf can improve cooking yield and reduce fat and cost without compromising on pH and sensory attributes.

Keywords: Breadfruit pulp flour, Comminuted pork, Meatloaf, Filler.

1. Introduction
The cost of processed meat products, particularly in developing countries, has experienced a significant surge due to the high demand driven by population growth and the corresponding increase in the price of meat, a vital component in the formulation of these products. To mitigate the impact of this trend, incorporating fillers, such as non-meat ingredients, has emerged as a promising strategy. The use of these fillers not only enhances the volume of the final product but also provides supplementary health benefits and other advantages. In addition to adding bulk to processed meat products, fillers such as starches and flours are utilized for their ability to absorb large amounts of water [1]. This utilization of fillers enables the meat industry to produce processed meat at lower costs. The realization of this potential has sparked research interest in Ghana, with a focus on examining the suitability of crops like plantain, cassava, and sweet potato flours as potential fillers for processed meat products.

Despite the widespread use of various fillers in the production of processed meat, one crop that has received limited attention is breadfruit (Artocarpus altilis). Breadfruit, which belongs to the botanical genus Artocarpus, is abundant in fat, ash, fibre, and protein [2]. Furthermore, research has shown that breadfruit pulp flour (BFPF) has a higher crude protein content compared to other staple starchy crops such as cassava, plantain, and sweet potato. In addition, BFPF is a relatively rich source of essential minerals like iron, potassium, calcium, and riboflavin [3]. This versatile product can be utilized in various dishes, including pounded, fried, boiled, or mashed to make porridge, as well as processed into flour for the preparation of bread and biscuits [4]. Previous studies have demonstrated the biological quality and safety of breadfruit pulp flour [5], [6]. Analysis has shown that breadfruit pulp flour contains between 3.4% to 4.1% crude protein, 0.51%...
to 2.6% fat, 1.4% to 2.7% ash, and 3.67% fibre [7]–[9]. Research conducted by Hafid et al. [10] also revealed a higher cooking yield when using breadfruit pulp flour as a substitute for chicken.

Given the positive results of previous studies, breadfruit pulp flour holds great potential as a filler in processed meat products, thus diversifying the use of these products and making them more widely available. Moreover, the challenge of procuring animal muscle and fat, which are indispensable ingredients in the formulation of sausages and meatloaves, at exorbitant prices in developing countries such as Ghana, can be mitigated through the utilization of breadfruit pulp flour as a filler. This incorporation has the potential to provide a cost-effective alternative and enhance the overall affordability of processed meat products.

Therefore, this study sought to convert breadfruit pulp flour into a more refined state and subsequently evaluated its effects on the physical and chemical characteristics, as well as consumer acceptability, when incorporated into the formulation of pork meatloaf.

2. MATERIALS AND METHODS

2.1. Study Area

The study was undertaken at the Meat Science and Processing Unit of the Department of Animal Science. The experimental site lies between latitude 06° 43′ N and longitude 1° 36′ W and falls between the moist semi-deciduous forest belts. The average monthly temperature ranges from 26.1 °C to 28.9 °C. There is a bimodal rainfall pattern for the area, with a mean annual total of 1,500 mm.

2.2. Flour Preparation

The breadfruits were washed, peeled, and washed again to remove any possible contaminants from the pulp. The pulp was sliced into pieces, after which they were oven dried at a temperature of 60 °C for three days. The chips were stirred as frequently as possible to ensure that there was uniform drying. After drying, the chips were milled into flour to pass through a 1 mm sieve size to produce breadfruit pulp flour (BFPF).

2.3. Meatloaves Formulation and Baking

The 1Mado Super Wolf meat grinder was utilized to grind 500 g of fat and then 2000 g of lean meat taken from pig shoulder and thigh. The ground meat, fat, curing salt (30 g), and a mixture of spices (20 g) were blended until fully combined. The mixture was then run through an electronic pH meter fitted with a glass electrode (FC 200)2.

The breadfruit pulp flour was added to the minced pork at 0%, 5%, 10%, and 15% to create four distinct treatments. The formulation of pork meatloaf.

\[
\text{Total batch weight} = 2530 \times 4
\]

2 pH meter, HI9024C, Hanna Instruments, USA.

- Meat grinder Mado Superwolf, type MEW513, weight 120 kg, dimensions W/D/H 86/74/115 cm, CE94 marketed and distributed by Foodbay. Moscow, Pravdi Street, 8K 13, entrance 3, floor 4, office 418.

\[
\frac{\text{Cooked weight} (W_1)}{\text{Fresh weight} (W_0)} \times 100
\]

where \( W_0 \) is the weight of patties before cooking, and \( W_1 \) is the weight after cooking.

2.6. Determination of pH

Ten grams of meatloaf samples (in triplicate) were homogenized in 50 ml of distilled water for the determination of pH. The pH values were obtained using an electronic pH meter fitted with a glass electrode (FC 200)2.

2.7. Sensory Evaluation

The sensory attributes of appearance, flavour, mouth feel, taste, texture, and overall acceptability of the meatloaf products were evaluated by 45 untrained panellists using a 9-point Hedonic scale (1 = like extremely, 2 = like very much, 3 = like moderately, 4 = like slightly, 5 = neither like nor dislike, 6 = dislike slightly, 7 = dislike moderately, 8 = dislike very much and 9 = dislike extremely). The products were sliced into equal pieces of approximately 2 cm, wrapped in kitchen foil, and assigned a blind code consisting of three random digits. The samples were oven-warmed at 180 °C for 10 minutes before serving. To control for individual differences among the panellists, the order of serving the samples was randomized, ensuring that all

\[
\% \text{NFE} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ crude fibre} + \% \text{ ash})
\]

\[
2 \text{ pH meter, HI9024C, Hanna Instruments, USA.}
\]

2.4. Determination of Chemical Composition

The proximate analytical procedure was employed by following the standard procedures of the Association of Official Analytical Chemists [11] to determine dry matter (DM), crude protein (CP = N \times 6.25), fat, crude fibre (CF), and ash. All the chemical analyses were carried out in triplicates. The nitrogen-free extract (NFE) was estimated by the formula:

\[
% \text{NFE} = 100 - (% \text{ moisture} + % \text{ fat} + % \text{ crude fibre} + % \text{ ash})
\]

\( = \frac{\text{Cooked weight} (W_1)}{\text{Fresh weight} (W_0)} \times 100
\]
treatments were served equally. Water was provided for the panellists to rinse their mouths between tastings. The taste evaluation took place in a laboratory environment, with well-lit white fluorescent lights and no distracting noises or unpleasant odours [12]. This was done to ensure the independence of the panellists throughout the evaluation process.

2.8. Statistical Analysis

The data were subjected to one-way analysis of variance (ANOVA) in a complete randomised design using Minitab Statistical Software, version 19.0. The means were separated by Tukey’s pairwise comparison. The probability level for declaration of significance was set at 5%.

3. Results

3.1. Analytical Nutrient Composition of Breadfruit Pulp Flour

Fig. 1 provides a comprehensive overview of the nutritional composition of the breadfruit pulp flour (BFPF) utilized in this study. The analysis revealed that BFPF consisted of 83 g/kg DM of moisture, approximately 917 g/kg DM of dry matter, 45.0 g/kg DM of crude protein, 42.3 g/kg DM of fat, 40.20 g/kg DM of crude fibre, 20.0 g/kg DM of ash, and 770.10 g/kg DM of nitrogen-free extract.

3.2. Effect of Breadfruit Pulp Flour on Nutrient Composition of Formulated Meatloaves

Table II demonstrates the influence of incorporating breadfruit pulp flour (BFPF) on the chemical composition of pork meatloaves. The inclusion of BFPF had a significant impact (p < 0.05) on the meatloaf composition. The moisture content of the meatloaves notably increased (p < 0.001) with higher BFPF levels, ranging from 593.7 g/kg DM in the control product (T1) to 804.3 g/kg DM in the product with 15% flour (T4). Similarly, the ash content, representing mineral content, followed this trend, varying from 6.3 g/kg DM (T1) to 15.4 g/kg DM (T4). In contrast, protein levels decreased significantly (p < 0.001) with rising BFPF levels, with values ranging from 162.7 g/kg DM in T4 to 211.7 g/kg DM in T1. Similarly, fat levels decreased as BFPF levels increased, ranging from 154.8 g/kg DM in T4 to 211.7 g/kg DM in T1.

3.3. Effect of Breadfruit Pulp Flour on Cooking Yield and pH of Meatloaves

As depicted in Table III, the inclusion of breadfruit pulp flour (BFPF) significantly (p < 0.05) increased the cooking yield of meatloaves. Cooking yield rose consistently with higher BFPF levels, ranging from 751.7 g/kg DM in T1 to 835.3 g/kg DM in T4. Simultaneously, the total batch cost per kilogram of meatloaf exhibited a linear reduction as the level of BFPF inclusion increased, following the sequence T1 (32 q) > T2 (30 q) > T3 (29 q) > T4 (27 q), as outlined in Table I. However, there were no significant pH differences (p > 0.05) between the control meatloaf and those containing BFPF.

3.4. Effect of Breadfruit Pulp Flour on Sensory Attributes of Meatloaves

Table IV summarizes the impact of breadfruit pulp flour on the sensory attributes of meatloaves. The findings indicated that there were no statistical differences (p > 0.05) between the control products and those with BFPF regarding appearance, flavour, mouth feel, taste, texture, and acceptability, as assessed by the panellists.

![Fig. 1. Analytical chemical composition of breadfruit pulp flour.](image-url)
TABLE IV: Effect of Breadfruit Pulp Flour on Sensory Attributes of Meatloaves

<table>
<thead>
<tr>
<th>Attributes</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>2.74</td>
<td>3.10</td>
<td>3.07</td>
<td>2.60</td>
<td>0.107</td>
<td>0.285</td>
</tr>
<tr>
<td>Flavour</td>
<td>2.63</td>
<td>2.47</td>
<td>2.86</td>
<td>3.10</td>
<td>0.112</td>
<td>0.210</td>
</tr>
<tr>
<td>Mouth feel</td>
<td>2.63</td>
<td>3.19</td>
<td>3.07</td>
<td>3.29</td>
<td>0.115</td>
<td>0.175</td>
</tr>
<tr>
<td>Taste</td>
<td>2.86</td>
<td>2.97</td>
<td>2.85</td>
<td>2.20</td>
<td>0.088</td>
<td>0.927</td>
</tr>
<tr>
<td>Texture</td>
<td>2.87</td>
<td>2.99</td>
<td>3.10</td>
<td>2.96</td>
<td>0.060</td>
<td>0.646</td>
</tr>
<tr>
<td>Acceptability</td>
<td>2.83</td>
<td>2.86</td>
<td>3.37</td>
<td>2.98</td>
<td>0.107</td>
<td>0.283</td>
</tr>
</tbody>
</table>

Note: Mean values in the same row showed no significant difference (p < 0.05). SEM = standard error of means. Values are means computed from the responses of 45 untrained panellists, using a 9-point Hedonic scale (1 = like extremely, 2 = like very much, 3 = like moderately, 4 = like slightly, 5 = neither like nor dislike, 6 = dislike slightly, 7 = dislike moderately, 8 = dislike very much and 9 = dislike extremely). T1 (control) = Meatloaf without breadfruit pulp flour, T2 = Meatloaf with 5% of breadfruit pulp flour, T3 = Meatloaf with 10% of breadfruit pulp flour, and T4 = Meatloaf with 15% of breadfruit pulp flour.

4. DISCUSSION

The development and assessment of food items that seek to satisfy customer needs and assure their safety and efficacy depend heavily on the analysis of nutrient content since it helps to assess the quality and nutritional value of food ingredients. The utilization of breadfruit flour (BFPF) as a key component in comminuted meat products brings forth a compelling case for its integration, supported by various advantageous attributes. Firstly, BFPF boasts a rich nutritional profile, potentially enhancing the overall healthiness of meatloaves. This shift in nutrient composition could also impact the overall nutritional balance. The nutritional value of breadfruit pulp flour (BFPF) surpassed that of other major starch crops in nutrient composition since it helps to assess the quality and efficacy depend heavily on the analysis of nutrient content. The variations in ash content observed in the meatloaves in this study can be attributed to the specific mineral content of the flour used in the meat product preparation. This observation resonates with the findings of two distinct studies conducted by Akwetey et al. [19] and Dzudie et al. [17], which investigated the impact of utilizing different types of flours, including breadfruit flour, whole cowpea flour, and common bean flour, on the ash content of products such as frankfurter-type sausages and beef sausages. These studies collectively underline the influence of flour choice on the mineral composition of meat products, highlighting the importance of flour selection in meatloaf formulation.

The lower protein content in breadfruit flour-incorporated meatloaves can be attributed to the inherently lower protein content of breadfruit flour. This observation is consistent with prior research, such as Tay [20], which demonstrated a reduction in crude protein levels in frankfurter-type sausages as cassava flour content increased, and Boateng [21], which noted a similar decline in crude protein content in frankfurter-type sausages with higher levels of sweet potato flour. However, these findings differ from those reported in Abaka [22], where a substantial increase in crude protein levels occurred with the addition of roasted cowpea flour, up to 15%, in comminuted meat patties. This discrepancy may be attributed to the inherently higher crude protein content of cowpea flour compared to breadfruit pulp flour, highlighting the significant influence of flour selection on protein content in meat products. To mitigate the protein reduction when incorporating breadfruit flour, further exploration of blending it with protein-rich ingredients or optimizing formulations may be considered.

Crucially, the study uncovered a noteworthy reduction in the fat content of the meatloaves with the increasing incorporation of breadfruit pulp flour. This reduction in fat content carries significant implications for the final product. Firstly, it contributes to extending the shelf life of meatloaves by mitigating the occurrence of rancid flavours, a common concern associated with high-fat content in pork-based products. Equally important, this fat reduction holds the potential for substantial health benefits for consumers. By diminishing the presence of unhealthy fats in the meatloaves, the overall nutritional profile of the product is enhanced, thereby reducing the risk of associated health issues, including heart disease.

Additionally, the substantial increase in cooking yield achieved with the incorporation of BFPF signifies its cost-effectiveness and potential for yielding more servings per batch. This aligns harmoniously with the growing concerns of consumers regarding the affordability of food products. Moreover, the linear reduction in cost per kilogram associated with the use of BFPF serves to underscore its economic feasibility in the context of meat processing.

These pronounced advantages substantiate the unique properties of breadfruit flour and establish it as a practical filler to enhance both yield and stability in meat-based formulations. Comparable observations have been made in prior studies employing other fillers, such as cowpea flour and unfermented African locust bean flour (Parkia biglobosa) in the preparation of comminuted beef sausages and frankfurter-type sausages. Ash content in meat plays a vital role as it offers valuable insights into the mineral composition of the food. The variations in ash content observed in the meatloaves in this study can be attributed to the specific mineral content of the flour used in the meat product preparation. This observation resonates with the findings of two distinct studies conducted by Akwetey et al. [19] and Dzudie et al. [17], which investigated the impact of utilizing different types of flours, including breadfruit flour, whole cowpea flour, and common bean flour, on the ash content of products such as frankfurter-type sausages and beef sausages. These studies collectively underline the influence of flour choice on the mineral composition of meat products, highlighting the importance of flour selection in meatloaf formulation.
meat products [15], [19], [23]. It can be inferred that the carbohydrates present in breadfruit flour fillers play a pivotal role in absorbing water and expanding during the cooking process. This expansion contributes to an increased bulk, which, in turn, positively impacts the water holding capacity, ultimately enhancing the overall yield of the final product. The inclusion of BFPF also imparts notable benefits to the texture and moisture retention of meatloaves. The fibre content within breadfruit flour assists in preserving moisture within the meat, resulting in a final product that is not only more tender but also juicier. Furthermore, the water-binding capacity of the flour contributes to the formation of a gel-like structure during cooking. This structural element serves to uphold the shape and stability of the meatloaves throughout the cooking process, thus ensuring a consistent and appealing appearance.

The pH level of meatloaves plays a pivotal role in determining the overall quality and safety of the product. Within the scope of this study, the introduction of breadfruit pulp flour (BFPF) was examined to assess its potential impact on pH levels in meatloaves. Remarkably, the incorporation of BFPF into the meatloaves exhibited minimal influence on the acidity levels, maintaining an average pH of 5.8. This pH value falls comfortably within the established normal range of 5.4 to 7.2 [23], providing a strong indicator of the high-quality meat used in this study. The preservation of pH within this acceptable range holds significant implications. The levels of pH in meat substantially influence several critical biological processes, including protein denaturation, enzymatic activities, and overall product deterioration [24]. The fact that pH levels remained stable in meatloaves even with the inclusion of up to 15% BFPF suggests a positive outcome. This implies that the integration of BFPF into the formulation does not have any detrimental effects on the overall quality or safety of the meatloaves. Thus, the ability to maintain pH levels within the accepted range when incorporating breadfruit pulp flour into meatloaves must be considered. It not only reaffirms the high quality of the meat employed but also underscores the compatibility of BFPF with meat products, as it does not compromise the safety or integrity of the final product. This finding strengthens the case for utilizing BFPF as a valuable ingredient and augments the appeal of breadfruit flour as a beneficial component within the meat processing industry.

The evaluation of sensory attributes of meatloaves is of great importance as it directly impacts consumer acceptability and purchasing decisions. This study found that the addition of breadfruit pulp flour up to 15% level has no noticeable impact on the sensory properties of the meatloaves, including appearance, flavour, mouth feel, taste, texture, and overall acceptability. This is probably because the texture, which is a key quality attribute that influences sensory perception and consumer acceptance [24], remained unchanged despite the varying levels of breadfruit pulp flour incorporation. These results are consistent with previous studies, such as Akwetey et al. [19], who used whole cowpea flour in Frankfurter-type sausages, and Annor-Frempong et al. [25], who utilized cassava flour as a fat substitute in comminuted pork sausages, both with no noticeable effect on the sensory qualities of the final products. These results reinforce the work of Olaoye et al. [26], who found breadfruit flour to be a viable ingredient for use in biscuit production, demonstrating its versatility in various food applications.

5. Conclusion

This study has illuminated the promising potential of breadfruit pulp flour (BFPF) in enhancing the quality and economic feasibility of meatloaves. The incorporation of breadfruit pulp flour (BFPF) effectively functioned as a filler for comminuted meat products, delivering multiple benefits such as improved nutrition, enhanced moisture retention, and increased cooking yield. Additionally, it positively influenced the texture and stability of the meatloaves, making them equally appealing to consumers. Furthermore, the results of sensory evaluations indicated that meat products with BFPF are well-received, underlining their potential acceptance by consumers in the food industry. In essence, BFPF emerges as a valuable ingredient that not only enhances the nutritional value and quality of meat products but also aligns with economic considerations. It could provide an opportunity for meat processors to produce products that are both appealing and cost-effective. Therefore, BFPF can be confidently embraced by meat processors as a practical and beneficial addition to their formulations, augmenting the overall appeal and sustainability of meat-based products in the food industry. Therefore, meat processors can confidently incorporate BFPF as a partial replacement for comminuted pork, up to 15%, without compromising the quality of the final product.

6. Research Gap

While this study has shed light on the remarkable potential of breadfruit pulp flour (BFPF) in enhancing the quality and economic feasibility of meatloaves, there remains a research gap in several areas. Firstly, addressing the protein content reduction observed when incorporating BFPF by investigating strategies for blending it with protein-rich ingredients or optimizing formulations presents a notable research direction. Additionally, extending the examination of the versatility of BFPF in various food applications beyond meatloaves could unlock its full range of benefits as an ingredient. Furthermore, investigating consumer awareness and education concerning the nutritional advantages of products containing BFPF can provide valuable insights into improving consumer acceptance. Lastly, evaluating the sustainability of BFPF production and its integration into food products from an environmental standpoint is crucial to ensure its long-term viability.

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CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

REFERENCES


