

Nutritional and Sensory Profile of Grilled Pork Marinated with Turmeric (*Curcuma longa*) Powder

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DOI: <https://doi.org/10.62154/ajasfr.2026.022.01012>

Abstract

Grilled pork is a globally popular food often enhanced with synthetic additives for visual appeal, contradicting the current consumer demand for natural, healthy ingredients. The efficacy of Turmeric (*Curcuma longa*) powder as a natural marinade for enhancing the nutritional and sensory characteristics of grilled pork was investigated. Fresh pork chunks were marinated in four concentrations of turmeric powder (T1: 0g; T2: 25g; T3: 50g; T4: 75g) and subsequently grilled. Samples were analysed for proximate composition (moisture, crude protein, fat, and ash), mineral profile (Na, K, Mg, Ca, Fe), and sensory attributes using standard procedures. Data generated were subjected to ANOVA ($\alpha_{0.05}$). Moisture content significantly decreased ($p < 0.05$) from 10.94% (T1) to 7.40% (T4) while crude protein, fat, and ash levels significantly increased ($p < 0.05$) in the treated groups. Mineral analysis revealed significant, dose-dependent fortification. Iron content doubled from 17.23 mg/100g (T1) to 42.80 mg/100g (T4). However, sensory scores for flavour and overall acceptability showed a linear decline at higher concentrations (T3, T4) due to pungent, earthy notes. Despite lower physical moisture, juiciness scores remained statistically similar ($p > 0.05$) across treatments. Turmeric marination successfully transforms grilled pork into a functional food with superior mineral density. While high doses (>50g) lead to sensory rejection, a 25g inclusion level (T2) is recommended as the optimal level for street-food vendors, providing significant nutritional fortification without compromising palatability.

Keywords: *Curcuma longa*, Functional Meat, Mineral Fortification, Clean Label, Street-Vended Food, Sensory Evaluation.

Introduction

Pork is one of the most widely consumed meats globally, appreciated for its rich flavour, affordability, and nutritional value (Pandey, *et al.*, 2024). In many regions, particularly in urban and peri-urban areas, grilled pork is a popular street-vended food, often served in skewered or chunked forms with a characteristic bright orange hue. In its raw state, pork exhibits a pink coloration, but upon cooking, it transitions to a dull grey or brown tone, which may be perceived as unappetizing by consumers.

To counteract this, vendors frequently incorporate synthetic colorants and flavour enhancers to achieve a vibrant coloration. This practice enhances the product's aesthetic and sensory attributes, improving visual appeal and consumer acceptance.

However, growing consumer awareness and demand for healthier foods free from artificial additives have prompted a shift toward the use of natural ingredients. Synthetic additives have been associated with adverse health effects, including hyperactivity in children and potential long-term risks in adults (Ambroziewicz, *et al.*, 2024), thereby intensifying the search for safer, plant-based alternatives.

Turmeric (*Curcuma longa*), often referred to as the "golden spice" or "king of spices," is renowned for its deep yellow pigment and has been traditionally used in various culinary applications, particularly in curries, sausages, and marinades. Beyond its colouring properties, turmeric is valued for its antioxidant, antimicrobial, and anti-inflammatory attributes, largely attributed to its active compound, curcumin (Kocaadam and Sanlier, 2017). These properties make turmeric a promising candidate for enhancing both the nutritional and sensory qualities of meat products. Several studies have expressed the antioxidant effect of Turmeric alone or in combination with other products (Bojorges *et al.*, 2020; Amiri *et al.*, 2019), its effect on cooked pig meat (Mancini *et al.*, 2017) and chicken mince (Sharma *et al.*, 2011) and rabbit burgers (Mancini *et al.*, 2015).

Despite its potential, the interaction of turmeric with the meat matrix under the extreme thermal stress of grilling is not understood. While studies have explored turmeric in cooked pork and burgers, there is a paucity of scientific literature regarding its ability to mitigate the loss of moisture and essential minerals such as iron and zinc which often leach out during the grilling process. It is currently unknown if turmeric marination acts as a protective barrier that preserves the proximate integrity and mineral density of the final product.

Therefore, this study aims to evaluate the proximate and mineral compositions, as well as the sensory characteristics, of grilled pork marinated in turmeric powder.

Materials and methods

Experimental Site

This study was carried out at the Animal Science and Biochemistry Laboratories, University of Uyo Annex.

Experimental Material

The pork used for this study was from the shoulder cut. The pork was purchased from a reputable butcher in Uyo metropolis. The Turmeric powder was purchased from Itam Market, Itu Local Government Area, Akwa Ibom State. Other materials and apparatus included polyethylene bags, masking tape, marker pens, grilling pan, knife and weighing balance.

Sample Preparation

A total of 6000g of pork shoulder was purchased from the butcher. About 500g each was weighed and cut for each replicate. A total of 12 chunks of pork shoulder weighing 500g were randomly assigned to four treatments and replicated thrice. Each of the 12 chunks were further chopped into smaller pieces and marinated in the turmeric powder.

Fresh turmeric rhizomes were washed, peeled and sliced into thin shreds and sundried for five days to a constant moisture. The dried shreds of turmeric were ground into powder and weighed according to treatments (0g, 25g, 50g, 75g). Each treatment was mixed with 65mls of groundnut oil in a bowl where the pork was marinated. This was left for 60mins before grilling for about 7minutes.

Experimental Design and Layout

The experiment was carried out in a Completely Randomized Design (CRD).

Parameters Measured

Chemical Analysis

Moisture, crude protein, crude fat, ash and mineral contents of the samples were determined according to A.O.A.C (2000).

Sensory Evaluation

The grilled pork samples were served to a 10-member panel of undergraduate students of the Department of Animal Science for the evaluation of the palatability attributes. One gram of the grilled pork from each treatment was served to the panelist. The panelists were pre-trained in the general procedure for evaluating the samples. Parameters such as flavor, juiciness, tenderness and overall acceptability of meat and colour were evaluated using a 9-point hedonic scale (1= extremely poor, and 9 = extremely desirable, extremely juicy, extremely easy, extremely loose, extremely absent, extremely like, extremely light respectively). Panelists were required to cleanse their palate between samples with water and cracker biscuits.

Statistical Analysis

Data generated from the experiment were subjected to analysis of variance (ANOVA) where significant differences occurred, the means were separated using Duncan Multiple Range Test (DMRT) on the SPSS version 20.0 (IBM SPSS, 2011).

Results and Discussion

Proximate Composition of Grilled Pork Meat Samples with Turmeric Powder

The Proximate composition of grilled pork marinated in turmeric powder is shown on Table 1. The moisture content of the grilled pork samples exhibited a significant ($p < 0.05$) linear decrease as the concentration of turmeric powder increased, ranging from 10.94% in the control (T₁) to 7.40% in the highest treatment group (T₄). This inverse relationship suggests that turmeric powder, in its dehydrated form, acts as a hygroscopic agent. During the marination and subsequent grilling process, the dry turmeric particles likely exerted osmotic pressure on the meat myofibrils, drawing internal water to the surface where it was more readily evaporated by the intense thermal radiation of the grill. Reduction in moisture content enhances the shelf-life of the product as low amount of

moisture in meat products inhibit microbial activity and chemical reactions that could lead to food quality deterioration (Gomez, *et al.*, 2020).

Furthermore, this reduction in moisture can be attributed to the dilution effect; as the proportion of dry matter (turmeric) increased in the meat matrix, the relative percentage of water naturally declined. From a food safety perspective, this reduction is highly advantageous for street-vended foods. Lower moisture levels correlate with reduced water activity (a_w), which serves as a critical barrier against microbial proliferation and lipid oxidation during ambient storage (Gomez *et al.*, 2020). However, while the lower moisture in T₄ (7.40%) optimizes shelf-stability, it may present a trade-off in sensory juiciness.

The crude protein content also increased ($p < 0.05$) significantly across treatment groups. Treatment 4 had the highest crude protein content (16.22 ± 0.03) and was significantly ($p < 0.05$) different from T₁ which had the least value (15.88 ± 0.23). T₂ (16.00 ± 0.01) and T₃ (16.10 ± 0.03) were significantly ($p > 0.05$) similar. This may be attributed to the concentration effect resulting from the significant loss of moisture during the grilling process. As water evaporated from the meat matrix, the relative proportion of nitrogenous compounds increased within the remaining dry matter (Fakolade, 2008). Furthermore, the antioxidant properties of curcumin may have played a protective role; by scavenging free radicals generated during high-heat grilling, turmeric potentially mitigated protein oxidation and the subsequent degradation of myofibrillar proteins. This suggests that turmeric marination not only maintains but may help concentrate the protein density of street-vended pork, enhancing its value as a functional protein source.

The fat content in T₄ (8.76%) was significantly ($p < 0.05$) higher than T₁ (8.21 ± 0.09), T₂ (8.39 ± 0.00) and T₃ (8.39 ± 0.03) while, T₁ (8.21 ± 0.09), T₂ (8.39 ± 0.00) and T₃ (8.39 ± 0.03) were significantly ($p > 0.05$) similar. This may be due to the concentration of the dry matter with decrease of moisture. Beyond the concentration of nutrients due to moisture loss, this increase may be influenced by the intrinsic lipid content of turmeric powder itself, which contains approximately 5–10% volatile and non-volatile oils (Jaiswal and Naik, 2021). From a sensory perspective, the higher fat retention in T₄ is essential as intramuscular fat acts as a thermal insulator and lubricant during mastication potentially masking the physical loss of water and maintaining consumer acceptability.

The ash content was significantly ($p < 0.05$) higher in T₄ (5.94 ± 0.06) compared to T₃ (4.71 ± 0.10), T₂ (4.32 ± 0.15) and T₁ (4.14 ± 0.10). This increase is a direct reflection of the mineral-rich profile of *Curcuma longa*, which is abundant in essential elements such as potassium, magnesium, iron, and calcium (Prasad and Aggarwal, 2011). The results suggest a synergistic fortifying effect: the turmeric powder acts as an external mineral source while simultaneously forming protein–mineral complexes that may reduce the leaching of endogenous minerals in the "drip loss" during grilling. This finding validates the use of turmeric as a natural fortificant, transforming a common street food into a more nutrient-dense meal capable of addressing micronutrient deficiencies in urban populations.

Table 1: Proximate composition of grilled pork marinated with Turmeric powders

Parameters	T ₁ (0g)	T ₂ (25g)	T ₃ (50g)	T ₄ (75g)
Moisture	10.94 ± 0.25 ^a	8.97 ± 0.14 ^b	8.58 ± 0.15 ^c	7.40 ± 0.02 ^d
Crude Protein	15.88 ± 0.23 ^b	16.00 ± 0.01 ^{ab}	16.10 ± 0.03 ^{ab}	16.22 ± 0.03 ^a
Crude Fat	8.21 ± 0.09 ^b	8.39 ± 0.00 ^b	8.39 ± 0.03 ^b	8.76 ± 0.17 ^a
Ash	4.14 ± 0.10 ^c	4.32 ± 0.15 ^c	4.71 ± 0.10 ^b	5.94 ± 0.06 ^a

^{ab} Means with different superscript in the same row are significantly (p<0.05) different

Mineral Composition of Grilled Pork Marinated in Turmeric Powder

The mineral composition of grilled pork marinated in Turmeric powder is presented in Table 2. There were significant (p>0.05) differences in all minerals assessed across the treatments. Sodium, Potassium, Magnesium calcium and iron all exhibited an increasing trend as the levels of Turmeric increased. This increase could be attributed to Turmeric powder as it is known to be rich in minerals (Olayinka, 2024). This linear increase in mineral content correlates with the high Ash content of Turmeric marinated grilled pork obtained in this study as ash content deduces a rough estimation of the mineral content of the product. The sodium content of T₄ (85.90mg/100g), having the highest value, was significantly (p<0.05) different from all other treatments (T₁, T₂, and T₃). Furthermore, T₂ (79.82mg/100g) and T₃ (81.22mg/100g) were statistically similar, but both were significantly (p<0.05) different from the T₁ (78.75mg/100g) which was the control. Potassium content in T₄(520.92mg/100g) was significantly (p<0.05) higher than T₁(380.08mg/100g), T₂(398.84mg/100g) and T₃(483.50mg/100g). Potassium has been reported to play vital role in maintaining fluid balance and proper functioning of the essential organs such as brain, nerves, heart and muscle (Toft *et al.*, 2024). Potassium aids nerve impulse transmission and it is a major cation of intracellular fluid. Same trend was seen in Magnesium with T₄(72.74mg/100g) being significantly (p<0.05) different from T₁(30.27mg/100g), T₂(43.87mg/100g) and T₃(51.90mg/100g). Magnesium provides strength to the bone, aids enzymatic action and helps with heart functions. The result from the calcium content of the samples indicates that T₄(69.65mg/100g) was significantly (p<0.05) higher than T₁(40.38mg/100g), T₂(45.95mg/100g) and T₃(52.38mg/100g). Calcium had been reported to play a major role in muscle contraction, building strong bones and teeth, blood clotting, nerve impulse, transmission, regulating heartbeat and fluid balance within cells (Yu & Sharma, 2023). It has also been identified to play a major role in managing blood pressure and preventing breast cancer. Iron content also exhibited T₄ (42.80mg/100g) being significantly (p<0.05) different from T₁ (17.23mg/100g), T₂ (21.18mg/100g) and T₃ (30.90mg/100g). Iron deficiency is a significant issue in human diets in underdeveloped nations, particularly for pregnant women and young children (0-5 years) (Van Huis *et al.*, 2013). The incorporation of turmeric into pork meat can help reduce iron deficiency disease in the world. Iron is involved in strengthening the immune system. Iron is the functional component of haemoglobin and other key compounds used in respiration, immune function and cognitive development. Therefore, addition of turmeric powder improves the mineral content of the grilled pork.

Table 2: Mineral composition of grilled pork meat marinated with Turmeric powder

Parameters	T1(0g)	T2 (25g)	T3 (50g)	T4(75g)
Na	78.75 ± 0.23 ^d	79.82 ± 0.04 ^b	81.22 ± 0.25 ^b	85.90 ± 0.13 ^a
K	380.08 ± 1.99 ^d	398.84 ± 1.83 ^c	483.50 ± 6.39 ^b	520.92 ± 0.76 ^a
Mg	30.27 ± 0.49 ^d	43.87 ± 1.22 ^c	51.90 ± 0.26 ^b	72.74 ± 2.53 ^a
Ca	40.38 ± 0.60 ^d	45.95 ± 0.23 ^c	52.38 ± 0.50 ^b	69.65 ± 0.72 ^a
Fe	17.23 ± 0.55 ^d	21.18 ± 0.86 ^c	30.90 ± 0.83 ^b	42.80 ± 1.02 ^a

^{a-d} means with the superscript in the row are significantly different ($p < 0.05$).

Sensory Evaluation

Table 3 shows the Sensory evaluation of grilled pork samples marinated with different levels of Turmeric powder. Flavour, juiciness, ease of fragmentation, apparent adhesion, residue after chewing, acceptability and colour were assessed.

There was a significant ($p > 0.05$) linear decrease in flavour scores as the levels of turmeric increased. T4 (2.50 ± 0.52) had the least flavor score while T1 (6.53 ± 0.40) had the highest flavor score. The flavour of the control samples was 'moderately desirable' compared to T4 which was 'very undesirable'. This could be attributed to the earthly flavour of turmeric which could be more intense when added in large quantity.

Although some studies have reported that Turmeric enhances flavour in meat (Augustyńska-Prejsnar, *et al.*, 2022; Hermawan, *et al.*, 2024) while others reported no effect of turmeric on the organoleptic properties of the meat (Khodadadi, *et al.*, 2021). This variation may be due to the mode and forms of application of the turmeric powder.

There were no significant ($p > 0.05$) differences in scores of Juiciness, Ease of Fragmentation and Residue after chewing. Junior *et al.*, (2019) also reported that turmeric had no effect on other sensory properties of mortadella. The scores for Apparent adhesion varied across the treatment groups. T4 (7.07 ± 1.15) was significantly ($P < 0.05$) higher than T1 (5.03 ± 0.76), T2 (4.93 ± 0.83), and T3 (4.90 ± 0.76) while T1, T2, T3 were similar. This may be attributed to the activities of proteolytic enzymes present in Turmeric as noted by Seizing *et al.*, 2020. Proteolytic enzymes break down protein thereby tenderizing meat. Apparent adhesion refers to the stickiness of the meat fibers during mastication and it is an indicator of tenderness. In terms of acceptability, the result shows significant variation across the treatment groups. The control samples (T1-6.17 ± 0.12) were rated highest, T4 (3.27 ± 1.55) had the least rating while T2 (5.13 ± 0.31) was similar to T1 and T3 (4.30 ± 0.10) was also similar to T4. It is evident from the result that as the levels of turmeric inclusion increase, the consumers appreciation of the turmeric marinated grilled pork decrease.

Colour is an attribute that affects the acceptance of meat and meat products by consumers. The colour ratings in this study varied across the treatment groups. T1 (6.20 ± 0.31) was significantly ($P < 0.05$) different from T2 (4.27 ± 0.32), T3 (3.17 ± 0.15) and T4 (1.60 ± 0.72). This result is akin to the works of Milon *et al.*, (2016) and Junior *et al.*, (2019), who reported unacceptable colour with increased turmeric addition in value added meatballs and lower colour rating of mortadella with addition of microcrystalline turmeric respectively.

Table 3: Sensory evaluation of grilled pork meat samples with Turmeric powder

PARAMETERS	T ₁ (0g)	T ₂ (25g)	T ₃ (50g)	T ₄ (75g)
Flavour	6.53 ± 0.40 ^a	5.00 ± 0.26 ^b	3.73 ± 0.58 ^c	2.50 ± 0.52 ^d
Juiciness	5.73 ± 0.76 ^a	6.43 ± 0.8 ^a	6.30 ± 0.36 ^a	6.23 ± 0.20 ^a
Ease of fragmentation	6.43 ± 0.61 ^a	5.67 ± 0.37 ^a	6.13 ± 0.21 ^a	6.53 ± 1.53 ^a
Apparent adhesion	5.03 ± 0.76 ^b	4.93 ± 0.83 ^b	4.90 ± 0.76 ^b	7.07 ± 1.15 ^a
Residue after chewing	4.13 ± 0.32 ^a	4.03 ± 0.72 ^a	4.60 ± 1.25 ^a	5.6 ± 1.39 ^a
Acceptability	6.17 ± 0.12 ^a	5.13 ± 0.31 ^{ab}	4.30 ± 0.10 ^{bc}	3.27 ± 1.55 ^c
Colour	6.20 ± 0.31 ^a	4.27 ± 0.32 ^b	3.17 ± 0.15 ^c	1.60 ± 0.72 ^d

^{a-d} Means with the same superscript in the row are not significantly different (p < 0.05)

Conclusion

This study evaluated the effect of incorporating Turmeric powder as a natural marinade on the proximate composition, mineral content, and sensory attributes of grilled pork. The proximate analysis showed that addition of Turmeric at the highest level of Inclusion (75g) in T₄ reduced Moisture while crude protein and crude fat were concentrated. It also proportionately increased the ash content, which was obvious in the mineral analysis, showing an increase in all minerals assessed. These resulted in the most nutritionally superior product. However, the sensory evaluation showed that the turmeric-treated samples maintained comparable juiciness and ease of fragmentation to the control, while increasing turmeric levels led to a significant and proportional decline in Flavour, Colour, and Overall Acceptability scores. The panelists strongly preferred the control sample's flavour and colour, over the highest inclusion level (T₄).

Therefore, while turmeric powder is highly effective at enhancing the nutritional profile (proximate and mineral composition) of grilled pork, its inclusion must be carefully managed to prevent negative sensory impact. Future research should focus on combining turmeric with other flavour masking agents to maximize nutritional benefits.

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