

Development and Evaluation of Spiced Meat (Beef and Chicken) Powder as a Flavour Enhancer for Culinary Applications

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DOI: <https://doi.org/10.62154/ajasfr.2025.021.01027>

Abstract

This study developed and evaluated shelf-stable spiced beef and chicken meat powders as natural flavour enhancers for culinary applications. Raw and boiled beef and chicken were dehydrated under controlled conditions, milled into fine powders, and blended with a standardized spice formulation consisting of black pepper (5 g), ginger (10 g), paprika (10 g), garlic powder (5 g), onion powder (5 g), and cumin (10 g) per 100 g of meat powder. Unspiced raw beef and chicken powders were used as controls. Comprehensive analyses were performed to determine proximate composition, energy value, physicochemical characteristics, mineral profile, microbial quality, and sensory acceptability. The results demonstrated that spicing slightly reduced acidity while maintaining high nutritional quality. Beef powders contained 62.50–78.75% protein, 7.94–23.61% carbohydrate, 5.42–5.43% lipid, 2.10–2.23% fibre, 2.89–3.27% ash, and 2.38–3.48% moisture, whereas chicken powders showed 59.10–75.20% protein, 7.61–22.15% carbohydrate, 5.09–8.01% lipid, 2.81–3.53% fibre, 4.14–5.26% ash, and 2.23–4.87% moisture. All samples were energy-dense, providing 370.81–403.33 kcal/100 g. Mineral analysis revealed appreciable levels of iron, sodium, calcium, and zinc, with spiced formulations exhibiting relatively higher sodium and calcium contents. Microbial assessment over six days showed minimal variation in microbial load and no detectable major foodborne pathogens, indicating product stability and safety. Sensory evaluation using a nine-point hedonic scale indicated a significant preference for beef-based powders, particularly the unspiced raw beef control. Consequently, the developed meat powders exhibited favourable nutritional composition, microbiological safety, and consumer acceptability. These findings support their potential use as convenient, nutrient-dense flavour enhancers in soups, sauces, and ready-to-prepare foods, providing a scientific basis for value-added meat products that meet growing demand for quick and functional protein ingredients.

Keywords: Raw Meat, Spices, Microbiological Load, Nutritional Composition and Herbs.

Introduction

Meat remains a major component of the human diet across many cultures (Sans *et al.*, 2015). It is predominantly derived from animal skeletal muscle and is characterized by substantial quantities of high-quality animal protein and saturated fatty acids, particularly

oleic acid (USDA, 2023). Globally, poultry, pork, and beef account for approximately 85% of total meat consumption (Food and Agriculture Organization, 2023). Epidemiological studies commonly classify meat into three categories: white meat (e.g., poultry), red meat (e.g., beef, pork), and processed meat (e.g., sausages, cured meats) (Smith *et al.*, 2020). With continued global population growth, meat consumption is projected to rise correspondingly (Bohrer, 2017). In most countries, consumption has increased steadily since the 1960s, with particularly sharp growth from the 1980s onward. Estimates indicate a 204% increase in meat supply between 1960 and 2010 (Basu, 2015), while more recent analyses report increases as high as 500% between 1992 and 2016 (Katare *et al.*, 2020). Collectively, these trends reflect major shifts in dietary patterns over the past century. Whereas protein availability in the 1960s was largely plant-based primarily from cereals such as wheat current data show that approximately 58% of available protein now derives from animal sources. Meat alone contributes about 28 g of protein per person per day, representing roughly 30% of daily caloric intake (Bonnet *et al.*, 2020). Livestock species such as cattle, pigs, poultry, and sheep remain the principal sources of meat globally (Lee *et al.*, 2023), with poultry and pork showing the highest rates of consumption growth (Basu, 2015; Milford *et al.*, 2019). Between 2014 and 2016, per capita global meat consumption averaged 34.1 kg/year, nearly 60% of which was red meat (Salter, 2018). FAO data indicate that global average meat consumption reached 43 kg per person in 2017 and is projected to rise to approximately 45 kg by 2030. Meat powder has emerged as a convenient, shelf-stable ingredient used in soups, stews, sauces, and seasonings. Its increasing demand is attributed to ease of handling, long shelf life, and preservation of nutritional value. While fresh meat is highly perishable due to its high moisture content, drying and powdering provide a stable alternative that can be incorporated into a wide variety of food products while maintaining essential protein quality.

Spices, traditionally defined as products that enhance or modify the sensory qualities of foods (Rosengarten, 1969), include a diverse range of plant-derived materials barks, leaves, roots, seeds, flowers, and fruits. They impart characteristic flavour, aroma, colour, and palatability (Abebe *et al.*, 2023) and are valued for both culinary and nutritional purposes. Their increasing global consumption is driven partly by growing awareness of associated health benefits (Bhathal *et al.*, 2020). As of 2023, China and India remain leading exporters of spices, with export values of approximately USD 641 million and USD 509 million, respectively (OEC, 2023; IBEF, 2023). In meat systems, spices, seasonings, and flavourings are essential for developing desirable sensory attributes (Sanusi *et al.*, 2023). They serve multiple functions, including flavour enhancement, preservation, colour development, and medicinal applications (Otunola *et al.*, 2022). Many spices exhibit antimicrobial, antifungal, antiviral, and antioxidant properties, enabling their use as natural preservatives, particularly in meat products. For example, cinnamon has been proposed as a natural alternative to synthetic preservatives, while spices such as coriander, fennel, turmeric, and cloves are associated with diverse therapeutic effects, including improved glycaemic control and treatment of certain skin and dental conditions (worldofspices, 2018). The incorporation of spices and herbs into meat powder offers potential for developing value-added products

with enhanced flavour, aroma, shelf stability, and nutritional quality. Their bioactive properties may further improve oxidative stability and microbial safety, making spiced meat powder a promising ingredient in modern food systems. The objective of this study was to develop and evaluate spiced beef and chicken meat powders for use as natural flavour enhancers in culinary applications.

Materials and methods

Material Procurement

Raw meat (chicken and beef) and spices (black pepper, ginger, paprika powder, garlic, onion, cumin) used for the production of spiced meat powder were purchased from Akpan Andem main market, Uyo, Akwa Ibom state, Nigeria. The samples were prepared in the Food Processing Laboratory, in the Department of Food Science and Technology, University of Uyo. All reagents used in this study were of analytical grade and were obtained from the Department of Food Science and Technology, University of Uyo, Uyo.

Preparation of Powdered Spices

Fresh ginger rhizomes, garlic cloves, and onions were washed thoroughly and peeled using a stainless-steel knife. The peeled materials were sliced into smaller pieces and dried in a Uniscope SM 9053 laboratory oven at 50 °C until adequate moisture removal was achieved. Black pepper, ginger, garlic, onion, and cumin were subsequently milled into fine powders using a Panasonic MX-AC210S electric blender and sieved to eliminate lumps and coarse particles. The resulting spice powders were packaged in airtight containers and stored until use.

Production of Meat Powder

This procedure was adapted from Argyri *et al.* (2017) with modifications. Fresh chicken and beef were cut into thin slices to facilitate drying and placed in a Uniscope SM 9053 laboratory oven at 65 °C. After drying, the meat slices were milled using a Panasonic MX-AC210S blender and sieved with a plastic mesh to obtain fine meat powder.

Incorporation of Spices

The prepared spice powders were incorporated into both chicken and beef powders by dry blending in a blender. The spiced meat powders were then packaged in airtight jars and stored under refrigeration.

Table 1: Formulation of Chicken and Beef Powder Samples

Sample Code	Meat Type	Processing Method	Spice Addition
C1	Chicken	Oven-dried → Ground	None (Control)
C2	Chicken	Oven-dried → Ground	Spices added
C3	Chicken	Boiled → Oven-dried → Ground	Spices added
B1	Beef	Oven-dried → Ground	None (Control)

Sample Code	Meat Type	Processing Method	Spice Addition
B2	Beef	Oven-dried → Ground	Spices added
B3	Beef	Boiled → Oven-dried → Ground	Spices added

Table 2: Formulation of Chicken and Beef Powder Samples

Spice	Quantity (g/100 g meat powder)
Black pepper	5 g
Ginger	10 g
Paprika	10 g
Garlic powder	5 g
Onion powder	5 g
Cumin	10 g

Method of Analysis

Physicochemical Analysis

The determination of pH of the meat powder samples was conducted using the AOAC (2023) Official Methods while the Total Titratable acidity (TTA) of the meat powders was determined according to the method described by the Association of Official Analytical Chemists (AOAC, 2000).

Proximate Analysis of Sample

The proximate composition of the spiced meat powder was determined using the standard analytical methods outlined by the Association of Official Analytical Chemists (AOAC). Protein, moisture and ash contents were determined using the method of AOAC (2010), while fibre content was determined using AOAC (1995) method. Lipid content was the method of AOAC (2019), but for carbohydrate and energy the method of AOAC (2023) was used.

Mineral Analysis

Minerals were determined using the Atomic Absorption Spectrometry (AAS) A. Analyst 400, USA. and flame photometry methods of AOAC (2023).

Microbial Analysis

Microbial analysis of the powdered meat samples was conducted using standard pour plate and spread plate techniques for the isolation of bacteria and fungi, respectively. Serial dilutions were prepared following the procedure described by Cheesbrough (2004). Microbiological examination was performed using standard methods outlined by Prescott *et al.* (2004). A series of biochemical and morphological characterization tests including Gram staining, catalase, coagulase, motility, starch hydrolysis, methyl red, Voges–Proskauer, oxidase, citrate utilization, urease, spore staining, hydrogen sulfide production, and carbohydrate fermentation were carried out to identify the isolates. Final identification of pure cultures was based on cultural, morphological, and physiological characteristics,

and compared with descriptions provided in *Bergey's Manual of Determinative Bacteriology* (Cowan, 1974; Buchanan *et al.*, 1974).

Sensory Evaluation

The sensory properties (appearance, aroma, taste, texture, after taste, overall acceptability) of the spiced meat powders were assessed by twenty (20) semi-trained (briefed about the product and how to use the hedonic scale to evaluate the samples) panellists from the Department of Food Science and Technology, Faculty of Agriculture, University of Uyo, Uyo using a nine-point Hedonic scale as described by Ihekoronye *et al.*, (1985), ranging from 9 (like extremely) to 1 (dislike extremely).

Statistical Analysis

All experiments were carried out in triplicate. The data obtained were subjected to statistical analysis of variance (ANOVA) using the Statistical Package for Social Statistics (SPSS Version 20). Means were separated with the use of Duncans New Multiple Range Test (DNMRT) and significance was accepted at 95% confidence interval.

Results and Discussion

Physico-Chemical Composition of the Meat Powder Samples

The meat powder samples exhibited generally low pH values (<7), consistent with the natural postmortem acidification of meat. Following slaughter, glycogen in muscle tissue is converted to lactic acid through postmortem glycolysis, resulting in a decline in pH from approximately 7.0 in living muscle to an ultimate pH between 5.4 and 5.8, depending on species and processing conditions (Terlouw *et al.*, 2021). Beef powders showed higher pH values and lower total titratable acidity (TTA) compared to chicken powders. This observation is consistent with the characteristics of red meat, which typically undergoes less lactic acid accumulation and therefore exhibits higher ultimate pH than white meat. Chauhan *et al.* (2019) similarly reported reduced pH decline in oxidative muscle despite adequate glycogen availability. Boiled samples recorded the highest pH values, reaching 6.73 in beef powder and 6.72 in chicken powder. This may be attributed to the leaching of water-soluble acids, such as lactic acid and other organic acids, during boiling, which subsequently reduces TTA and elevates pH. Quayson *et al.* (2021) also noted that blanching and soaking processes facilitate the leaching of soluble compounds, improving drying efficiency and altering chemical profiles. Spiced samples exhibited higher pH values than their respective controls. Spices such as garlic, ginger, and black pepper possess antimicrobial properties; their inhibitory effects on lactic acid bacteria and other fermentative microorganisms may reduce post-processing acidification, thereby limiting further pH decline during storage (Banik *et al.*, 2022).

Table 3: Physico-Chemical Composition of Meat Powder Samples

Sample	pH	TTA (%)
Raw beef powder (control)	6.66 ^c ± 0.001	1.36 ^c ± 0.001
Spiced raw beef Powder	6.68 ^c ± 0.000	1.34 ^c ± 0.003
Spiced boiled beef Powder	6.73 ^a ± 0.002	0.72 ^e ± 0.001
Raw chicken powder (control)	6.45 ^e ± 0.001	1.94 ^a ± 0.002
Spiced raw chicken Powder	6.54 ^d ± 0.002	1.68 ^b ± 0.001
Spiced boiled chicken Powder	6.72 ^b ± 0.002	0.80 ^d ± 0.000

Values are mean ± Standard deviation of 3 replicate determinations. Means differently superscripted along columns are significantly different ($P < 0.05$).

Key: TTA: Total Titratable Acidity.

Proximate Composition of the Meat Powder Samples

Table 2 presents the proximate composition moisture, ash, fibre, protein, lipid, and carbohydrate of the meat powder samples. The control samples exhibited the lowest moisture contents (2.38% in beef and 2.23% in chicken). In contrast, the spiced raw samples showed the highest moisture contents within each meat type (4.41% in beef and 5.04% in chicken). This increase is likely attributable to the hygroscopic nature of many spices, such as garlic, ginger, onion, clove, and black pepper, which contain moisture-retaining carbohydrates, fibres, and essential oils (Mousavi *et al.*, 2019). The lower moisture content observed in the spiced boiled samples may be due to protein denaturation and muscle fibre shrinkage during boiling, which facilitates water loss prior to drying (Zhao *et al.*, 2020). Overall, the moisture ranges of 2.23–5.04% is advantageous, as low moisture reduces water activity, inhibits microbial growth, and enhances product stability and shelf life (Yin *et al.*, 2022). Reduced moisture also contributes to decreased packaging and transportation costs due to lower bulk density (Joardder *et al.*, 2017). Ash content was generally higher in chicken powders than in beef powders, with the spiced boiled chicken powder having the highest ash value (5.26%). This trend aligns with findings by Naveena *et al.* (2017), who noted that white meat (chicken) typically contains higher levels of minerals and phosphate groups than red meat (beef), reflecting differences in muscle fibre type and biochemical composition.

Fibre content ranged from 2.10% to 3.72%, with the spiced raw samples exhibiting the highest values. This is expected because spices contribute additional plant-based dietary fibre (Srinivasan *et al.*, 2016), and the absence of boiling minimizes fibre loss through leaching and thermal degradation (Kumar *et al.*, 2017). Dietary fibre plays an essential role in digestive health by increasing faecal bulk, promoting regular bowel movements, and preventing constipation (Stephen *et al.*, 2017). All samples demonstrated high protein contents, consistent with the protein-rich nature of meat. Protein supports muscle growth and repair, enzymatic regulation, immune function, and tissue maintenance (Wu *et al.*, 2016). Deficiency in dietary protein can lead to severe malnutrition disorders, including kwashiorkor characterized by oedema and fatty liver and marasmus, marked by extreme wasting (FAO *et al.*, 2019; UNICEF, 2021). Lipid contents ranged from 5.09% to 10.66%. Moderate lipid levels are desirable, as they maintain product stability while reducing susceptibility to oxidative rancidity, which is more pronounced in high-fat foods (Zamora *et al.*, 2016). Carbohydrate content was lowest in the control samples and highest in the spiced boiled samples. Carbohydrate levels largely reflect residual muscle glycogen (Zhao *et al.*, 2021) and additional carbohydrates contributed by spices. Carbohydrates serve as a primary energy source for the body, supplying essential fuel for highly glucose-dependent tissues such as the brain and red blood cells (Van *et al.*, 2018). The energy content of the meat powder samples ranged between 370.81 and 403.33 kcal/100 g, reinforcing previous reports that meat is a highly nutrient-dense and energy-rich component of the human diet (Pereira *et al.*, 2019).

Table 4: Proximate Composition of Meat Powder Samples

Sample	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	Lipid (%)	CHO (%) (kcal/100g)	Energy
Raw beef powder (control)	2.38 ^d ± 0.001	3.27 ^d ± 0.002	2.23 ^e ± 0.001	78.75 ^a ± 0.015	5.43 ^c ± 0.002	7.94 ^e ± 0.005 ± 0.006	395.36 ^c
Spiced raw Beef Powder	4.41 ^c ± 0.001	3.75 ^c ± 0.001	2.55 ^d ± 0.002	65.80 ^d ± 0.020	7.35 ^b ± 0.003	16.14 ^c ± 393.91 ^d ± 0.010	0.004
Spiced boiled beef Powder	3.48 ^{cd} ± 0.002	2.89 ^e ± 0.002	2.10 ^f ± 0.001	62.50 ^e ± 0.010	5.42 ^c ± 0.002	23.61 ^a ± 393.22 ^d ± 0.012	0.003
Raw chicken	2.23 ^{de} ± 0.001	4.14 ^b ± 0.003	2.81 ^c ± 0.002	75.20 ^b ± 0.025	8.01 ^b ± 0.004	7.61 ^e ± 403.33 ^a ± 0.006	0.005

Sample	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	Lipid (%)	CHO (%) (kcal/100g)	Energy
Powder (control)							
Spiced raw chicken Powder	5.04 ^a ± 0.002	4.99 ^a ± 0.001	3.72 ^a ± 0.001	63.20 ^e ± 0.015	10.66 ^a ± 0.003	12.39 ^d ± 398.30 ^b ± 0.010	0.004
Spiced boiled chicken Powder	4.87 ^b ± 0.001	5.26 ^a ± 0.002	3.53 ^b ± 0.000	59.10 ^f ± 0.010	5.09 ^c ± 0.002	22.15 ^b ± 370.81 ^e ± 0.015	0.003

Values are mean ± Standard deviation of 3 replicates determination. Means differently superscripted along columns are significantly different (p<0.05).

Key: CHO – Carbohydrate.

Mineral Composition of Meat Powder Samples

The mineral analysis revealed notable variations among the meat powder samples. The raw beef powder (control) contained the lowest iron (Fe) concentration, whereas the raw chicken powder (control) exhibited the highest iron level, followed closely by the spiced boiled chicken powder and the spiced raw beef powder. Iron is a critical component of hemoglobin, which facilitates oxygen transport in red blood cells, and of myoglobin in muscle tissues, where it supports oxygen storage and muscle activity (StatPearls Contributors, 2025). Sodium (Na) levels were generally high across all samples. The control samples recorded the lowest sodium concentrations—37.69 mg/100 g in raw beef powder and 42.78 mg/100 g in raw chicken powder. In contrast, the spiced samples contained substantially higher sodium levels, ranging from 54.96 mg/100 g to 65.61 mg/100 g. Sodium is an essential electrolyte involved in fluid balance, nerve impulse transmission, and normal muscle function. Sodium deficiency (hyponatremia) disrupts action potential generation, impairing neuromuscular function (Guyton *et al.*, 2016), and can disturb osmotic balance, leading to cellular swelling and potentially cerebral oedema (Gankam *et al.*, 2023). Calcium (Ca) content was generally higher than most other minerals in the meat powders, with the exception of the spiced boiled beef and spiced raw chicken powders, where sodium exceeded calcium levels. The spiced boiled chicken powder recorded the highest calcium concentration (216.00 mg/100 g). Calcium requirements are elevated during adolescence due to rapid skeletal growth, and in older women due to postmenopausal bone loss and increased risk of osteoporosis. Adequate calcium intake is vital for bone and dental health, muscle contraction, nerve signaling, and blood coagulation (Cashman *et al.*, 2022; Weaver, 2016). For zinc (Zn), the raw chicken powder (control) had the lowest content (3.98 mg/100 g), while the spiced boiled chicken powder had the highest (6.05 mg/100 g). Zinc is essential for brain development, neurotransmission, and the regulation of cognitive and mood

functions (Bonaventura *et al.*, 2015). It also supports tissue repair and plays a key role in maintaining skin integrity and promoting wound healing (Liu *et al.*, 2017).

Table 5: Mineral Composition of Meat Powder Samples

Sample	Fe (mg/100 g)	Na (mg/100 g)	Ca (mg/100 g)	Zn (mg/100 g)
Raw beef powder (control)	0.111 ^f ± 0.001	37.69 ^f ± 0.003	72.00 ^c ± 0.010	4.86 ^d ± 0.003
Spiced raw beef Powder	0.202 ^c ± 0.002	65.61 ^a ± 0.005	96.00 ^b ± 0.011	5.11 ^c ± 0.005
Spiced boiled beef Powder	0.133 ^e ± 0.003	58.17 ^c ± 0.002	48.00 ^d ± 0.015	4.61 ^e ± 0.004
Raw chicken Powder (control)	0.250 ^a ± 0.001	42.78 ^e ± 0.004	48.30 ^d ± 0.012	3.98 ^f ± 0.003
Spiced raw chicken Powder	0.186 ^d ± 0.002	54.96 ^d ± 0.005	24.00 ^e ± 0.020	5.15 ^b ± 0.004
Spiced boiled chicken Powder	0.216 ^b ± 0.003	61.74 ^b ± 0.004	216.00 ^a ± 0.100	6.05 ^a ± 0.005

Values are mean ± Standard deviation of 3 replicates determination. Means differently superscripted along columns are significantly different ($p < 0.05$).

Key: Fe – Iron, Na – Sodium, Ca – Calcium, Zn – Zinc

Microbial Load of Meat Powder Samples

The microbial stability of the different meat powder samples was monitored over a six-day storage period. Throughout the entire duration, Salmonella–Shigella Count (SSC), Vibrio Count (VC), and Reinforced Clostridial Count (RCC) were not detected in any of the samples. The absence of these pathogens can be attributed primarily to the low water activity of the meat powders. Pathogenic microorganisms such as *Salmonella spp.*, *Shigella spp.*, *Vibrio spp.*, and several *Clostridium spp.* are unable to proliferate below specific water-activity thresholds, making water activity a critical determinant of food safety (Agriculture Institute, 2023). Drying and powdering of meat substantially reduce free water availability, thereby lowering water activity to levels that inhibit the growth and survival of these organisms, as reflected by the low moisture contents of the meat powders (Table 2). Under

such conditions, pathogens, even if initially present, may become non-culturable or die off entirely. On Day 1, all six samples exhibited Total Heterotrophic Bacterial Count (THBC). The raw beef powder (control) and spiced boiled chicken powder recorded the highest counts (2.5×10^6 CFU/g), whereas the raw chicken powder (control) showed the lowest count (1.7×10^6 CFU/g). Although low water activity suppresses many pathogenic bacteria, several heterotrophic bacteria—including *Bacillus*, *Micrococcus*, *Staphylococcus*, and *Corynebacterium* species are relatively tolerant of low-moisture environments and may persist in dormant or spore forms. In particular, spores of *Bacillus* and *Clostridium* species exhibit high resistance to heat and dehydration and can remain viable in powdered meat products after processing (Cho *et al.*, 2020). With respect to Total Coliform Count (TCC), all samples except the raw chicken powder (control) showed detectable growth on Day 1, with the spiced boiled chicken powder recording the highest value (1.6×10^6 CFU/g). The presence of coliforms in most samples likely indicates environmental or processing contamination, as coliform bacteria are commonly associated with water, equipment surfaces, air, and handling practices, and are widely used as indicators of hygiene during food processing (Martin *et al.*, 2016). Fecal coliforms (FC) were absent in the raw beef powder (control), spiced boiled beef powder, and raw chicken powder (control) on Day 1, whereas the spiced boiled chicken powder showed the highest FC count (2.0×10^5 CFU/g). Staphylococcus Count (SC) was detected only in the raw beef powder (control) and spiced raw chicken powder on Day 1. In addition, all samples contained Fungal Count (FUC), with the spiced boiled chicken powder recording the highest value (3.0×10^4 CFU/g), while the raw chicken powder (control) and spiced raw beef powder had the lowest counts (1.0×10^4 CFU/g).

By Day 6, THBC remained at 2.5×10^6 CFU/g in both the raw beef powder (control) and spiced boiled chicken powder, while the raw chicken powder (control) increased to the same level. The spiced raw chicken powder recorded the lowest THBC (2.3×10^6 CFU/g). Total coliform counts were highest in the spiced raw chicken powder, whereas the raw chicken powder (control) continued to show no coliform growth. Fecal coliforms remained absent in the raw beef powder (control), spiced boiled beef powder, and raw chicken powder (control), while the spiced boiled chicken powder consistently exhibited the highest FC count (1.9×10^5 CFU/g). No SC growth was observed in the spiced raw beef, spiced boiled beef, raw chicken (control), and spiced boiled chicken powders on Day 6; however, the raw beef powder (control) recorded the highest SC (2.4×10^5 CFU/g). All samples still contained fungi, with the raw beef powder (control) and spiced raw chicken powder having the highest fungal counts (4.0×10^4 CFU/g), while the raw chicken powder (control) maintained the lowest count (1.0×10^4 CFU/g). Regarding microbial diversity, the spiced raw beef powder exhibited the highest occurrence of microbial isolates on Day 1, whereas the spiced boiled beef, raw chicken (control), and spiced raw chicken powders showed the least. By Day 6, the raw beef powder (control) had the highest occurrence of microbial isolates, while the raw chicken powder (control) consistently recorded the lowest, followed by the spiced raw beef and spiced boiled chicken powders. The elevated microbial load observed in spiced samples may be linked to the use of spices, which are often heavily contaminated with

microorganisms including coliforms due to inadequate drying, handling, and storage conditions, thereby serving as potential sources of contamination in spiced meat products (Assessment of the Microbiological Quality of Spices and Herbs, 2019). Furthermore, raw beef provides abundant nutrients and a near-neutral pH, creating favorable conditions for microbial survival (Nkandi *et al.*, 2017). In contrast, spiced boiled beef and chicken powders exhibited comparatively lower microbial loads on Day 1, likely due to the lethality of boiling on vegetative cells and the faster microbial die-off associated with chicken meat under low-moisture storage conditions (Okoh *et al.*, 2019). By Day 6, the dominance of microbial populations in raw beef powder may be attributed to beef's compositional and surface characteristics, which support prolonged microbial survival, whereas the lower counts in chicken-based powders reflect reduced persistence of microorganisms under low water-activity conditions (Mediani *et al.*, 2022; Lei *et al.*, 2023).

Day 1

Table 6: Microbial Load of Meat Powder Samples

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SSC (CFU/g)	SC (CFU/g)	VC (CFU/g)	RCC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	$2.5^a \times 10^6$	$4.0^d \times 10^5$	NG	NG	$7.0^b \times 10^4$	NG	NG	$2.0^b \times 10^4$
Spiced raw beef powder	$2.0^d \times 10^6$	$1.2^e \times 10^5$	$1.0^b \times 10^4$	NG	NG	NG	NG	$1.0^c \times 10^4$
Spiced boiled beef powder	$2.3^c \times 10^6$	$7.0^c \times 10^5$	NG	NG	NG	NG	NG	$2.0^b \times 10^4$
Raw chicken powder (control)	$1.7^e \times 10^6$	NG	NG	NG	NG	NG	NG	$1.0^c \times 10^4$
Spiced raw chicken powder	$2.4^b \times 10^6$	$1.02^b \times 10^6$	$1.0^b \times 10^4$	NG	$8.0^a \times 10^4$	NG	NG	$2.0^b \times 10^4$
Spiced boiled chicken powder	$2.5^a \times 10^6$	$1.6^a \times 10^6$	$2.0^a \times 10^5$	NG	NG	NG	NG	$3.0^a \times 10^4$

Day 2

Table 6: Microbial Load of Meat Powder Samples

Sample s	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SSC (CFU/g)	SC (CFU/g)	VC (CFU/g)	RCC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	2.5 ^a X 10 ⁶	5.0 ^d X10 ⁵	NG	NG	9.0 ^b X10 ⁴	NG	NG	3.0 ^a X10 ⁴
Spiced raw beef powder	2.2 ^c X 10 ⁶	1.5 ^e X 10 ⁵	3.0 ^b X10 ⁴	NG	NG	NG	NG	1.0 ^c X10 ⁴
Spiced boiled beef powder	2.3 ^b X 10 ⁶	9.0 ^c X10 ⁵	NG	NG	NG	NG	NG	1.0 ^c X10 ⁴
Raw chicken powder (control)	1.9 ^d X10 ⁶	NG	NG	NG	NG	NG	NG	2.0 ^b X10 ⁴
Spiced raw chicken powder	2.5 ^a X 10 ⁶	1.2 ^b X10 ⁶	1.3 ^c X10 ⁴	NG	1.1 ^a X10 ⁵	NG	NG	3.0 ^a X10 ⁴
Spiced boiled chicken powder	2.5 ^a X10 ⁶	1.8 ^a X10 ⁶	2.5 ^a X 10 ⁵	NG	NG	NG	NG	3.0 ^a X10 ⁴

Day 3

Table 6: Microbial Load of Meat Powder Samples

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	2.4 ^a X 10 ⁶	7.0 ^c X10 ⁵	NG	1.4 ^b X10 ⁵	5.0 ^a X10 ⁴
Spiced raw beef powder	2.4 ^a X 10 ⁶	1.8 ^d X 10 ⁵	5.0 ^b X10 ⁴	NG	3.0 ^c X10 ⁴
Spiced boiled beef powder	2.5 ^a X 10 ⁶	1.3 ^d X10 ⁵	NG	NG	3.0 ^c X10 ⁴
Raw chicken powder (control)	2.1 ^b X10 ⁶	NG	NG	NG	4.0 ^b X10 ⁴
Spiced raw chicken powder	2.5 ^a X 10 ⁶	1.5 ^b X10 ⁶	1.7 ^c X10 ⁴	1.6 ^a X10 ⁵	5.0 ^a X10 ⁴

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SC (CFU/g)	FUC (CFU/g)
Spiced boiled chicken powder	$2.3^a \times 10^6$	$2.1^a \times 10^6$	$2.2^a \times 10^5$	NG	$5.0^a \times 10^4$

Day 4

Table 6: Microbial Load of Meat Powder Samples

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	$2.5^a \times 10^6$	$9.0^b \times 10^5$	NG	$1.7^a \times 10^5$	$3.0^a \times 10^4$
Spiced raw beef powder	$2.0^c \times 10^6$	$1.4^c \times 10^5$	$3.0^b \times 10^4$	NG	$2.0^b \times 10^4$
Spiced boiled beef powder	$2.3^b \times 10^6$	$1.7^c \times 10^5$	NG	NG	$1.0^c \times 10^4$
Raw chicken powder (control)	$2.4^{ab} \times 10^6$	NG	NG	NG	$2.0^b \times 10^4$
Spiced raw chicken powder	$2.4^{ab} \times 10^6$	$1.2^a \times 10^6$	$1.4^c \times 10^4$	$1.2^b \times 10^5$	$3.0^a \times 10^4$
Spiced boiled chicken powder	$2.0^c \times 10^6$	$9.1^b \times 10^5$	$1.4^a \times 10^5$	NG	$3.0^a \times 10^4$

Day 5

Table 6: Microbial Load of Meat Powder Samples

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	$2.2^{cd} \times 10^6$	$1.2^c \times 10^5$	NG	$2.4^a \times 10^5$	$2.0^c \times 10^4$
Spiced raw beef powder	$2.3^{bc} \times 10^6$	$1.1^c \times 10^5$	$1.0^c \times 10^4$	NG	$1.0^d \times 10^4$
Spiced boiled beef powder	$2.0^e \times 10^6$	$1.3^c \times 10^5$	NG	NG	$1.0^d \times 10^4$
Raw chicken powder (control)	$2.5^a \times 10^6$	NG	NG	NG	$3.0^b \times 10^4$
Spiced raw chicken powder	$2.1^{de} \times 10^6$	$1.5^a \times 10^6$	$1.1^b \times 10^5$	$1.6^b \times 10^5$	$2.0^c \times 10^4$
Spiced boiled chicken powder	$2.4^{ab} \times 10^6$	$7.1^b \times 10^5$	$1.7^a \times 10^5$	NG	$5.0^a \times 10^4$

Day 6

Table 6: Microbial Load of Meat Powder Samples

Samples	THBC (CFU/g)	TCC (CFU/g)	FC (CFU/g)	SC (CFU/g)	FUC (CFU/g)
Raw beef powder (control)	$2.5^a \times 10^6$	$1.7^c \times 10^5$	NG	$2.4^a \times 10^5$	$4.0^a \times 10^4$
Spiced raw beef powder	$2.4^{ab} \times 10^6$	$1.4^c \times 10^5$	$5.0^c \times 10^4$	NG	$2.0^{bc} \times 10^4$
Spiced boiled beef powder	$2.4^{ab} \times 10^6$	$1.6^c \times 10^5$	NG	NG	$3.0^{ab} \times 10^4$
Raw chicken powder (control)	$2.5^a \times 10^6$	NG	NG	NG	$1.0^c \times 10^4$
Spiced raw chicken powder	$2.3^b \times 10^6$	$1.7^a \times 10^6$	$1.3^b \times 10^5$	$1.6^b \times 10^5$	$4.0^a \times 10^4$
Spiced boiled chicken powder	$2.5^a \times 10^6$	$9.1^b \times 10^5$	$1.9^a \times 10^5$	NG	$3.0^{ab} \times 10^4$

Values are mean, means with different superscript along columns are significantly different ($p < 0.05$).

Key: NG: No Growth, THBC- Total Heterotrophic Bacterial Count, TCC -Total Coliform Count, FC - Fecal Coliform, SSC – Salmonella and Shigella Count, SC – Staphylococcus Count, VC – Vibrio Count, RCC – Re-enforced Clostridial Count, FUC – Fungal Count.

Sensory Analysis of Meat Powder Samples

Sensory evaluation of the meat powder samples using the nine-point hedonic scale revealed a consistent preference for beef-based powders over chicken-based counterparts. This trend may be attributed to the inherently richer flavour profile of beef, which contains higher levels of flavour precursors such as amino acids, peptides, and lipids. During processing, these compounds participate in Maillard reactions and lipid oxidation, resulting in more intense and characteristic meaty flavours compared with poultry products (Khan *et al.*, 2015). In addition, the darker and more intense colour of beef powders is largely associated with their higher myoglobin content, a quality attribute that consumers often perceive as an indicator of product richness and acceptability (Ramanathan *et al.*, 2018). In contrast, chicken meat is characterized by a milder flavour and lower fat content, which generally yield less pronounced taste and aroma attributes (Farrell, 2023). Among the beef-based samples, the raw beef powder (control) recorded the highest overall acceptability scores, followed closely by the spiced raw beef powder and the spiced boiled beef powder. The raw beef powder (control) was consistently rated highest across all evaluated sensory attributes—aroma, taste, appearance, aftertaste, and texture indicating strong consumer preference for minimally processed beef products. The spiced raw beef powder also performed favourably across most attributes, suggesting that moderate seasoning enhanced sensory appeal without masking inherent beef flavours. For the chicken-based powders, the raw chicken powder (control) was the most preferred overall, followed by the spiced raw chicken powder. The raw chicken powder (control) received the highest scores

for aroma, taste, aftertaste, and texture, highlighting the role of minimal processing in preserving desirable sensory qualities. However, the spiced boiled chicken powder achieved the highest score for appearance, suggesting that heat treatment and spice incorporation improved visual appeal, likely through enhanced colour uniformity and perceived tenderness (John *et al.*, 2024). Overall, the higher acceptability of the raw beef and chicken powders may be attributed to minimal processing, which preserves natural flavour compounds, aroma, and textural characteristics that consumers often associate with freshness and product authenticity. Although spicing contributed positively to certain attributes particularly appearance its more intense or novel flavour profiles were not universally preferred by panellists, indicating variability in consumer response to spiced meat powders (Gómez *et al.*, 2020).

Table 7: Mean Sensory Score of Meat Powder Samples

Sample	Aroma	Taste	Appearance	Aftertaste	Texture	Overall Acceptability
Raw beef powder (control)	7.30 ^a ± 0.95	7.50 ^a ± 1.08	7.50 ^a ± 0.97	7.20 ^a ± 1.03	7.20 ^a ± 1.03	8.00 ^a ± 0.82
Spiced raw beef Powder	6.70 ^b ± 1.16	7.00 ^b ± 1.05	7.40 ^a ± 1.07	6.80 ^b ± 1.03	7.10 ^a ± 1.10	7.40 ^b ± 1.08
Spiced boiled beef Powder	6.50 ^b ± 1.02	6.90 ^b ± 1.20	6.50 ^b ± 1.25	6.50 ^b ± 1.43	6.80 ^a ± 0.92	7.20 ^b ± 1.17
Raw chicken Powder (control)	6.60 ^b ± 1.07	6.80 ^b ± 1.13	6.40 ^b ± 0.84	6.50 ^b ± 1.08	6.60 ^b ± 0.70	7.10 ^b ± 0.99
Spiced raw chicken Powder	5.90 ^c ± 1.14	6.10 ^c ± 1.10	6.10 ^b ± 1.20	5.80 ^c ± 1.13	6.10 ^b ± 1.20	6.20 ^c ± 1.23
Spiced boiled chicken Powder	6.10 ^c ± 1.10	6.20 ^c ± 1.14	6.50 ^b ± 1.27	5.90 ^c ± 1.07	6.10 ^b ± 1.10	6.10 ^c ± 1.10

Values are mean ± Standard deviation of 3 replicates determination. Means differently superscripted along columns are significantly different (p<0.05).

Conclusion

This study demonstrated that beef and chicken meat powders produced under different processing conditions possess desirable physicochemical, nutritional, and microbiological qualities that support their suitability as shelf-stable food ingredients. The generally low pH values (<7) reflected normal postmortem acidification, while variations were influenced by

meat type, boiling, and spicing. Beef powders exhibited higher pH and lower total titratable acidity than chicken powders, whereas boiling increased pH through the leaching of organic acids. Spicing moderately elevated pH, likely due to the antimicrobial activity of spices that limited further acidification. Proximate analysis revealed low moisture contents (2.23–5.04%), which are advantageous for reducing water activity, inhibiting microbial growth, and improving storage stability. All samples were rich in protein and energy, contained moderate lipid levels, and provided nutritionally relevant amounts of essential minerals, particularly iron, calcium, and zinc, underscoring their potential contribution to dietary nutrient intake.

Microbiological evaluation confirmed the safety of the meat powders, as no *Salmonella*, *Shigella*, *Vibrio*, or *Clostridium* species were detected during the six-day storage period. The low moisture content and reduced water activity were key factors limiting pathogen survival, although heterotrophic bacteria, coliforms, and fungi persisted at levels typical of low-moisture foods, with higher counts generally associated with spiced samples and beef-based powders. Sensory evaluation revealed a consistent preference for beef powders over chicken powders, with minimally processed samples achieving the highest acceptability across aroma, taste, texture, and overall quality. While spicing improved certain attributes such as appearance, consumer response to spiced flavours varied. Overall, the results indicate that minimally processed beef and chicken meat powders are microbiologically safe, nutritionally dense, and sensorially acceptable, highlighting their potential application as protein-rich ingredients in convenience foods, fortification strategies, and long-shelf-life food products.

Recommendations

- i. Further shelf-life and storage studies should be conducted
- ii. Product formulation and application trials should be expanded
- iii. Appropriate packaging materials such as airtight glass jars, food-grade plastic airtight containers, and vacuum-sealed polyethylene bags should be used
- iv. Scale-up production and economic feasibility studies are recommended.

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