Research Articles

Journal of Meat Science
Year 2026 (June), Volume-21, Issue-1

www.acspublisher.com

ISSN 0975-5209 (Print)
ISSN 2581-6616 (Online)

Processing and Storage Stability Assessment of Buffalo Meat Powder

R. J. Zende[1*], V. M. Vaidya[1], V. H. Shukla[2], A. S. Nair[1], P. S. Gaikwad[1], N.S. Panicker[1], A. H. Shirke[1], S. M. Tambe[1], S. G. Kori[1]

[1]Department of Veterinary Public Health and Epidemiology, Mumbai Veterinary College, Parel, Mumbai, MAFSU, Nagpur
[2]Department of Livestock Products and Technology, Mumbai Veterinary College, Parel, Mumbai, MAFSU, Nagpur

ARTICLE INFO

*Corresponding author:
*E-mailaddress: ravindrazende@mafsu.ac.in
Received 2025-06-20; Accepted 2026-02-28

doi10.48165/jms.2026.21.01.10

ABSTRACT

Buffalo meat plays a significant role in the meat industry, with India being a major global producer and exporter. However, its short shelf life caused by microbial spoilage and oxidative deterioration creates challenges for sustainable use. This study aimed to develop buffalo meat powder as a protein-rich, shelf-stable product for the pet food industry. The buffalo meat was prepared using a hot air-drying method and stored at ambient temperature (30±1°C), then evaluated under Atmospheric Packaging (P1), Vacuum Packaging (P2), and Nitrogen Gas Packaging (P3). All parameters, including physicochemical properties, proximate composition, bulk properties, and microbiological factors, were analysed at ambient temperature until spoilage. Results showed that P2 had the lowest lipid oxidation, stable pH and moisture levels, and minimal protein and fat degradation compared to other packaging methods. Microbiological analysis confirmed the absence of pathogens in all samples, with P2 maintaining superior shelf life and quality throughout storage. These findings demonstrate the effectiveness of vacuum packaging in preserving buffalo meat powder, which is made from buffalo meat and has potential as a viable ingredient for high-quality, sustainable pet food alternatives.
Keywords: Buffalo meat powder, Quality and Shelf-life, Packaging methods.

INTRODUCTION

The global buffalo population is estimated to be around 200 million, with 97% concentrated in Asia across 40 countries. As per the 20th livestock census, India has 109 million buffaloes, accounting for 20.47% of its total livestock (Hegde, 2019). In 2024, buffalo meat production was projected at 4.55 million metric tons, with exports reaching 1.64 MMT, reflecting a 5% rise due to increasing domestic and international demand (APEDA 2024). India exports buffalo meat to more than 70 countries, including key markets in South-East Asia, West Asia, Africa, Vietnam, Malaysia, Egypt, the UAE, and Iraq (APEDA 2023), highlighting its economic importance. However, preserving the meat remains challenging due to its short shelf life caused by oxidative and microbial spoilage. At room temperature, it lasts only about 18 hours (Maheswarappa et al. 2022). Refrigeration (0–4°C) extends it to 3–5 days and combining it with vacuum or Modified Atmosphere Packaging (MAP) can increase it to 20–30 days. However, substantial post-harvest losses still occur. Efficient buffalo meat and by-product utilization is essential for profitability and dehydration offers a viable method for shelf-life extension. Traditional drying methods like sun drying are slow and may cause color darkening, shrinkage, nutrient loss, lipid oxidation and poor rehydration (Aykın Dincer, 2023), whereas oven drying is faster and more efficient (Mishra et al. 2017).

The developed buffalo meat powder is easy to pack and transport, with a longer shelf life and improved quality. Given the 35–40% supply deficit and high import costs of pet food in India, it offers a valuable opportunity for domestic production of high-protein pet foods. The meat powder could be used to prepare various dried and value-added meat products with an extended shelf life. Therefore, this study aimed to develop buffalo meat powder and assess its quality and shelf life under atmospheric, vacuum, and nitrogen gas packaging at ambient temperature (30 ± 1°C).

MATERIALS AND METHODS

The study was carried out at the Department of Veterinary Public Health, Mumbai Veterinary College, Parel. Deboned meat from freshly slaughtered buffaloes (6 –7 years old) was obtained within 1 hour after slaughter from Deonar Slaughter House, Mumbai. Visible fascia and external fat were trimmed, and the meat was stored frozen until further use.

Process protocol for development of Buffalo Meat Powder

Buffalo meat was minced by passing twice using a pre-sterilized 4mm meat mincer, then spread on stainless steel trays and dried in a hot air oven at 70 °C for 36 h until a constant weight was achieved. The minced meat was turned every two hours to ensure uniform drying. The dried meat was then milled using a meat mixer to obtain the buffalo meat powder. The average yield, calculated as (final weight / initial weight) × 100, was noted to be 21.20% (Ahmad et al. 2024).

Experimental Setup

For analysis and storage studies, three packaging methods were used: P1: atmospheric packaging, P2: vacuum packaging and P3: modified atmospheric packaging with 100% nitrogen gas. Low-Density Polyethylene (LDPE) pouches (50 μ) were used for P1, while aluminium pouches (50 μ) were used for both P2 and P3.

Estimation of Quality and Shelf-life of Buffalo Meat Powder

Buffalo meat powder was evaluated for physico-chemical properties, proximate composition, bulk characteristics, and microbiological quality following standard guidelines, with all parameters monitored until spoilage at ambient temperature.

Physico-chemical parameters

Estimation of pH was performed using probe type amplified pH/ temperature HANNA Meat pH meter (model no. HI 2020, USA) (Troutt et al. 1992). Tyrosine value was determined as per the method of Strange et al. (1977) and expressed as mg tyrosine per 100 g of powder. TBARS (Thio-Barbituric Acid Reactive Substances) value were estimated using the extraction method of Witte et al. (1970) and expressed as mg malonaldehyde per kg of powder.

Proximate Analysis

Proximate parameters like total ash, protein, fat, fiber and ash percentage were evaluated as per Official methods of analysis of AOAC (2023).

Bulk properties

Bulk density was measured using 1 g of buffalo meat powder in a 10 ml plastic measuring cylinder, tapped until a constant volume was reached and calculated as the ratio of sample weight to filled volume (Mahdavi et al. 2016). Flowability of the buffalo meat powder was determined by placing 10 g powder in a 25 ml cylinder, recording the initial volume (Vb), tapping 10 times, and recording the final volume (Vf), as per the method given by Hausner (1967).

$$\text{Hausner ratio (HR)} = Vb/Vf$$

The Water Solubility Index (WSI) was measured following the method described by Mahdavi et al. (2016), where 12.5 g of buffalo meat powder was vortexed thoroughly with 30 ml of water for 2 minutes, incubated at 37°C in a water bath for 30 minutes, and then centrifuged at 17640 rpm for 20 minutes at 4°C. The supernatant was dried at 105°C overnight to determine WSI, while the remaining pellet was used to assess the Water-Binding Capacity (WBC).

WSI= (weight difference of the supernatant after drying)/ Initial sample weight × 100

WBC= (weight of pellet - Initial sample weight)/ Initial sample weight × 100

Microbiological Analysis

The isolation and identification of spoilage and pathogenic microorganisms were performed using selective media as described by Speck (1982). The Total Viable Count (TVC) was enumerated using the standard pour plate method (IS 54402:2012). Differential counts of *Bacillus cereus*, *Staphylococcus aureus, E. coli* and yeast and moulds were performed in duplicates using selective media and the spread plate method. Results were calculated as log colony-forming units (cfu) per gram.

Statistical analysis

All data were reported as Mean ± S.E. and analysed in triplicate using SPSS Statistics 20.0 (SPSS Inc., Chicago, IL, USA) under a randomized block design. Duncan's multiple range test was used to assess differences among storage periods and treatments. The significant difference between the two means ($p < 0.05$) was reported.

RESULTS AND DISCUSSION

The buffalo meat powder was subjected to shelf-life study using three packaging methods: Atmospheric (P1), Vacuum (P2), and Nitrogen Gas (P3), stored at ambient temperature (30 ± 1°C).

Physico-chemical parameters

The buffalo meat powder analysis on zero day revealed 4.51% moisture, 85.18% protein, 7.04% fat and 3.64% ash (Table 1). The initial pH was 5.60 ± 0.06 across all treatments. However, over time, pH declined in P1 and P3 to 5.40 and 5.39, respectively, while P2 maintained more stable levels. This reduction may be attributed to protein oxidation and amino acid modification during prolonged storage (Hellwig, 2019). Long and Mohan (2021) reported that the analysis of the pH of beef tongue powder dried using different techniques was 6.1 and is in accordance to the results obtained for buffalo meat powder in the present study. Tahseen and Gurunathan (2024) also reported a significant reduction in pH of meat samples ($p<0.05$) with storage period. The reduction in pH of meat origin products could attributed to the continuous acid production by breakdown of proteins into acid-precursor amino acids by enzymatic activity under prolonged storage (Abril et al. 2023).

Tyrosine content increased significantly ($p < 0.05$), from 6.85 to 11.09, 11.02 and 9.74mg/100 g in P1, P2 and P3, respectively. The highest rise was in P1, likely due to microbial proteolysis during storage (Thamizhannal et al. 2017). Pame et al. (2017) observed similar increases in tyrosine in pet food made from slaughterhouse by-products, rising from 37.59 to 104.92 mg per 100 g over a 60-day storage duration; while Sahla et al. (2024) reported increased tyrosine in poultry by-product meal stored aerobically. This increase is generally linked to microbial and enzymatic breakdown of proteins which release free tyrosine and amino acids, marking the progression of proteolysis and quality changes in the stored meat product (Biswas et al. 2017).

The TBARS values, indicating lipid oxidation, rose significantly ($p < 0.05$) from 0.31 to 0.50, 0.53 and 0.51mg MA/kg in P1, P2 and P3, respectively. The results align with those of Jayawardena et al. (2022), who reported increased TBARS in buffalo lung powder over storage time from 0.25 to 0.55 mg/kg at 50–100°C drying temperatures, which was probably due to lipid oxidation leading to rapid production of free radicals at high temperature. Karthik et al. (2010) also observed rising TBARS in pet foods with spent hen meal inclusion.

Overall, vacuum packaging (P2) showed superior efficacy in preserving the physicochemical quality. The findings align with Stasiewicz et al. (2014), who reported that vacuum-packaged samples maintained more stable pH and colour during storage than MAP. Vacuum packaging effectively slows spoilage by inhibiting microbial growth, thereby extending the shelf life of animal-origin products (Qian et al. 2021).

Proximate analysis

Moisture content of buffalo meat powder increased significantly ($p < 0.05$) over 120 days from 4.51% to 10.52% in P1, 7.06% in P2, and 8.94% in P3 at ambient temperature (Table 2), which is acceptable as per the criteria (Bramoulle et al. 2012).

Fat content, initially 7.04%, declined significantly ($p < 0.05$) in all treatments during storage. Similar trends were observed by Sarkar et al. (2020) in spent hen meat powder stored under aerobic and vacuum conditions during a 180-day storage period. Fat degradation may result from microbial activity and enzymatic oxidation of unsaturated fatty acids. However, Chukwu and Imodiboh (2009) reported a contrasting increase in fat content of dehydrated buffalo product from 2.43 to 5.00 over 21 days. Vacuum packaging minimizes oxygen and light exposure, thereby slowing lipid oxidation (Amaral et al. 2018), as also demonstrated in this study.

Ash content showed a slight decline across treatments, with vacuum-packaged samples retaining more ash. This aligns with Sarkar et al. (2020), who observed higher ash stability in vacuum-packaged spent hen meat powder compared to aerobic packaging, possibly due to reduced moisture absorption.

Protein content, initially 85.18%, decreased to 84.25% (P1), 84.84% (P2), and 84.80% (P3) by the end of storage. These results are comparable to those of Jayawardena et al. (2022), who reported approximately 85% protein in buffalo lung powder on a dry weight basis. A decreasing trend in the protein content of spent hen meat powder during 120-day storage has also been noted by Sarkar et al. (2020), likely due to moisture uptake and associated degradation.

Among the packaging methods, vacuum packaging (P2) was the most effective in maintaining overall nutritional quality. This supports findings by Qian et al. (2021), who reported that vacuum packaging effectively delays microbial spoilage and extends shelf life in meat-based pet food products.

Bulk properties

The bulk density (bulk) of the buffalo meat powder declined from an initial value of 0.46 to 0.41 (P1), 0.40 (P2), and 0.41 (P3) over the storage interval of 120 days (Table 3). This decline aligns with findings by Long and Mohan (2021) who reported spray-dried buffalo lung powder had a bulk density range of 0.30–0.55 g/105 dL. Jayawardena et al. (2022) noted that bulk density tends to increase with higher temperatures.

The Hausner Ratio (HR), indicating flowability, increased over time: P2 (1.33), P3 (1.44), and P1 (1.45), reflecting an increase in flowability. Based on standards, P2 falls under the Passable category, while P1 and P3 are classified as Poor (Fitzpatrick, 2024). A HR below 1.25 is considered ideal for handling food powders, with higher values indicating flow issues (Saw, 2016).

Water Solubility Index (WSI) declined from 3.87 to 3.30 (P2), 3.41 (P3), and 2.92 (P1). Similarly, WBC values dropped from 138.70 to 111, 85.12 and 67.24 for P2, P3 and P1, respectively. These reductions may be attributed to increased moisture affecting solubility and water absorption during longer storage intervals (Padma et al. 2022). Heinevetter et al. (1987) also observed that meat powders generally exhibit lower WBC than whole meat due to protein denaturation and structural loss from drying and grinding.

Table 1. Physico-chemical Analysis of Buffalo Meat Powder in Atmospheric Packaging (P1) stored at room temperature (Mean±S.E.)

Parameters	0 Day	15 Day	30 Day	45 Day	60 Day	70 Day	80 Day
Moisture (%)	4.51±0.04 ^{a}	6.09±0.10 ^{a}	7.89±0.03 ^{a}	9.47±0.02 ^{a}	9.98±0.03 ^{a}	10.06±0.02 ^{a}	10.52±0.01 ^{a}
pH	5.60±0.013	5.58±0.06	5.55±0.10	5.50±0.01	5.47±0.04	5.43±0.01	5.40±0.03
Fat (%)	7.04±0.02 ^{a}	5.56±0.71 ^{b}	3.88±0.43 ^{c}	2.46±0.06 ^{d}	2.05±0.15 ^{e}	1.81±0.11 ^{ef}	1.85±0.05 ^{ef}
Ash (%)	3.64±0.32	3.60±0.16	3.56±0.16	3.51±0.03	3.46±0.06	3.42±0.04	3.38±0.02
Protein (%)	85.18±0.42 ^{a}	85.13±0.49 ^{a}	85.07±0.23 ^{ab}	85.0±0.14 ^{ab}	84.82±0.26 ^{b}	84.57±0.47 ^{bc}	84.25±0.07 ^{c}
Bulk Density (g/ml)	0.46±0.00	0.45±0.012	0.44±0.02	0.43±0.03	0.42±0.02	0.42±0.02	0.41±0.03
Flowability (Hausner ratio(H.R.)	0.98±0.02 ^{g}	1.06±0.05 ^{f}	1.15±0.02 ^{e}	1.25±0.01 ^{d}	1.30±0.03 ^{c}	1.39±0.02 ^{b}	1.45±0.01 ^{a}
WSI (%)	3.87±0.00 ^{a}	3.70±0.22 ^{b}	3.53±0.02 ^{c}	3.30±0.08 ^{d}	3.13±0.04 ^{e}	3.02±0.05 ^{f}	2.92±0.02 ^{g}
WBC (%)	138.70±1.1 ^{a}	125.25±0.7 ^{b}	112.1±0.85 ^{c}	98.25±0.14 ^{d}	89.05±3.16 ^{e}	75.57±0.22 ^{f}	67.24±0.22 ^{g}
TBA (mg/kg)	0.31±0.0 ^{c}	0.36±0.01 ^{c}	0.41±0.01 ^{b}	0.46±0.08 ^{b}	0.47±0.06 ^{b}	0.49±0.01 ^{b}	0.50±0.02 ^{a}
Tyrosine (mg/kg)	6.85±0.25 ^{g}	7.67±0.11 ^{f}	8.93±0.04 ^{e}	10.13±0.14 ^{d}	10.32±0.15 ^{c}	10.79±0.06 ^{b}	11.09±0.06 ^{a}

N=6; Mean±S.E. with different superscript differ significantly ($p < 0.05$)

Table 2. Physico-chemical Analysis of Buffalo Meat Powder in Vacuum Packaging (P2) stored at room temperature (Mean±S.E.)

Parameters	0 Day	15 Day	30 Day	45 Day	60 Day	70 Day	80 Day	90 Day	100 Day
Moisture (%)	4.51±0.04 ^{a}	5.30±0.10	6.10±0.03	7.00±0.02	7.12±0.03	7.17±0.06	7.11±0.02	7.09±0.02	7.06±0.04
pH	5.60±0.03 ^{a}	5.59±0.06 ^{a}	5.57±0.10 ^{a}	5.54±0.05 ^{a}	5.48±0.07 ^{a}	5.73±0.04 ^{a}	5.80±0.02 ^{a}	5.84±0.02	5.87±0.02 ^{a}
Fat (%)	7.04±0.02 ^{a}	6.31±0.71 ^{b}	5.58±0.43	4.77±0.35 ^{c}	4.62±0.29 ^{d}	4.19±0.08 ^{de}	3.98±0.04 ^{ef}	3.87±0.03 ^{f}	3.67±0.03 ^{fg}
Ash (%)	3.72±0.03 ^{a}	3.24±0.04 ^{d}	3.21±0.05 ^{d}	3.17±0.02 ^{d}	3.18±0.04 ^{d}	3.15±0.04 ^{d}	3.25±0.02 ^{c}	3.30±0.01 ^{b}	3.35±0.01 ^{b}
Protein (%)	85.18±0.42 ^{a}	85.15±0.49 ^{a}	85.11±0.23 ^{a}	85.06±0.25 ^{a}	85.04±0.19 ^{ab}	85.03±0.35 ^{b}	84.98±0.05 ^{b}	84.90±0.04 ^{c}	84.84±0.12 ^{c}
Bulk Density (g/ml)	0.46±0.04 ^{a}	0.46±0.02 ^{a}	0.45±0.02 ^{ab}	0.44±0.02 ^{b}	0.43±0.03 ^{bc}	0.41±0.01 ^{cd}	0.40±0.02 ^{d}	0.40±0.01 ^{d}	0.40±0.02 ^{d}
Flowability (H.R.)	0.98±0.02 ^{i}	0.99±0.02 ^{h}	1.02±0.02 ^{g}	1.10±0.01 ^{f}	1.14±0.01 ^{e}	1.22±0.04 ^{d}	1.27±0.02 ^{c}	1.30±0.03 ^{b}	1.33±0.02 ^{a}
WSI (%)	3.87±0.03 ^{a}	3.78±0.22 ^{b}	3.69±0.02 ^{bc}	3.58±0.03 ^{c}	3.43±0.12 ^{d}	3.39±0.05 ^{d}	3.34±0.02 ^{de}	3.33±0.02 ^{e}	3.30±0.15 ^{e}
WBC (%)	138.7±0.09 ^{a}	131.9±0.76 ^{b}	125.0±0.85 ^{c}	118.1±0.15 ^{d}	115.96±0.91 ^{e}	114.2±1.45 ^{f}	113.0±1.05 ^{fg}	112.0±1.05 ^{g}	111.1±1.21 ^{g}
TBA (mg/kg)	0.31±0.01 ^{g}	0.34±0.01 ^{f}	0.39±0.04 ^{e}	0.45±0.03 ^{d}	0.50±0.01 ^{c}	0.51±0.04 ^{b}	0.52±0.01 ^{ab}	0.52±0.01 ^{ab}	0.53±0.02 ^{a}
Tyrosine (mg/kg)	6.85±0.25 ^{h}	7.25±0.11 ^{g}	8.30±0.04 ^{f}	9.53±0.01 ^{e}	9.91±0.09 ^{d}	10.08±0.24 ^{c}	10.78±0.02 ^{b}	10.98±0.02 ^{ab}	11.02±0.42 ^{a}

N=6; Mean±S.E. with different superscript differ significantly ($p < 0.05$)

Table 3. Physico-chemical Analysis of Buffalo Meat Powder in Nitrogen Gas Packaging (P3) stored at room temperature (Mean±S.E.)

Parameters	0 Day	15 Day	30 Day	45 Day	60 Day	70 Day	80 Day	90 Day
Moisture (%)	4.51±0.04 ^{g}	5.70±0.05 ^{f}	6.90±0.04 ^{e}	7.95±0.02 ^{d}	8.23±0.05 ^{c}	8.72±0.03 ^{b}	8.83±0.01 ^{b}	8.94±0.02 ^{a}
pH	5.60±0.03 ^{a}	5.58±0.03 ^{a}	5.56±0.02 ^{a}	5.54±0.02 ^{a}	5.51±0.03 ^{a}	5.48±0.02 ^{ab}	5.43±0.01 ^{b}	5.39±0.01 ^{b}
Fat (%)	7.04±0.02 ^{a}	5.93±0.03 ^{b}	4.82±0.05 ^{c}	4.42±0.04 ^{d}	4.23±0.02 ^{de}	4.05±0.01 ^{e}	3.95±0.02 ^{ef}	3.89±0.04 ^{f}
Ash (%)	3.27±0.03 ^{a}	3.23±0.05 ^{ab}	3.19±0.04 ^{b}	3.15±0.05 ^{bc}	3.13±0.06 ^{c}	3.11±0.02 ^{cd}	3.10±0.01 ^{d}	3.07±0.03 ^{d}
Protein (%)	85.18±0.42 ^{a}	85.14±0.02 ^{a}	85.09±0.03 ^{a}	84.98±0.04 ^{b}	84.73±0.31 ^{c}	84.44±0.28 ^{d}	84.25±0.04 ^{e}	84.04±0.08 ^{f}
Bulk Density (g/ml)	0.46±0.04 ^{a}	0.45±0.03 ^{ab}	0.45±0.02 ^{ab}	0.46±0.01 ^{a}	0.44±0.02 ^{b}	0.43±0.01 ^{c}	0.42±0.06 ^{cd}	0.41±0.05 ^{d}
Flowability (H.R.)	0.98±0.02 ^{h}	1.05±0.04 ^{g}	1.10±0.01 ^{f}	1.15±0.03 ^{e}	1.20±0.01 ^{d}	1.33±0.02 ^{c}	1.39±0.02 ^{b}	1.44±0.01 ^{a}

WSI (%)	3.87±0.03[a]	3.74±0.04[b]	3.62±0.05[c]	3.55±0.02[cd]	3.50±0.004[d]	3.48±0.02[de]	3.45±0.01[e]	3.41±0.20[e]
WBC (%)	138.7±0.90[a]	128.6±2.46[b]	118.6±3.85[c]	109.8±2.25[d]	101.5±1.94[e]	95.24±0.01[f]	91.41±0.02[g]	85.12±0.02[h]
TBA (mg/kg)	0.31±0.05[a]	0.35±0.04[a]	0.40±0.06[a]	0.45±0.01[a]	0.47±0.02[a]	0.49±0.03[a]	0.50±0.01[a]	0.51±0.02[a]
Tyrosine (mg/kg)	7.67±0.11[a]	7.46±0.05[a]	8.62±0.06[a]	9.21±0.02[a]	9.55±0.04[a]	9.67±0.06[a]	9.72±0.01[a]	9.74±0.04[a]

N=6; Mean±S.E. with different superscript differ significantly ($p < 0.05$)

Microbiological parameters

The initial Total Plate Count (TPC) across all treatments was 0.95 ± 0.02 cfu/g, which further increased to 4.75 ± 0.01 (P1), 4.10 ± 0.06 (P2), and 4.40 ± 0.07 cfu/g (P3) by 80th, 100th day, and 90th, respectively (Fig. 1). The lowest count observed in P2 may be attributed to vacuum packaging, which restricts microbial growth by limiting oxygen availability. There was absence of *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus, Bacillus* spp. and Yeast and Mould count in buffalo meat powder throughout the storage period. Thus, the shelf life of buffalo meat powder is 70, 90 and 80 days, using P1, P2 and P3, respectively.

The microbial stability may be due to the low moisture content and strict hygienic practices during preparation. These findings are in line with Sarkar et al. (2009), who reported microbial absence in spent hen meat powder due to similar conditions. The modified atmospheric packaging (Nitrogen gas flushing) method and vacuum packaging method have been reported to prolong the shelf life of the food products by removal of humid air from the headspace (Pagarkar et al. 2020).

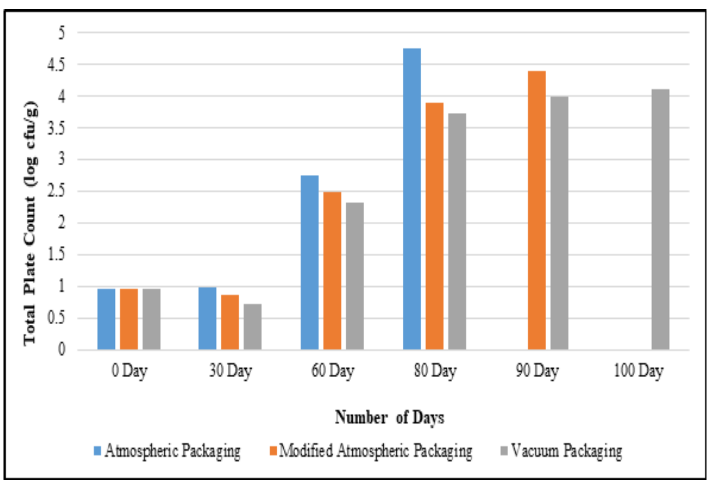

Fig. 1. Comparative TPC (log CFU/g) in buffalo meat powder under different packaging methods

CONCLUSION

The buffalo meat powder was formulated with 4.51% moisture, 85.18% protein, 7.04% fat and 3.27% ash, suitable for extended storage. Among the three packaging methods, vacuum packaging was the most effective in preserving the physicochemical and nutritional quality while maintaining the lowest microbial counts and extending the shelf life at ambient storage. Although nitrogen gas packaging showed favourable outcomes, it was less effective than vacuum packaging. Thus, preparation of buffalo meat powder not only supports better utilization and preservation of buffalo meat, but also presents a sustainable approach to producing high-protein, locally manufactured pet food, while reducing post-harvest losses in the buffalo meat sector.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the financial support provided by the ICAR-AICRP on PHET, which facilitated this research work. We also extend our gratitude to the project team and collaborators for their valuable contributions and support throughout the study.

DISCLOSURE STATEMENT

The authors report no conflicts of interest. The author alone is responsible for the content and writing of the paper.

FUNDING

This work was financially supported by ICAR- AICRP on PHET.

REFERENCES

Abril B, Bou R, Garcia-Perez JV and Benedito J (2023). Role of enzymatic reactions in meat processing and use of emerging technologies for process intensification. Foods, 12: 1940.

Ahmad Jaelan NH, Kumar P, Sazili AQ and Ismail-Fitry MR (2024). Effect of high-pressure processing on the quality of beef and buffalo meat. Journal of Meat Science, 19 (2).

Amaral AB, Silva MVD and Lannes SCDS (2018). Lipid oxidation in meat: mechanisms and protective factors – a review. Food

Science Technology, 38: 1–15.

AOAC International (2023). Official Methods of Analysis, 22nd ed, USA.

APEDA (2023). Agricultural & Processed Food Products Export Development Authority: Animal Products, New Delhi, Government of India.

Aykın Dinçer E (2023). Dried Meat Products Obtained by Different Methods from Past to Present. Food Reviews International, 39(5): 2457–2476.

Biswas O, Talwar NA, Bhattacharya D, Das SK and Chaudhary S (2017). Effect of refrigeration on quality and stability of fresh fish and poultry muscles. Indian Journal of Animal Health, 56: 65–76.

Bramoulle L, Ruaud J, Guiller I and Levesque A (2013). Method for producing highly palatable dry cat food. Justia Patents. Patent No. 20130287930.

Chukwu O and Imodiboh LI (2009). Influence of storage conditions on shelf-life of dried beef product (Kilishi). World Journal of Agricultural Research, 5(1): 34–39.

Fitzpatrick J (2024). Powder properties in food production systems. Handbook of food powders. Woodhead Publishing, 203-218

Hausner HH (1967). Friction Conditions in a Mass of Metal Powder. International Journal of Powder Metallurgy, 3(4): 7–13.

Hegde NG (2019). Buffalo Husbandry for Sustainable Development of Small Farmers in India and Other Developing Countries. Asian Journal of Research in Animal and Veterinary Sciences, 3(1): 1–20.

Heinevetter L, Gassmann B and Kroll J (1987). Evaluation of the water binding properties of meat binders, substitutes and extenders by different physical and chemical methods. Nahrung, 31: 889–898.

Hellwig M (2019). The Chemistry of Protein Oxidation in Food. Angewandte Chemie International Edition, 58(47): 16742–16763.

Jayawardena Mudiyanselage SR, Morton J, Bekhit EDA, Bhat ZF and Brennan CS (2022). Effect of drying temperature on nutritional, functional, and pasting properties and storage stability of beef lung powder, a prospective protein ingredient for food supplements. Lebensmittel-Wissenschaft & Technologie, 161: 113315.

Karthik P, Kulkarni VV and Sivakumar K (2010). Preparation, storage stability and palatability of spent hen meal-based pet food. Journal of Food Science, 47: 330 –334.

Long JM and Mohan A (2021). Development of Meat Powder from Beef Byproduct as Value-Added Food Ingredient. Lebensmittel-Wissenschaft & Technologie, 146: 111460.

Mahdavi SA, Jafari SM, Assadpoor E and Dehnad D (2016). Microencapsulation Optimization of Natural Anthocyanins with Maltodextrin, Gum Arabic, and Gelatin. International Journal of Biological Macromolecules, 85: 379–385.

Maheswarappa NB, Muthupalani M, Mohan K, Banerjee R, Sen AR and Barbuddhe SB (2022). Chilling, Freezing, and Other Preservation Methods of Buffalo Meat. In: Asiatic Water Buffalo: A Sustainable and Healthy Red Meat Source. Springer Nature Singapore: Singapore, 93–111.

Mishra B, Mishra J, Pati P and Rath P (2017). Dehydrated Meat Products —A Review. International Journal of Livestock Research, 7(11): 10–22.

Padma M, Rao PJ, Edukondalu L, Aparna K and Babu GR (2022). Determining the effects of spray drying conditions on water absorption index, water solubility index, solubility, and water activity of rice milk powder. Current Advances in Geography, Environment and Earth Science, 9: 16–36.

Pagarkar AU, Gaikwad BV, Kudale AS, Chogale ND, Satam SB, Pol VR, Shingare PE, Sawant SK, Rathod NB, Bhosale BP and Yadav BM (2020). Modified atmosphere packaging: an approach to seafood industry. Journal of Experimental Zoology India, 2: 23.

Pame K, Sathu T, Vasudevan VN, Prajwal S and Gunasekaran P (2017). A study on the effect of physicochemical characteristics, palatability and storage quality of kibbles incorporated with slaughter house by-products for canine. International Journal of Livestock Research, 7: 228–237.

Qian M, Liu D, Zhang X, Yin Z, Ismail BB, Ye X and Guo M (2021). A review of active packaging in bakery products: applications and future trends. Food Science Technology, 114: 459–471.

Sahla K, Irshad A, Sanal E, Vasudevan VN, Sathu T and Bincy M (2024). Evaluation of storage stability of poultry by-product meal incorporated fish feed under aerobic storage condition. Journal of Veterinary and Animal Sciences, 55: 558–564

Sarkar BK, Hazarika M, Laskar SK, Das A, Upadhyay S, Gogoi P and Deuri D (2020). Proximate, microbiological, and sensory evaluation of solar and oven dried spent hen meat powder incorporated with phytoingredients. Journal of Entomology and Zoology Studies, 8: 12–23.

Saw HY (2016). Characterization and flow of food and mineral powders: a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Engineering at Massey University, Manawatū, New Zealand. Doctoral dissertation, Massey University, 85–89.

Speck ML (1982). Compendium of Methods for the Microbiological Examination of Foods. American Public Health Association., USA.

Stasiewicz M, Lipiński K and Cierach M (2014). Quality of meat products packaged and stored under vacuum and modified atmosphere conditions. Journal of Food Science and Technology, 51(9): 1982–1989.

Strange ED, Benedict RC, Smith JL and Swift CE (1977). Evaluation of Rapid Tests for Monitoring Alterations in Meat Quality During Storage. Journal of Food Protection, 40(12): 843–847.

Tahseen A and Gurunathan K (2024). Evaluation of modified atmospheric packaged chicken breast meat during refrigeration storage. Journal of Meat Science, 19(2): 78–86.

Thamizhannal M, Rao VA, Raja SS, Arul S, Thanigaivel P and Ruban W (2017). Proteolytic Changes in Chicken Meat Packed in Ecofriendly Packaging Materials. Indian Journal of Pure & Applied Biosciences, 5(1): 277–281.

Troutt ES, Hunt MC, Johnson DE, Claus JR, Kastner CL and Kropf DH (1992). Characteristics of Low-Fat Ground Beef Containing Texture Modifying Ingredients. Journal of Food Science, 57(1): 9–24.

USDA, United States Department of Agriculture; Foreign Agricultural Service (2024). Livestock and Products Semi-Annual Report, Washington, D.C., United States.

Witte VC, Krause GF and Bailey ME (1970). A New Extraction Method for Determining 2-Thiobarbituric Acid Values of Pork and Beef During Storage Journal of Food Science, 35: 582–585.