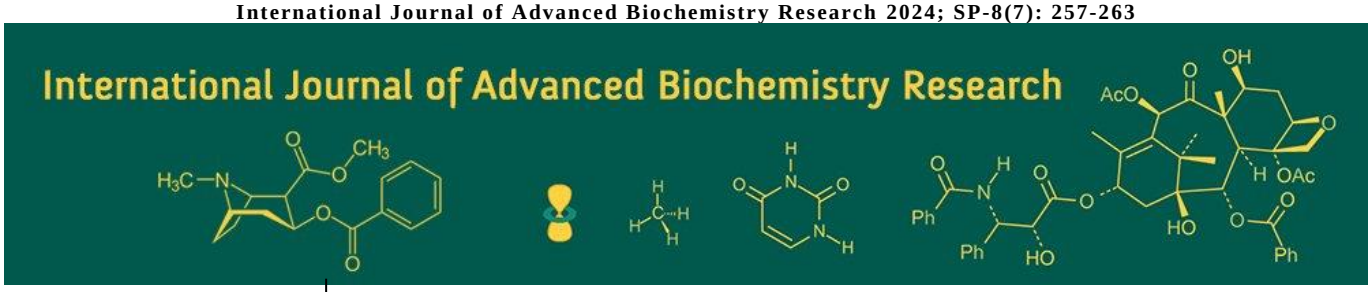

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(7): 257-263
www.biochemjournal.com
Received: 22-04-2024
Accepted: 25-05-2024

Varsha Vihan
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

VP Singh
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Pramila Umaraw
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Akhilesh K Verma
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Chirag Singh
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, DUVASU, Mathura, Uttar Pradesh, India

Corresponding Author:
Varsha Vihan
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Exploring the impact of integrating goat by-products and barnyard millet flour on the storage stability of Arija: A Himalayan ethnic meat product

Varsha Vihan, VP Singh, Pramila Umaraw, Akhilesh K Verma and Chirag Singh

DOI: https://doi.org/10.33545/26174693.2024.v8.i7Sd.1480

Abstract
This study aimed to assess the quality attributes of "Arija," a traditional Himalayan meat product, by varying the inclusion levels of goat by-products (liver, heart, and spleen) and barnyard millet flour (BMF). Four formulations were developed: C (0% by-products and BMF), T_1 (5% by-products, 2% BMF), T_2 (10% by-products, 4% BMF), and T_3 (15% by-products, 6% BMF), with lean meat replaced accordingly. Physicochemical properties, microbiology, and sensory characteristics were evaluated. Results indicated significant increases ($p<0.05$) in pH and decrease in water activity with higher levels of by-products and BMF. Significant ($p<0.05$) increase in TBARS and FFA values was seen with the progression of storage and with enhancing the levels of by-products and BMF. Microbial count (SPC, psychrophilic count, coliform count and yeast & mould count) also increased significantly ($p<0.05$) with increase in level of by-products and BMF and along with the storage. However, there were no significant ($p>0.05$) differences in appearance, texture, and juiciness between formulations C, T_1, and T_3, while T_2 exhibited significantly ($p<0.05$) superior scores in these attributes along with overall acceptability, although the sensory scores reduced significantly ($p<0.05$) with the passing storage study. The study concludes that formulation T_2, comprising 10% goat by-products and 4% BMF, maintains favorable physical, chemical, and sensory qualities, suggesting its suitability for preparing Arija.

Keywords: Arija, barnyard millet flour, lipid oxidation and microbiology

Introduction
The Himalayan region is home to a diverse array of traditional foods, among which the meat product "Arija" holds significant cultural and nutritional value, known for its unique flavor and traditional preparation methods. Arija is a staple in the diet of many Himalayan communities. However, with changing consumer preferences and increasing demand for nutritionally enhanced and shelf-stable food products, there is a need to innovate traditional foods without compromising their authenticity.

In the meat industry, the integration of slaughterhouse by-products presents a promising approach to enhance nutritional value and promotes sustainability by reducing waste (Umaraw *et al.*, 2015) [19]. This practice not only upholds cultural heritage but also offers economic advantages by valorizing underutilized resources (Vanathi *et al.*, 2020) [21]. In recent times, the consumption of edible by-products from goats, such as liver, heart and spleen has gained popularity in dietary habits, primarily due to their nutritional advantages. Goat by-products are rich in essential nutrients and bioactive compounds, making them valuable additions to meat products. Goat liver serving is a key source of iron, vitamin A, B vitamins, cobalamin, niacin, folacin, pyridoxine and ascorbic acid (Webb, 2014) [24] and metals like manganese (0.128 to 0.344 mg/100 g) (Irshad and Sharma, 2015) [7]. The heart and spleen are indeed rich sources of protein, heart contains approximately 20 grams of protein per 100 grams of tissue, while the spleen contains around 13 grams per 100 grams (Webb, 2014) [24]. Additionally, these organs are abundant in essential minerals such as iron, zinc, and phosphorus (Cordeiro *et al.*, 2022) [4], further enhancing the nutritional profile of the meat product.

As widely acknowledged that processed foods including meat products, often lack fiber. To address this, meat industries utilize non-meat additives rich in protein or carbohydrate to enhance functionality and reduce costs. Millets are valued for their diverse array of phytochemicals, serving as potent sources of antioxidants like total phenols, tannins and phytic acid (Mishra *et al.*, 2014) [11]. These qualities make millets a sought-after ingredient in meat products, contributing to improved nutrition and health benefits. Barnyard millet (*Echinochloa* spp.) is a drought-resistant crop known for its high nutritional value, including dietary fiber, protein, and essential minerals such as iron and magnesium (Saleh *et al.*, 2013) [15]. It is also gluten-free, making it suitable for individuals with gluten intolerance or celiac disease (Gull *et al.*, 2018) [6]. Barnyard millet flour's antioxidative properties reduce lipid oxidation and microbial growth in meat products, thereby extending their shelf life and enhancing their nutritional profile (Krishnan and Meera, 2018) [10]. Studies have indicated that adding millet flours to meat products can improve their quality and storage stability (Babaoglu, 2022) [2]. Furthermore, millet flours have been shown to boost antioxidant activity in meat products, which contributes to enhanced preservation and a longer shelf life (Krishnan and Meera, 2018) [10].

The incorporation of goat by-products and barnyard millet flour into Arija presents multifaceted benefits. By utilizing goat by-products, not only enhances the nutritional value of Arija but also promotes sustainable food production through waste minimization. Additionally, the nutritional enrichment of Arija with these ingredients has the potential to tackle prevalent nutritional deficiencies in the Himalayan region, such as anemia and calcium deficiency. Moreover, improving the storage stability of Arija can facilitate its wider distribution, thereby promoting the traditional product beyond its regional boundaries.

This study aims to investigate the effects of incorporating goat by-products (liver, heart, and spleen) and barnyard millet flour on the storage stability of Arija. The research will focus on key parameters such as lipid oxidation, microbial growth and sensory attributes over a defined storage period. By leveraging the nutritional and preservative qualities of these ingredients, the study seeks to develop an enhanced version of Arija that maintains its traditional appeal while offering improved shelf life and nutritional benefits.

Materials & Methods

Raw materials

Goat meat procured from retail outlets in Meerut town, further processing like deboning, trimming of fat and washing of meat with clean water was done hygienically in meat processing laboratory of the department. Deboned meat was carefully packaged in UV-sterilized low-density polyethylene (LDPE) and stored in the laboratory freezer at -18±1 °C for subsequent use in the preparation of arija. For goat by-products (GBP), a similar process was followed. They were gathered under hygienic conditions, thoroughly cleaned, and individually packed in UV-sterilized LDPE bags. These bags were then placed in a frozen state at -18±1 °C until further use.

Casing preparation

Freshly slaughtered goat small intestines were acquired from a local market and brought to the meat processing laboratory of the Department of LPT. To prepare them as casings, they underwent a thorough process of flushing, scraping and cleaning to eliminate any impurities. After cleaning, the intestines were immersed in a 10% saline solution. Subsequently, they were carefully stretched to eliminate any twists or kinks and sorted based on size and quality. This process also facilitated the separation of the outer fat and inner mucosa lining. Then a careful scraping process followed, meticulously removing all layers except for the sub-mucosa. The cleaned casings were rinsed with clean water and stored in a saline solution at refrigeration temperature (4±1 °C) until needed. The casings were salted to lower water activity, thereby inhibiting microbial growth and preserving them for future use.

Barnyard millet flour (BMF)

Food-grade Indian barnyard millet (*Echinochloa frumentacea*), also known as sawa millet or jungle rice was procured from the market. The millet was then milled into flour and utilized in the study.

Tomato puree (TP)

To make tomato puree, washed and blanched ripe tomatoes in boiling water for 1-2 minutes, then cooled them in an ice bath. Peeled and deseeded the tomatoes, chopped them and blended until smooth, adding a little water and strained the mixture to remove any skins and seeds. Then, heated the puree to 85-90 °C for 10-15 minutes to sterilize it, then let it cool. Finally, transferred the puree into sterilized containers and stored it in the refrigerator or a cool, dark place until use.

Other ingredients

The study utilized commercially available, food-grade items sourced from the local market: salt, refined sunflower oil, whole chicken eggs, tomato puree, and a variety of spices and condiments such as onion, garlic, and ginger. Media and standard chemicals obtained from Hi-media and CDH Chemicals, India, were employed for the diverse analyses conducted in this study.

Formulation and preparation of Himalayan ethnic meat product "Arija"

In the product formulation, four distinct batches were developed: a control batch (without GBP, BMF, and TP), T_1 (5% GBP, 2% BMF, and 1% TP), T_2 (10% GBP, 4% BMF, and 2% TP), and T_3 (15% GBP, 6% BMF, and 3% TP). GBP, BMF and TP were incorporated by replacing an equivalent amount of meat in each batch. The lean meat content (w/w) for the control, T_1, T_2, and T_3 groups was 76.7%, 68.7%, 60.7%, and 52.7%, respectively. Each batch also contained 2.0% common salt, 0.3% sodium tripolyphosphate, 0.012% sodium nitrite, 5% ice flakes, 5% liquid whole egg, 5% refined sunflower oil, 3% condiment mix (comprising onion, garlic, and ginger in a 3:2:1 ratio) and 3% spice mix.

Preparation of emulsion

To prepare the Arija, frozen meat and GBP were allowed to thaw to 7 °C overnight in a refrigerator. Grinding of meat and GBT was done carefully using a meat mincer equipped with an 8-mm plate. Subsequently emulsion was then prepared by using a mixer grinder (Inalsa food processor; Model: Kitchen Master 1000). The preparation process

involved sequentially adding minced meat and other ingredients at specific intervals. Initially, the minced meat along with minced liver, heart, spleen were mixed with common salt, sodium tripolyphosphate, sodium nitrite and ice flakes for one minute. Liquid whole egg and refined sunflower oil were then added and mixed for another minute. Finally, the condiment mix, dried spice mix, TP (for T-1, T-2, and T-3 only) and BMF (for T-1, T-2, and T-3 only) were added and mixed uniformly for an additional two-three minutes using the mixer grinder.

Forming, cooking and packaging of "Arija"

The resulting emulsion was stuffed into casings and linked at intervals of approximately 10-12 cm. To reduce wrinkles, the product was then steam-cooked for about 45 minutes in pressure cooker without placing the whistle. After steam cooking, product underwent convection cooking at a temperature range of 70-80˚C for 10 minutes to remove surface moisture and achieve the desired appearance for the "Arija." Finally, the Arija were allowed to cool to room temperature before each batch was packed in LDPE pouches using a sealing machine for subsequent analysis of various physicochemical and functional characteristics.

Analytical procedures

pH and water activity

The pH of the samples was determined with a digital pH meter (Esico Model-1012, Microprocessor-based pH system) after homogenizing 10 grams of each sample with 50 milliliters of distilled water for one minute, in accordance with the method outlined by Troutt *et al*. (1992) [18]. For accuracy, each pH measurement was taken three times. Additionally, the water activity of each sample was measured in duplicate, three times, using a LabSwift water activity meter (Novasina), ensuring reliable and precise results.

Thio-barbituric Acid Reactive Substances (TBARS mg malonaldehyde/kg)

The TBARS value in the sample was determined using a modified method from Witte *et al*. (1970) [25]. The 10 g of meat was homogenized with 25 ml of pre-cooled 20% TCA in 2 M orthophosphoric acid for 2 minutes. The mixture was rinsed with 25 ml of distilled water, filtered through Whatman No. 1 paper, and 3 ml of the filtrate was mixed with 3 ml of 0.005 M TBA reagent. The solution was incubated in the dark for 16 hours, and a blank test was prepared with distilled water instead of the sample. Absorbance at 532 nm was measured with a UV-VIS spectrophotometer, and TBARS values were calculated as mg malonaldehyde/kg by multiplying the O.D. by 5.2.

TBARS (mg malonaldehyde/kg) = O.D ×5.2

Free Fatty Acids (FFA % oleic acid)

Free fatty acid was analyzed as % oleic acid following Koniecko (1979) [9]. 5 g of meat was blended with 5 ml of anhydrous sodium sulfate and 30 ml of chloroform for 2 minutes. The mixture was filtered through Whatman No. 1 paper. To the filtrate, 2-3 drops of 0.2% phenolphthalein indicator were added, and the solution was titrated with 0.1N alcoholic potassium hydroxide. The amount of free fatty acids was calculated using the volume of potassium iodide used.

$$\text{Free fatty acid (\% oleic acid)} = \frac{0.1 \times \text{mL 0.1N alcoholic KOH} \times 0.282}{\text{Sample weight (g)}} \times 100$$

Microbiological analysis

The microbiological count (cfu/g) of the sample was determined following the procedures outlined by APHA, 2002 [1]. Initially, a 10 gram sample was aseptically weighed and homogenized in 90 milliliters of sterile diluent, such as peptone water, using a stomacher or blender. Serial dilutions were then prepared, and appropriate dilutions were plated on selective and non-selective agar media. The plates were incubated at specified temperatures and durations, depending on the target microorganisms. After incubation, colonies were counted, and the results were expressed as colony-forming units per gram (cfu/g).

Sensory Evaluation

Arija were cooked, kept warm, and evaluated by a semi-trained sensory panel (seven) faculty and postgraduate students from COVAS, Meerut, India. Following approved protocols, the experiment's nature was explained without revealing sample identities. Pre-warmed, coded samples were served randomly at individual booths. Panelists rated appearance, flavor, juiciness, texture, and overall acceptability using an 8-point hedonic scale, where 8 indicated extremely desirable and 1 extremely undesirable. Scores from 5 to 8 were considered acceptable. Evaluation followed Keeton (1983) [8] guidelines. Cylindrical pieces of Arija were served at room temperature, and panelists used filtered water to cleanse their palates between samples.

Statistical analysis

Data for the analysis were collected from three independent experiments, with analyses conducted in duplicate (n = 6) for all parameters. Statistical analysis was carried out using the methodology outlined by Snedecor and Cochran (1994) [17], including analysis of variance (ANOVA) and Duncan's multiple range test to compare means and assess the impact of treatments. The statistical software SPSS for Windows was utilized for data analysis, facilitating a comprehensive evaluation of treatment effects and trends within the dataset.

Results & Discussions

Physico-chemical properties

The variations in pH within a meat system can serve as an indicator of microbial status. From day 0, a significant (p<0.05) difference in pH was observed among the groups, with group C showing the lowest pH and T_3 the highest (Table 1). This trend of increasing pH continued throughout the 9-day storage period. As storage time advanced, an overall significant (p<0.05) increase in pH was noted in all the groups. The rise in pH of arija during storage could be due to microbial growth, where certain bacteria produce ammonia as a metabolic byproduct, leading to higher pH levels. Additionally, factors such as alkali autolysis, increased microbial population, and protein degradation also contribute to the increase in pH (Wang *et al.,* 2020) [23]. The higher pH in the treatment groups might be attributed to the presence of millet flour, which naturally has a higher pH. This observation aligns with Mishra *et al.* (2014) [11], who reported a significant (p<0.05) increase in pH in dehydrated chicken meat rings formulated with different levels of barnyard millet flour.

Water activity (a_w) measures a product's vulnerability to microbial contamination and indicates the microbial status of meat and meat products. In this study, a significant ($p<0.05$) reduction in a_w was observed over time across all groups (Table 1). The progressive decrease in a_w in the treated products may result from the increased levels of barnyard millet flour, which binds water more effectively. On the first day of storage, T_3 had the lowest ($p<0.05$) a_w, while C had the highest. Overall, all groups showed a similar trend of decreasing water activity as storage progressed, likely due to microbes utilizing the available water for growth and multiplication, similar results were seen in duck meat sausages with black gram flour incorporation (Saikia *et al*., 2019) [14].

Table 1: Changes in physico-chemical properties of Arija incorporated with different level of by-products and barnyard millet flour

Groups	Day 0	Day 4	Day 8	Day 12
pH				
C	6.21 ± 0.02^{Aa}	6.28 ± 0.01^{Ab}	6.40 ± 0.02^{Ac}	6.47 ± 0.01^{Ad}
T_1	6.29 ± 0.01^{Ba}	6.33 ± 0.01^{Bb}	6.49 ± 0.01^{Bc}	6.71 ± 0.02^{Bd}
T_2	6.32 ± 0.01^{Ca}	6.39 ± 0.01^{Cb}	6.57 ± 0.01^{Cc}	6.78 ± 0.02^{Cd}
T_3	6.42 ± 0.02^{Da}	6.49 ± 0.02^{Db}	6.66 ± 0.02^{Dc}	6.85 ± 0.01^{Dd}
Water activity (a_w)				
C	0.913 ± 0.001^{Dd}	0.906 ± 0.003^{Dc}	0.899 ± 0.002^{Db}	0.895 ± 0.001^{Da}
T_1	0.896 ± 0.002^{Cc}	0.878 ± 0.001^{Cb}	0.866 ± 0.001^{Ca}	0.867 ± 0.001^{Ca}
T_2	0.881 ± 0.001^{Bd}	0.867 ± 0.002^{Bc}	0.859 ± 0.001^{Bb}	0.856 ± 0.002^{Ba}
T_3	0.862 ± 0.004^{Ad}	0.851 ± 0.004^{Ac}	0.842 ± 0.004^{Ab}	0.843 ± 0.004^{Aa}

Means values bearing small letters (A, B, C, D….) group wise in column and capital letters (a, b, c, d…..) day wise in rows differ significantly ($p<0.05$) n=6.

Changes in lipid oxidation of Arija

The TBARS values exhibited a significant ($p<0.05$) difference among all groups from the first day of storage (Table 2). On day 0, T_1 had the lowest TBARS value ($p<0.05$), followed by group C and T_2, while T_3 showed the highest TBARS values ($p<0.05$), although the differences were not critically large. From day 3 onwards, a consistent trend emerged with C showing the lowest TBARS values ($p<0.05$) and T_3 the highest, continuing until the end of the storage period. An overall significant ($p<0.05$) increase in TBARS values over time across all groups highlights the progressive nature of lipid oxidation during storage. These findings underscore the importance of monitoring lipid oxidation to maintain the quality and shelf life of meat products. Similar, trends were also reported by the Verma *et al*. 2023 [22] in chevon nuggets and Umaraw *et al*., 2024 [20] in meat ball sored at refrigeration temperature.

In terms of free fatty acids (FFA), on day 0, T_1 had the lowest FFA value ($p<0.05$) and T_3 the highest, though the differences among the groups were not substantial (Table 2). By day 3, the trend had shifted, with C having the lowest FFA value ($p<0.05$) and T_3 the highest. This pattern of increasing FFA values continued throughout the storage period for all groups. Overall, FFA values significantly ($p<0.05$) increased with each day of storage. The significantly ($p<0.05$) higher FFA values in T_3 could be attributed to the incorporation of increasing levels of organ meat in the treatment groups compared to the control where no organ meat was added, as organ meats are more susceptible to lipid oxidation than regular meat. This aligns with similar findings reported by Singh *et al*. (2021) [16] in their study on Sorpotel-incorporated finger millets.

Table 2: Changes in lipid oxidation of Arija incorporated with different level of by-products and barnyard millet flour

Groups	Day 0	Day 4	Day 8	Day 12
TBARS (mg malonaldehyde/ kg)				
C	0.218 ± 0.001^{Ba}	0.228 ± 0.001^{Ab}	0.283 ± 0.001^{Ac}	0.314 ± 0.001^{Ad}
T_1	0.215 ± 0.001^{Aa}	0.246 ± 0.002^{Bb}	0.338 ± 0.002^{Bc}	0.494 ± 0.002^{Bd}
T_2	0.221 ± 0.002^{Ca}	0.275 ± 0.001^{Cb}	0.392 ± 0.001^{Cc}	0.572 ± 0.002^{Cd}
T_3	0.226 ± 0.002^{Da}	0.292 ± 0.001^{Db}	0.412 ± 0.001^{Dc}	0.648 ± 0.001^{Dd}
FFA (% oleic acid)				
C	0.140 ± 0.003^{Ba}	0.161 ± 0.004^{Ab}	0.186 ± 0.002^{Ac}	0.228 ± 0.002^{Ad}
T_1	0.139 ± 0.003^{Aa}	0.182 ± 0.001^{Bb}	0.208 ± 0.001^{Bc}	0.282 ± 0.002^{Bd}
T_2	0.141 ± 0.004^{Ca}	0.212 ± 0.002^{Cb}	0.237 ± 0.001^{Cc}	0.315 ± 0.001^{Cd}
T_3	0.144 ± 0.004^{Da}	0.258 ± 0.001^{Db}	0.296 ± 0.001^{Dc}	0.417 ± 0.001^{Dd}

Means values bearing small letters (A, B, C, D….) group wise in column and capital letters (a, b, c, d…..) day wise in rows differ significantly ($p<0.05$) n=6.

Changes in microbiological parameters of Arija

Throughout the storage period, a significant increase ($p<0.05$) in SPC count was observed across all groups. On day 0, group C exhibited the lowest SPC count compared to the treatment groups T_1, T_2, and T_3, which can be attributed to its composition devoid of goat meat by-products (Table 3). By day 4, there were no significant differences ($p>0.05$) in SPC count among the groups. However, starting from day 8, T_3 recorded the highest SPC count, while group C maintained the lowest count. The elevated SPC count in the treatment groups may be attributed to the inclusion of goat meat by-products, which are more susceptible to microbial degradation due to their higher fat and water content. Vanathi *et al.* (2020) [21] similarly noted a non-significant ($p>0.05$) increase in TPC count with higher levels of goat meat by-products in goat meat nuggets.

A significant increase ($p<0.05$) in psychrophilic count was noted from day 4 onwards throughout the storage period in all groups (Table 3). On day 0, no psychrophilic count was detected. However, by day 4, all groups had detectable

levels, with group C consistently showing the lowest counts and T_3 the highest. This pattern continued until the end of the storage period, further highlighting the impact of goat meat by-products on microbial growth under refrigeration.

Coliform counts showed a similar pattern, with no detection until day 4. From day 8 onwards, there was a significant difference ($p<0.05$) in coliform counts among the groups, with group C consistently having the lowest counts and T_3 the highest (Table 3). This trend continued through day 12. Overall, coliform counts increased significantly ($p<0.05$) from day 8 to day 12 across all groups. According to Devatkal *et al.* (2004) [5], higher total plate counts and the presence of coliforms in edible offals are likely due to on-floor slaughter practices, contamination from skin and hair, and improper handling during evisceration.

For yeast and mould count, no colonies were detected on day 0. From day 3 onwards, a significant difference ($p<0.05$) in yeast and mould count was observed among all groups, with T_3 consistently showing the highest counts and group C the lowest (Table 3). The yeast and mould counts increased with storage time regardless of the group. The inclusion of goat meat by-products increases microbial counts in meat products due to their high fat and water content, necessitating stringent handling and storage protocols. However, incorporating barnyard millet flour into these products can help maintain microbial counts within permissible limits. The antimicrobial properties and high fiber content of millet flour, along with its ability to reduce water activity and stabilize pH, create a less favorable environment for microbial growth, thereby enhancing storage stability and safety.

Table 3: Changes in microbiological parameters of Arija incorporated with different level of by-products and barnyard millet flour

Groups	Day 0	Day 4	Day 8	Day 12
SPC count (cfu/g)				
C	2.32 ± 0.01^{Aa}	2.89 ± 0.02^{b}	3.21 ± 0.01^{Ac}	4.32 ± 0.01^{Ad}
T_1	2.35 ± 0.01^{Ba}	2.87 ± 0.01^{b}	3.44 ± 0.02^{Bc}	4.83 ± 0.02^{Bd}
T_2	2.37 ± 0.02^{Ca}	2.82 ± 0.02^{b}	3.42 ± 0.02^{Bc}	4.85 ± 0.01^{Bd}
T_3	2.38 ± 0.01^{Da}	2.98 ± 0.01^{b}	3.58 ± 0.01^{Cc}	5.21 ± 0.01^{Cd}
Psychrophilic count (cfu/g)				
C	ND	2.28 ± 0.01^{Aa}	2.54 ± 0.01^{Ab}	2.92 ± 0.01^{Ac}
T_1	ND	2.32 ± 0.01^{Ba}	2.65 ± 0.01^{Bb}	3.31 ± 0.01^{Bc}
T_2	ND	2.32 ± 0.01^{Ba}	2.68 ± 0.01^{Bb}	3.35 ± 0.01^{Cc}
T_3	ND	2.37 ± 0.01^{Ca}	2.77 ± 0.02^{Cb}	3.77 ± 0.01^{Dc}
Coliform count (cfu/g)				
C	ND	ND	1.45 ± 0.01^{Aa}	2.32 ± 0.01^{Ab}
T_1	ND	ND	1.54 ± 0.02^{Ba}	2.67 ± 0.01^{Bb}
T_2	ND	ND	1.52 ± 0.02^{Ba}	2.72 ± 0.01^{Cb}
T_3	ND	ND	1.59 ± 0.01^{Ca}	3.13 ± 0.01^{Db}
Yeast and moulds count (cfu/g)				
C	ND	1.72 ± 0.02^{Aa}	1.82 ± 0.01^{Ab}	2.12 ± 0.01^{Ac}
T_1	ND	1.77 ± 0.01^{Ba}	1.94 ± 0.01^{Bb}	2.47 ± 0.01^{Bc}
T_2	ND	1.76 ± 0.01^{Ba}	1.97 ± 0.01^{Cb}	2.51 ± 0.01^{Cc}
T_3	ND	1.82 ± 0.02^{Ca}	2.21 ± 0.02^{Db}	2.82 ± 0.01^{Dc}

Means values bearing small letters (A, B, C, D….) group wise in column and capital letters (a, b, c, d…..) day wise in rows differ significantly ($p<0.05$) n=6.

Changes in sensory scores of Arija

The sensory evaluation of arija by semi-trained panelists during storage revealed significant ($p<0.05$) differences among the groups (Table 4). Notably, significant ($p<0.05$) differences in colour scores were observed from day 0, with T_3 recording the lowest scores, while other groups showed no significant differences ($p>0.05$). By day 12, T_2 had the highest colour scores. For flavour, a significant ($p<0.05$) reduction in scores was seen over time across all groups. On day 0, T_3 had the lowest flavour scores ($p<0.05$), with no significant differences ($p>0.05$) among other groups. By the end of the study, T_2 had the highest flavour scores, and C and T_3 had the lowest ($p<0.05$). Texture scores remained consistent among groups until day 8, but by day 12, T_2 had the highest scores, although T_1 and T_3 were not significantly different ($p>0.05$) from T_2. Juiciness scores showed that T_1 and T_2 had the highest scores ($p<0.05$) throughout the study, with a general reduction in scores over time. By day 12, T_1 and T_2 maintained significantly ($p<0.05$) higher juiciness scores compared to T_3, which also showed no significant difference ($p>0.05$) from the other groups. This improvement in juiciness was attributed to the addition of millet flour, enhancing fat and water binding in the treatment groups versus the control. Similar findings were noted by Behailu and Abebe (2020) [3] in beef sausages with soy and finger millet flour.

Overall acceptability scores initially were highest in C, T_1, and T_2 ($p<0.05$), but by day 12, a significant reduction was observed in all groups. T_2 recorded the highest overall acceptability scores, while C had the lowest ($p<0.05$). T_3's lower scores might be due to reduced meat flavour intensity from increased millet flour. Mishra *et al.* (2014) [11] observed similar results in dehydrated chicken meat rings. Additionally, Naveena *et al.* (2006) [12] demonstrated that incorporating up to 7.5% finger millet (*Eleusine coracana*) flour (FMF) in chicken patties improved the cooking yield. However, the sensory evaluation indicated that overall acceptability scores were favorable only up to a 5% inclusion, with a decline in acceptability at the 7.5% level. Reddy *et al.* (2022) [13] also reported higher sensory scores in buckwheat flour incorporated chevon sausages compared to control. The least sensory scores in treated sample (T_3) were likely due to the high level of organ meat, affecting texture and flavour over storage.

Table 4: Changes in sensory scores of Arija incorporated with different level of by-products and barnyard millet flour

Groups	Day 0	Day 4	Day 8	Day 12
Colour				
C	8.21 ± 0.24^{Bb}	7.93 ± 0.31^{Bb}	7.57 ± 0.25^{ABb}	6.14 ± 0.28^{Aa}
T_1	8.25 ± 0.24^{Bb}	8.07 ± 0.20^{Bb}	7.50 ± 0.32^{ABab}	6.93 ± 0.22^{Ba}
T_2	8.43 ± 0.17^{Bc}	8.29 ± 0.10^{Bbc}	7.86 ± 0.21^{Bab}	7.64 ± 0.21^{Ca}
T_3	7.43 ± 0.31^{A}	7.00 ± 0.21^{A}	6.93 ± 0.22^{A}	6.86 ± 0.21^{B}
Flavour				
C	8.14 ± 0.23^{Bc}	7.57 ± 0.17^{Bbc}	7.21 ± 0.24^{Bb}	6.57 ± 0.17^{ABa}
T_1	8.29 ± 0.28^{Bc}	7.86 ± 0.09^{Bbc}	7.57 ± 0.17^{BCab}	7.07 ± 0.25^{BCa}
T_2	8.57 ± 0.17^{Bb}	8.43 ± 0.22^{Cb}	8.07 ± 0.20^{Cab}	7.64 ± 0.26^{Ca}
T_3	7.00 ± 0.21^{Ac}	6.71 ± 0.10^{Abc}	6.43 ± 0.17^{Aab}	6.14 ± 0.21^{Aa}
Texture				
C	8.14 ± 0.28^{b}	7.86 ± 0.14^{b}	7.43 ± 0.17^{b}	6.57 ± 0.35^{Aa}
T_1	8.07 ± 0.20^{b}	7.93 ± 0.17^{b}	7.50 ± 0.21^{ab}	6.86 ± 0.32^{ABa}
T_2	8.57 ± 0.17^{b}	8.25 ± 0.21^{b}	7.64 ± 0.17^{a}	7.43 ± 0.17^{Ba}
T_3	8.00 ± 0.24^{b}	7.79 ± 0.24^{b}	7.07 ± 0.25^{a}	6.71 ± 0.18^{ABa}
Juiciness				
C	7.57 ± 0.20^{ABb}	7.21 ± 0.32^{Ab}	7.07 ± 0.13^{Ab}	5.86 ± 0.26^{Aa}
T_1	8.14 ± 0.26^{BCb}	8.00 ± 0.28^{Bab}	7.57 ± 0.25^{ABab}	7.21 ± 0.26^{Ba}
T_2	8.59 ± 0.18^{Cb}	8.00 ± 0.10^{Bb}	8.07 ± 0.25^{Bb}	7.29 ± 0.18^{Ba}
T_3	7.43 ± 0.17^{Ab}	7.57 ± 0.17^{ABb}	7.14 ± 0.23^{Aab}	6.50 ± 0.34^{ABa}
Overall Acceptability				
C	8.14 ± 0.17^{Bc}	7.07 ± 0.31^{Ab}	6.57 ± 0.27^{Aab}	5.86 ± 0.26^{Aa}
T_1	8.29 ± 0.18^{Bc}	7.79 ± 0.30^{ABbc}	7.43 ± 0.27^{BCab}	6.86 ± 0.21^{Ba}
T_2	8.64 ± 0.14^{Bb}	8.07 ± 0.20^{Bb}	8.07 ± 0.17^{Cb}	7.79 ± 0.21^{Ca}
T_3	7.43 ± 0.25^{Ab}	7.14 ± 0.09^{Ab}	6.79 ± 0.24^{ABab}	6.43 ± 0.22^{ABa}

Means values bearing small letters (A, B, C, D….) group wise in column and capital letters (a, b, c, d…..) day wise in rows differ significantly ($p<0.05$) n=6.

Conclusion

The integration of goat by-products and barnyard millet flour into Arija, a traditional Himalayan ethnic meat product, significantly enhances its storage stability and sensory profile. The study demonstrates that incorporating goat by-products did not hamper the shelf life and sensory qualities of Arija when added up to the level of 10 %. The goat by-products helped in utilization of underutilized organs and made product economic, while the barnyard millet flour contributes dietary fiber, antioxidants and impart good textural properties in the product at 4 % level of incorporation, making Arija a healthier option. Therefore, among all the treatments T_2 delivered best results in storage and sensory evaluation of Arija. Moreover, this approach aligns with sustainable food practices by utilizing otherwise underutilized goat by-products and promoting the use of indigenous grains like barnyard millet. Overall, the successful integration of these ingredients presents a viable strategy for improving traditional meat products, supporting both health and environmental sustainability.

References

1. APHA. Standard methods for the examination of water and wastewater, 20th edn. American Public Health Association, Washington, DC; c2002.
2. Babaoglu AS. Effects of Replacing Breadcrumbs with Buckwheat, Chickpea, Corn and Millet Flour in Gluten-Free Meatball Formulation. Selcuk J Agric Food Sci. 2022;36(3):399-404.
3. Behailu B, Abebe M. Effect of soybean and finger millet flours on the physicochemical and sensory quality of beef meat sausage. Asian J Chem Sci. 2020;7(1):6-14.
4. Cordeiro ARRDA, Bezerra TKA, Madruga MS. Valuation of goat and sheep by-products: Challenges and opportunities for their use. Animals. 2022;12(23):3277.
5. Devatkal S, Mendiratta SK, Kondaiah N. Quality characteristics of loaves from buffalo meat, liver and vegetables. Meat Sci. 2004;67(3):377-383.
6. Gull A, Prasad K, Kumar P. Nutritional, antioxidant, microstructural and pasting properties of functional pasta. Saudi J Biol Sci. 2018;17(2):147-153.
7. Irshad A, Sharma BD. Abattoir by-product utilization for sustainable meat industry: A review. J Anim Prod Adv. 2015;5(6):681-696.
8. Keeton JT. Effects of fat and NaCl/phosphate levels on the chemical and sensory properties of pork patties. J Food Sci. 1983;48:878-881.
9. Koniecko R. Handbook for meat chemists. Wayne, NJ: Avery Publishing Group Inc., Wayne, New Jersey, USA; c1979. p. 68-69.
10. Krishnan R, Meera MS. Pearl millet minerals: Effect of processing on bio-accessibility. LWT-Food Sci Technol. 2018;55:3362-3372.
11. Mishra BP, Chauhan G, Mendiratta SK, Desai PRB. Effect of barnyard millet flour on the quality characteristics of dehydrated chicken meat rings. Poult Sci. 2014;45:530-534.
12. Naveena BM, Muthukumar M, Sen AR, Babji Y, Murthy TRK. Quality characteristics and storage stability of chicken patties formulated with finger millet flour (*Eleusine coracana*). J Muscle Foods. 2006;17(1):92-104.
13. Reddy GV, Sen AR, Ambedkar YR, Reddy BV. Effect of buckwheat flour on quality characteristics of chevon sausages. Indian J Small Ruminants. 2022;28(2):365-372.
14. Saikia K, Laskar SK, Hazarika M, Das A, Talukdar A, Nath R. Evaluation of Certain Physico-Chemical and

Sensory Qualities of Duck Meat Patties Incorporated with Black Gram Flour. Int J Livest Res. 2019;9(5).
15. Saleh AS, Zhang Q, Chen J, Shen Q. Millet grains: nutritional quality, processing, and potential health benefits. Compr Rev Food Sci Food Saf. 2013;12(3):281-295.
16. Singh VP, Verma AK, Umaraw P, Roy D, Rawat S. Quality and storage life of sorpotel using finger millet. Indian J Small Ruminants (The). 2021;27(1):100-104.
17. Snedecor GW, Cochran WG. Statistical Methods. 8 ed., Affiliated East-West Press, New Delhi and Iowa State University Press, Iowa, USA. 1994.
18. Troutt ES, Hunt MC, Johnson DE, Claus JR, Kastner CL, Kropf DH, *et al*. Chemical, physical, and sensory characterization of ground beef containing 5 to 30 percent fat. J Food Sci. 1992;57:25-29.
19. Umaraw P, Pathak V, Rajkumar V, Verma AK, Singh VP, Verma AK. Microbial quality, instrumental texture and colour profile evaluation of edible byproducts obtained from Barbari goats. Vet World. 2015;8(1):97-102.
20. Umaraw P, Singh VP, Verma AK. Effect of Addition of Mango Seed Extract on Storage Stability of Chevon Meatballs at Refrigeration Temperature. Foods. 2024;13(5):676. https://doi.org/10.3390/foods13050676.
21. Vanathi A, Rajkumar V, Mendiratta SK, Verma AK, Rao VA, Kumar RR, *et al*. Quality characteristics of goat meat nuggets incorporated with edible goat by products. Environ. 2020;6(2):954-964.
22. Verma AK, Umaraw P, Singh VP. Effect of mushroom extract on storage stability of chevon nuggets at refrigerated temperature. J Food Process Preserv. 2023;(1):8972331. https://doi.org/10.1155/2023/8972331.
23. Wang Y, Zhang L, Wang P, Xu X, Zhou G. pH-shifting encapsulation of curcumin in egg white protein isolate for improved dispersity, antioxidant capacity and thermal stability. Food Res Int. 2020;137:109366.
24. Webb EC. Goat meat production, composition, and quality. Front Anim Sci. 2014;4(4):33-37.
25. Witte VC, Krause GF, Bailey ME. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. J Food Sci. 1970;35(5):582-585.