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# Influence of Barn Yard Millet Flour on Quality Characteristics and Fatty Acid Profile of Chicken Meat Nuggets

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## ARTICLE INFO

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## ABSTRACT

An investigation was conducted to evaluate the effect of incorporating barnyard millet (*Echinochloa esculentum)* flour (0, 2, 4, and 6 %) on the quality attributes and omega-3 fatty acid profile of chicken meat nuggets. Nuggets containing 6 % barnyard millet flour exhibited improved physicochemical properties, including higher cooking yield, emulsion stability, and water-holding capacity. Increasing levels of barnyard millet flour resulted in higher moisture, crude fiber, and ash contents, accompanied by a reduction in protein content. Textural quality was enhanced, as indicated by lower shear force values and improved textural attributes compared with the control. Instrumental colour scores increased with barnyard millet flour incorporation. Omega-3 fatty acid content was higher in nuggets formulated with 6 % barnyard millet flour. Sensory evaluation also indicated superior acceptability for nuggets containing 6 % barnyard millet flour. Overall, incorporation of barnyard millet flour at 6 % improved the quality characteristics and enhanced the omega-3 fatty acid content of chicken meat nuggets.
*Keywords:* Barnyard Millet Flour, Chicken meat nuggets, Fatty acid profile, Quality characteristics.

## Introduction

In India, processed meat product market is projected to grow from USD 6,064.48 million in 2023 to an estimated USD 10,503.32 million by 2032, with a compound annual growth rate (CAGR) of 6.28% from 2024 to 2032 (Credence Research Report 2025). This growth reflects increasing demand for processed meat products, driven by changing consumer preferences and urbanization. Moreover, consumers are seeking more diverse and high-quality meat products, contributing to the expansion of the fresh processed meat sector. In India, poultry meat consumption is increasing with growing population (FAO 2023). Among the poultry meats, chicken meat is mostly consumed (Pakseresht et al. 2022) and has been developed into different forms for consumption which include chicken nuggets. Chicken nuggets have gained popularity due to its variety of benefits such as reduced preparation time, low cost, and long shelf life under frozen storage. Also, it has become an important ready for sale food served at almost all fast food restaurant chains across India (Pakseresht et al. 2022). This has led to an increasing demand for chicken nuggets with respect to preference for quality, taste and health value (Bhaskar Reddy et al. 2008). Thus, in order to diversify the quality, taste and health value, the use of different millets used as extenders to meet up with consumer's demand. Millets are a good source of proteins, dietary fibers, iron, zinc, calcium, phosphorus, potassium, vitamin B and constitute a range of vital amino acids than major cereals (Saleh et al. 2013). Barnyard millet (*Echinochloa esculenta*) is an ancient millet crop cultivated in warm and temperate regions of the world. It is abundantly harvested in Asia, notably in India, China, Japan and Korea (Madhusudhana et al. 2018). Barnyard millet is classified as a minor cereal crop providing higher nutrients than other cereals (Shanmugapriya and Nazni, 2020). It provides ample nutrients and is a healthy grain (Veena Bharati et al. 2005) which is high in protein, fiber, fat, vitamins and minerals such as iron, zinc, calcium, magnesium and essential amino acids (Chandel et al. 2014 and Singh et al. 2022). It is rich in essential fatty acids like linoleic acid, palmitic acid and oleic acid as well as minerals like iron, calcium and magnesium, where magnesium and niacin ($B_3$) help to lower cholesterol levels and phosphorus minerals, improve the metabolic process and food conversion into energy (Veena Bharati et al. 2005). Barnyard millet having a proximate composition /100 gm is 10.5% protein, 3.6–3.8% fat, 51.5–62 g/100gm carbohydrate, 398 kcal/100 g energy, 5.41–6.8% crude fiber and the total dietary fiber content is found to be high of about 12.6% including soluble (4.2%) and insoluble (8.4%) dietary fiber (Ugare et al. 2014 and Singh et al. 2022). By understanding the potential benefits of barn yard millet, an investigation was carried out to include barnyard millet flour in the chicken nuggets formulation with an aim to improve the functional properties of the product with enhanced dietary fiber and healthy fatty acid profile for the development of nutrient rich chicken nuggets.

## Materials And Methods

Processing of functional chicken meat nuggets

Fresh broiler boneless chicken meat, barnyard millet flour (BMF) and other non-meat ingredients were procured from local market of Tirupati and analytical grade chemicals and food grade additives were procured from standard companies. The formulation for processing of chicken meat nuggets was shown in Table 1 and process flow of the product shown in Figure 1.

**Fig. 1:** Process flow chart for preparation of chicken meat nuggets.

Fresh broiler boneless chicken meat
↓
Cutting into small chunks
↓
Mincing through 4 mm plate using meat mincer
↓
Chopping in bowl chopper by addition of curing ingredients about 1 min
(Salt, STPP, Sodium nitrate, Sodium ascorbate, Sugar and 50 % of ice flakes)
↓
Divide the meat batter into 4 equal parts and chop separately by addition of oil, spice and condiment mix and barn yard millet flour (0, 2, 4 and 6 %) with remaining 50 % ice flakes
↓
Final chopping (3 min)
↓
Emulsion temperature maintained at 12–15 °C
↓
Filling emulsion into rectangular steel moulds
↓
Steam cooking (30 min) till internal temperature of product should reach 75 ± 2 °C
↓
Immediate chilling of the Loaf
↓
Slicing into nuggets
(4 × 1.5 × 1.5 cm)
↓
Quality evaluation

The fresh broiler boneless chicken meat cut into small chunks and minced in a meat mincer (Sirman, TC 12 E, Italy) through 4 mm plate. The emulsion was prepared by chopping the minced meat along with other non-meat ingredients in a bowl chopper (Scharfen, Model No: TC 11, Germany). The minced chicken meat was mixed with salt, STPP, sodium nitrate, sodium ascorbate, sugar and ice flakes and chopped for one min followed by addition of oil and again chopped for one min and added spice mix, condiment mix (onion and garlic: 3:1), barn yard millet flour used @ 0, 2, 4 and 6 per cent in control, T1, T2 and T3 respectively and finally chopped for 3 min. The temperature of the emulsion was maintained between 12 to 15ºC. The emulsions of control, T1, T2 and T3 was separately filled in a rectangular steel mould and steam cooked for 30 minutes to an internal temperature of 75±2ºC as indicated by the temperature probe. The meat blocks were immediately chilled and sliced into nuggets of uniform size i.e., 4 x 1.5 x 1.5 cm and subjected for various quality attributes like physico-chemical characteristics, proximate composition, textural attributes, instrumental colour scores, fatty acid profile and sensory characteristics.

**Table 1.** Formulation for the development of chicken meat nuggets extended with barnyard millet flour.

| S.No | Ingredients (%) | Control | T1 | T2 | T3 |
|---|---|---|---|---|---|
| 1. | Chicken meat | 78 | 76 | 74 | 72 |
| 2. | Barnyard millet flour | 0 | 2 | 4 | 6 |
| 3. | Salt | 1.7 | 1.7 | 1.7 | 1.7 |
| 4. | STPP | 0.4 | 0.4 | 0.4 | 0.4 |
| 5. | Sodium nitrite (ppm) | 150 | 150 | 150 | 150 |
| 6. | Sodium ascorbate | 0.5 | 0.5 | 0.5 | 0.5 |
| 7. | Sugar | 1.0 | 1.0 | 1.0 | 1.0 |
| 8. | Refined sunflower oil | 6.0 | 6.0 | 6.0 | 6.0 |
| 9. | Spice mix | 2.4 | 2.4 | 2.4 | 2.4 |
| 10. | Condiment mix | 4.0 | 4.0 | 4.0 | 4.0 |
| 11. | Ice flakes | 6.0 | 6.0 | 6.0 | 6.0 |
| | Total | 100 | 100 | 100 | 100 |

### Physico-chemical characteristics

Cooking yield (%) of the final product was determined by calculating the weight difference of samples before and after cooking. For estimating the emulsion stability, about 25 g of meat emulsion was taken in low density polyethylene bags and heated in a thermostatically controlled water bath at 80°C for 20 min. Then the exudates was drained out and dried with tissue paper and the cooked mass was weighed and the percentage of cooked mass was expressed as emulsion stability (Kondaiah et al. 1985). Water-holding capacity (WHC) was determined according to Wardlaw et al. (1973). 20 g of sample was placed in a centrifuge tube containing 30 ml NaCl (0.6 M) and was stirred with glass rod for 1 minute. The tube was then kept at refrigeration temperature (4±1°C) for 15 min, stirred again and centrifuged at 3000 rpm using refrigerated centrifuge (Remi) for 15 min. The supernatant was measured and amount of water retained by samples was expressed as % WHC. The pH of samples was determined by homogenizing 10 g of sample with 50 ml distilled water with the help of tissue homogenizer (Daihan Scientifics, WiseMix, HG-15D, Korea) for 1 min. The pH was recorded using micro controlled based pH system with electrode (Model: 361, Systronics, India).

### Proximate composition

The moisture content was determined by hot air oven drying, protein by automatic Kjeldahl method, fat by Soxhlet extraction with petroleum ether and total ash by muffle furnace as described in AOAC (2002). The crude fiber was determined according to the method of Prosky et al. (1988).

### Texture profile analysis (TPA)

The Texture Profile Analysis (TPA) of RBMS was conducted following Bourne (1978) procedure using a Texturometer (Tinius Olsen, Model H1KF, 6 Perrywood Business Park, Redhill, RH1 5DZ, England). Prior to analysis, refrigerated samples were allowed to equilibrate to room temperature (25°C). Test samples of uniform size (1.5 $cm^3$) were taken from the central part of each block. The analysis was carried out under the following conditions: Load cell: 50 N, Pre-test speed: 300 mm/min, Post-test speed: 10 mm/s, Distance: 12 mm, Time: 3 min, Trigger: Auto, Probe: 75 mm compression plate. The TPA parameters calculated from the test were hardness (N), springiness (mm), cohesiveness (ratio), gumminess (N), and chewiness (N mm).

### Instrumental color scores

The *CIE* (*Commission Internationale de l'Eclairage,* 1986) employed for evaluation of instrumental color of developed RBMS by using a Konica Minolta colour reader (Model No: CR 20) by using illuminant D-65 with a 10° standard observer and aperture size was 25 mm. The instrument used was pre-calibrated, and the color meter's aperture was positioned vertically on the surface **of** the samples. The results were digitally displayed on an LCD screen of the color reader, indicating lightness ($L^*$), redness ($a^*$) and yellowness ($b^*$). Each sample underwent three measurements at different locations, and the mean value was calculated.

### Fatty acid profile

To study the fatty acid profiles, total lipids extracted from meat sample as per Folch et al. (1957) and dissolved in 10 ml of heptane. Five ml of heptane solution was taken and 5 ml of 2N methanolic Potassium hydroxide was added to it. Test tubes were inverted twice and heated to develop fatty acid methyl esters (FAMES). The supernatant was injected directly into gas chromatograph for separation of fatty acid methyl esters (FAMES). Thermo Focus Gas Chromatograph fitted with a DB225 polar column (30 m, 0.322 mm, 0.251) and Flame Ionization Detector was used for the analysis of fatty acid composition. The temperatures of oven, injector and detector blocks were maintained at 210, 230 and 250 °C respectively. Nitrogen was used as the carrier gas. Peaks were identified by comparison with relative retention times (RT) of standard FAMES. Concentration of each fatty acid was recorded by normalization of peak areas using GC post run analysis software, manual integration and reported as % of the particular fatty acid.

### Sensory characteristics

The chicken meat nuggets were warmed and served to trained panelists and evaluated for sensory characteristics like appearance, flavour, juiciness, tenderness and overall acceptability using a 8-point hedonic scale (where, 8=extremely desirable, 1=extremely undesirable) as described by (Keeton, 1983).

### Statistical analysis

The data generated for the different quality attributes were duplicated for each of the four replicated experiments, and data were expressed as means ± standard error. Statistical analysis was processed using SPSS-PASW statistics software version 20.0 for Windows, with One-way analysis of variance (ANOVA). Paired *t*-test and Duncan's multiple range tests were used to compare the means, and determine the significant differences ($P<0.05$) between groups (Snedecor and Cochran, 1989).

## Results And Discussion

### Physico-chemical characteristics

Addition of barnyard millet flour (BMF) on mean physico-chemical characteristics of chicken meat nuggets were presented in Table 2. Addition of BMF significantly ($P<0.05$) increased the cooking yield from 81.10% in control to 87.28% in 6% BMF added nuggets. The improvement in cooking yield could be due to the increased water and fat absorption capacity in the stabilized nuggets matrix. Further, due to hydrophilic nature of barn yard millet starch and also gelatinizing property on heating, which prevented evaporative moisture loss during cooking. The results are in agreement with (Sen et al. 2009) in mutton nuggets incorporated with wheat fiber.

Addition of 6 % BMF significantly (P<0.05) increased the emulsion stability and water holding capacity (WHC) of chicken meat nuggets. The higher emulsion stability could be due to the greater extent of gelatinization of its starch components. The possible interaction between soluble meat and vegetable proteins has been indicated as the binders appearing to increase fat agglomeration during emulsion making, thus improving the stability of product (Bhaskar Reddy et al. 2022). The higher WHC might be due to higher moisture absorption capacity of barnyard millet flour in meat emulsion. A positive relationship was observed between increasing cooking yield and higher WHC in chicken meat nuggets by adding various levels of barnyard millet flour. Similarly, (Sen et al. 2009) also noticed highest WHC values in mutton nuggets incorporated with wheat fiber. Addition of different levels of BMF did not significantly (P>0.05) affect the pH values of functional chicken meat nuggets. Cooked nuggets had higher pH values compared with their corresponding raw samples. Similar results were also observed by (Sharma et al. 2014) in restructured mutton chops extended with flax seed flour.

**Table 2.** Mean ± S.E values of physico-chemical characteristics and proximate composition of chicken meat nuggets extended with barnyard millet flour*.

| Parameters | | Control | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Cooking yield (%) | | $81.10\pm0.31^{d}$ | $84.27\pm0.28^{c}$ | $85.16 \pm 0.38^{b}$ | $87.28\pm0.27^{a}$ |
| Emulsion stability (%) | Emulsion | $77.08\pm0.20^{d}$ | $81.25\pm0.13^{c}$ | $85.01\pm0.22^{b}$ | $88.36\pm0.17^{a}$ |
| Water-holding capacity (%) | Emulsion | $33.28\pm0.37^{d}$ | $36.74\pm0.23^{c}$ | $37.08\pm0.09^{b}$ | $39.85\pm0.37^{a}$ |
| | Product | $38.07\pm0.46^{d}$ | $38.92\pm0.62^{c}$ | $40.09\pm0.18^{b}$ | $42.45\pm0.24^{a}$ |
| pH | Emulsion | 5.51±0.12 | 5.59±0.29 | 5.61±0.27 | 5.55±0.20 |
| | Product | 5.92±0.17 | 6.01±0.27 | 6.05±0.28 | 5.93±0.28 |
| Moisture (%) | Emulsion | $70.25\pm0.16^{c}$ | $71.55\pm0.23^{b}$ | $71.24 \pm 0.34^{b}$ | $73.09\pm0.22^{a}$ |
| | Product | $63.67\pm0.37^{c}$ | $64.14\pm0.34^{b}$ | $64.02 \pm 0.22^{b}$ | $66.03\pm0.24^{a}$ |
| Protein (%) | Emulsion | $22.59\pm0.71^{a}$ | $21.38\pm0.13^{b}$ | $19.92\pm0.29^{c}$ | $18.72\pm0.47^{d}$ |
| | Product | $23.42\pm0.08^{a}$ | $22.25\pm0.22^{b}$ | $20.36 \pm 0.15^{c}$ | $19.54\pm0.29^{d}$ |
| Fat (%) | Emulsion | 6.92±0.30 | 6.79±0.31 | 7.02±0.18 | 6.85±0.23 |
| Product | | 7.28±0.17 | 7.19±0.43 | 7.17±0.13 | 7.25±0.16 |
| Total Ash (%) | Emulsion | $1.96\pm0.12^{d}$ | $2.15\pm0.17^{c}$ | $2.68\pm0.10^{b}$ | $2.91\pm0.32^{a}$ |
| | Product | $2.17\pm0.23^{d}$ | $2.71\pm0.15^{c}$ | $2.98\pm0.22^{b}$ | $3.47\pm0.16^{a}$ |
| Crude fiber (%) | Emulsion | $0.37\pm0.11^{d}$ | $0.63\pm0.13^{c}$ | $0.92 \pm 0.16^{b}$ | $1.14\pm0.26^{a}$ |
| | Product | $0.53\pm0.09^{d}$ | $0.71\pm0.37^{c}$ | $1.04\pm0.27^{b}$ | $1.25\pm0.30^{a}$ |

Note: Mean values within row bearing different superscripts are differ significantly (P<0.05).

* n=6

## Proximate composition

The proximate composition showed that chicken meat nuggets added with 6% BWF had significantly (P<0.05) higher moisture, total ash and crude fiber contents than the control and remaining formulations (Table 2). The ability of proteins in BMF to bind moisture is important for retention of more water in the cooked product. Higher total ash and crude fiber in treated nuggets could be due to higher fiber content (10% on dry matter basis) of barnyard millet flour. Addition of BMF significantly (P<0.05) reduced the protein content of both raw and cooked chicken meat nuggets. Reduced protein content could be due to replacement of chicken meat with BMF which is having lower protein content than chicken meat. Increased protein content in cooked chicken meat nuggets compared to raw samples could be due to compositional changes in the product which is attributed to the change in total product mass during cooking. The per cent fat content was not significantly (P>0.05) affected by addition of various levels of BMF in both raw and cooked meat. Similar findings were observed by Kumar et al. (2015) in chevon patties.

## Texture profile analysis (TPA)

Addition of BMF significantly (P<0.05) influenced the all texture profiles of chicken meat nuggets (Table 3). Chicken meat nuggets incorporated with 6% BMF had recorded significantly (P<0.05) lower chewiness, gumminess, hardness and springiness values compared to control and remaining formulations. As the level of BMF increased, a gradual reduction of above textural characteristics was noted, but cohesiveness values were increased. The lower chewiness values in BMF added chicken meat nuggets is due to less force required for texture probe to compress the product with higher moisture content. Formation of wheat flour favors the formation of strong gels in emulsion matrix thus stabilized the emulsion during cooking which might favors more cohesive in barnyard millet added nuggets than control sample. Hardness is the most important quality characteristic when evaluating the textural properties of nuggets. In the present investigation, the control nuggets had significantly (P<0.05) highest hardness values amongst the nuggets samples and the hardness of the sausage samples gradually decreased with the increased level of BMF. Reduction of hardness values could be due to moisture retention properties of BMF (Sharma et al. 2014). These results indicate that BMF is useful in preparing nuggets with softer/optimal textural quality.

**Table 3.** Mean ± S.E values of textural characteristics of chicken meat nuggets extended with barnyard millet flour *.

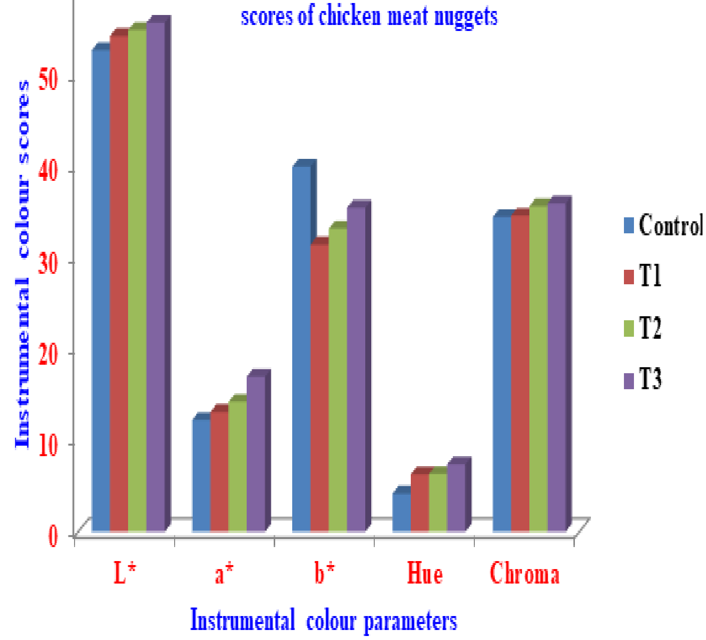
| Parameters | Control | T1 | T2 | T3 |
|---|---|---|---|---|
| Chewiness (N/cm) | 8.61 ±0.40[a] | 7.21±0.19[b] | 6.50±0.31[c] | 6.13±0.28[d] |
| Cohesiveness (Ratio) | 0.57±0.11[a] | 0.59±0.20[a] | 0.63±0.08[b] | 0.69±0.28[c] |
| Gumminess ($N/cm^2$) | 1.35±0.17[a] | 1.12±0.07[b] | 1.09±0.16[b] | 0.89±0.10[c] |
| Hardness (N) | 3.87±0.51[a] | 3.15±0.38[b] | 2.64±0.40[c] | 2.07±0.19[d] |
| Springiness (cm) | 8.42±0.30[a] | 8.11±0.13[b] | 7.68±0.44[c] | 6.54±0.17[d] |

Note: Mean values within row bearing different superscripts are differing significantly (P<0.05). * n=6

## Instrumental colour scores

There was a significant increase in instrumental color scores of chicken meat nuggets that which includes lightness, redness, yellowness, hue, chroma values due to addition barnyard millet flour at various levels (Figure 2). Color is a crucial factor for consumer appeal which also has the ability to affect other sensory properties. The *L** values of chicken meat nuggets were between 52.59 to 55.56 and among the prepared nuggets, control samples significantly (P<0.05) lower instrumental *L** values than BMF added nuggets which reflected well in its physical appearance, being the darkest among all nuggets. It is common to grade the color of meat products by its redness (*a**) value which is reported to have a high correlation (r = 0.947) with L* values. As in the case of *L** values, the higher *a** value (6.96) was recorded in chicken nuggets added with 6 % BMF (T3). The chicken meat nuggets developed with BMF had significantly (P>0.05) lower mean b* (yellowness) values in the range of 31.37 (T1) to 39.89 (Control) and presented a significant difference (P < 0.05) among them. The chroma values of the nuggets ranged from 4.18 (Control) to 7.39 (T3). Higher hue values are associated with higher pigment concentration and increased perception of color intensity and as the values decreased, the samples became darker. A little significant (P<0.05) higher chroma values were found in the BMF added chicken meat nuggets. In this study, the prepared chicken meat nuggets were stored in a refrigerator for 18 h and sliced as nuggets then subjected to instrumental colour evaluation which may have affected the measured values. Barn yard millet grains with different levels have varying quantities of pigments and other compounds imparting each variety a unique color. This has resulted in wide variations in the color of chicken meat nuggets prepared from different levels of barn yard millet flour. The major pigments present in barn yard millet grains include carotenoids (lutein and zeaxanthin), anthocyanins, tannins and flavonoids which may contribute to the color of the developed chicken meat nuggets (Siwela et al. 2007 and Li et al. 2021).

Fig. 2: Influence of bard yard millet flour on instrumental color scores of chicken meat nuggets




## Fatty acid profile

The fatty acid composition of chicken meat nuggets influenced by addition of various levels of BMF was presented in Table 4. Addition of BMF significantly (P<0.05) influenced both saturated and unsaturated fatty acid composition in chicken meat nuggets. The chicken nuggets formulated with different levels of BMF had significantly (P<0.05) reduced the predominant saturated fatty acids (SFA), palmitic (C16:0) and stearic acid (C18:0) acids (%)

from 4.29 to 1.86 and 48.92 to 31.80 respectively. Generally, the higher SFA contents were found for control nuggets and addition of BMF decreased the SFA content of chicken nuggets. The lower amount of palmitic and stearic acid in barn yard millet flour is responsible for reducing the total above said fatty acids in the treated nuggets. Addition of BMF did not significantly (P>0.05) influenced the lauric acid content of chicken meat nuggets. Addition of barn yard millet flour significantly (P<0.05) increased the oleic acid (%) from 32.98 to 49.83±1.76, linoleic acid from 0.72 to 3.18, arachidic acid from 0.19 to 1.98, linolenic acid from 0.03 to 0.37 and docosahexaenoic acid from 0.18 to 0.50 in chicken meat nuggets. Barn yard millet flour had higher amount of oleic acid, linoleic acid, arachidic acid, linolenic acid, and docohexaenoic acid which were significantly increased the product fatty acid profile. In the human diet, the recommended adequate intake for C 18:3 n-3 (α-linolenic acid) is 2.22 g/ day based on a 2000 kcal diet (Simopoulos et al. 1999). Therefore, 50 g portion of chicken nuggets with 9 per cent added flaxseed flour would provide between 60% and 100% of this recommended intake. Similar results were obtained by (Valencia et al. 2008) in cooked pork sausages containing linseed oil. (Bilek and Turhan, 2009) also noticed similar results in beef patties added with various levels of flax seed flour. Further, (Bhaskar Reddy et al. 2018) found significant increase of healthy fatty acid profile by addition of flax seed flour in chicken meat nuggets.

**Table 4.** Mean ± S.E values of fatty acid profile of chicken meat nuggets extended with barnyard millet flour *.

| Fatty acids (%) | Barnyard Millet | Control | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Capric Acid | ND | ND | ND | ND | ND |
| Lauric Acid | ND | 1.25±0.36 | 1.28±0.22 | 0.23±0.31 | 0.26±0.18 |
| Myristic Acid | 3.78 | $10.33±1.29^{c}$ | $11.51±0.59^{b}$ | $11.43±1.05^{b}$ | $12.14±1.88^{a}$ |
| Palmitic Acid | 6.89 | $4.29±0.68^{a}$ | $1.86±0.33^{b}$ | $1.90±0.72^{b}$ | $1.93±0.92^{b}$ |
| Palmitoleic Acid | 3.96 | $6.79±1.32^{a}$ | $4.04±0.67^{b}$ | $4.06±0.34^{b}$ | $4.12±0.85^{b}$ |
| Stearic Acid | 17.90 | $48.92±2.42^{a}$ | $37.63±1.79^{b}$ | $34.78±1.47^{c}$ | $31.80±2.06^{d}$ |
| Oleic Acid | 30.98 | $32.98±0.88^{d}$ | $42.54±2.55^{c}$ | $45.72±1.28^{b}$ | $49.83±1.76^{a}$ |
| Linoleic Acid | 2.19 | $0.72±0.44^{d}$ | $1.19±0.13^{c}$ | $2.40±0.20^{b}$ | $3.18±0.55^{a}$ |
| Arachidic Acid | 3.01 | $0.19±0.21^{d}$ | $0.89±0.15^{c}$ | $1.24±0.31^{b}$ | $1.98±0.06^{a}$ |
| Linolenic Acid | 1.89 | $0.03±0.19^{b}$ | $0.47±0.17^{a}$ | $0.44±0.04^{a}$ | $0.37±0.11^{a}$ |
| Behenic Acid | ND | ND | ND | ND | ND |
| Eicosapentaenoic Acid | ND | ND | ND | ND | ND |
| Docosahexaenoic Acid | 1.33 | ND | $0.18±0.33^{c}$ | $0.27±0.19^{b}$ | $0.50±0.03^{a}$ |

Note: Mean values within row bearing different superscripts are differ significantly (P<0.05).
* n=4

## Sensory characteristics

The mean values of the sensory parameters scored on a 8-point hedonic scale are tabulated in Table 5. The panelists expressed that BMF added chicken meat nuggets was superior colour, flavor, juiciness, tenderness and overall acceptability than control nuggets. Higher colour scores in treated nuggets is due to the combined effects of pigments present in both chicken meat as well as barn yard millet flour which rated superior colour scores. The flavour and juiciness scores significantly (P<0.05) increased on addition of BMF and the scores for flavor and juiciness up to 9 % BMF were 'very acceptable' as per the 8 point hedonic rating by the sensory panel. A significant (P<0.05) higher scores for tenderness and overall acceptability also noted in chicken nuggets added with BMF compared with control nuggets. Similar to these results, (Santhi and Kalaikannan, 2015) observed that the addition of a different variety of pearl millet up to 4% in low fat chicken meat balls had acceptable sensory properties. In the same way, the sensory attributes of chicken nuggets prepared with 10 % pearl millet flour (Para and Ganguly, 2015) and low-fat chicken meat balls prepared with a combination of 3.50 % pearl millet flour and 5.00% wheat flour (Santhi et al. 2020) was found to be good. Addition of buck wheat flour significantly enhanced the sensory scores of chevon sausages (Bhaskar Reddy et al. 2022).

**Table 5.** Mean ± S.E values of sensory characteristics of chicken meat nuggets extended with barnyard millet flour *.

| Parameters | Control | T1 | T2 | T3 |
|---|---|---|---|---|
| Colour | $6.45±0.11^{d}$ | $6.79±0.15^{c}$ | $7.01±0.42^{b}$ | $7.26±0.21^{a}$ |
| Flavor | $6.59±0.52^{b}$ | $6.89±0.32^{a}$ | $6.91±0.41^{a}$ | $6.97±0.41^{a}$ |
| Juiciness | $6.43±0.20^{b}$ | $6.68±0.19^{a}$ | $6.79±0.25^{a}$ | $6.87±0.14^{a}$ |
| Tenderness | $6.52±0.25^{d}$ | $6.74±0.17^{c}$ | $6.98±0.31^{b}$ | $7.13±0.24^{a}$ |
| Overall acceptability | $6.63±0.10^{d}$ | $6.79±0.13^{c}$ | $6.92±0.30^{b}$ | $7.07±0.31^{a}$ |

Note: Mean values within row bearing different superscripts are differ significantly (P<0.05).
* n=24

## Conclusion

Based on the obtained results, it was concluded that incorporation of barnyard millet flour positively influenced the nutritional quality of functional chicken meat nuggets. The addition of barnyard millet flour improved cooking yield, emulsion stability, and water-holding capacity, while also modifying the proximate composition. Progressive inclusion of barnyard millet flour enhanced the fatty acid profile, particularly the proportion of unsaturated fatty acids, and improved textural properties, instrumental colour values and sensory scores. Thus, it may be useful for commercial uses with production of cost-effective and nutritionally enriched processed meat products.

## Competing Interests

The authors do not have any competing interests among themselves or others related to this research work.

## Ethics Statement

Not applicable

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