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Effect of incorporation of pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*) flours on sensory and physico-chemical properties of chicken meat rolls

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Abstract

The objective of this study was to develop chicken meat rolls with the inclusion of Pearl millet flour (PMF) and Foxtail millet flour (FTMF) as a replacer of semolina. The products were assessed for pH, water holding capacity (WHC), cooking yield (CY), emulsion stability (ES) and sensory properties. Chicken meat rolls were prepared with the addition of 3%, 6%, 9% and 12% Pearl millet flour (PMF) and 3%, 6% and 9% Foxtail millet (FTMF) flour as well as their combination 3% FTMF + 3% PMF, 5% FTMF + 3% PMF, 3% FTMF + 5% PMF and 5% FTMF + 5% PMF in chicken meat. Among all of these 9% level of Pearl Millet Flour, 6% level of Foxtail Millet (FTMF) and 3%FTMF + 5%PMF level of their combination was selected on the basis of their sensory evaluation. Scores for different sensory attributes i.e. colour, flavour, texture, tenderness, juiciness and overall acceptability (OAA) of all selected treatments were compared with control and well above 7.0 on 8 point descriptive scale indicating very good acceptability of chicken meat rolls. WHC, Emulsion stability and cooking yield was significantly ($p < 0.05$) higher at selected level of incorporation as compared to control.

Keywords: Chicken Meat Rolls, Cooking Yield, Foxtail Millet Flour, Pearl Millet Flour, Sensory attributes

Introduction

In the present global scenario, there is a substantial demand for naturally occurring meat products that are health conscious and minimally processed. Concerns regarding the quality and safety of food have also grown in recent years due to increasing health issues. Therefore, producing functional meat products to enhance lifestyle to prevent chronic diseases such as obesity, cardiovascular disease, colon cancer, anxiety, depression, and other health conditions is crucial for imparting value to meat products. Meat and meat products are important sources of protein, fat, essential amino acids, minerals, and vitamins (Hong *et al.*, 2021) [9]. Meat products, on the other hand, lack sufficient amount of complex carbohydrates like dietary fibre (Sanchez-Zapata *et al.*, 2010) [19]. Poultry meat is more acceptable due to its lower price, easier availability, excellent flavours, good texture and high protein content. It is also a good source of thiamine, nicotinic acid, vitamin A, iron and phosphorus (Koblitz, 2000) [11]. Poultry meat contains proteins (18.4-23.4%), lipids (2-6.0%) and minerals (0.8-1.2%) (Culioli *et al.*, 2003) [5].

Millets are rich in valuable nutrients such as carbohydrates, proteins, dietary fiber, minerals and vitamins (Himanshu *et al.*, 2018). Due to enrichment of dietary fiber millets exhibit an excellent binding ability to the cholesterol at neutral pH (Liu *et al.*, 2011) [13]. Millet grains are gluten-free and add as a alternative for patient with celiac diseases for a normal and healthy lifestyle (Jukanti *et al.*, 2016) [10]. The incorporation of antioxidants enriched millet grains in meat products can increase the shelf life by scavenging the oxidizing free radical molecules (Chandrasekara and Shahidi, 2011) [4]. Moreover with consumption of millets reduces risk of heart disease, protects from diabetes, improve immunity, lowers the risk of cancer and improve digestive system (Scalbert *et al.*, 2005) [20].

Pearl millet (*Pennisetum glaucum*) is commonly known as bajra. It is the most widely grown summer crop because of its tolerance to drought, low soil fertility and high temperature (Abdelrahman *et al.*, 2005) ^[1]. Pearl millet is a good source of energy with a calorific value of 361 Kcal/100g. It contains about 92.5% dry matter, 2.1% ash, 7.8% crude fat, 13.6% crude protein, and 63.2% starch (Ali *et al.*, 2003). Dietary fiber content is approximately 11.9-13.3% (Pushparaj and Urooj, 2011) ^[15]. Mineral contents in pearl millet varied from 40.07-42.67 mg/100g calcium, 255.67-327.82 mg/100g phosphorus (Kulthe *et al.*, 2016) ^[12]. The phytic acid, tannin and polyphenol contents in pearl millet varied from 566-618mg/100g, 225-232mg/100g and 403-445 mg/100g respectively (Kulthe *et al.*, 2016) ^[12].

Foxtail millet (*Setaria italica*) is one of the oldest cultivated fast-growing summer annual crop (FAO, 2011). Among the millets, foxtail millet is a good source of energy (351g/100g), protein (12.3g/100g), dietary fiber (14g/100g), minerals (3g/100g) and β carotene (126-191 μ g/100g) (Sharma and Niranjana, 2017) ^[21]. The antioxidant activities of foxtail millet have also been reported (Sripriya *et al.*, 1996) ^[23].

The goal of this research was to optimize the inclusion levels of Pearl Millet and Foxtail Millet flours, both individually and in combination, in chicken rolls. This aims to enhance the meat with dietary fiber and enriched the developed products with various health-promoting properties.

Experimental details

The present research was conducted in the Department of Livestock Products Technology, College of Veterinary Sciences, LUVAS, Hisar.

Materials required

Healthy broiler birds of about 5 - 6 weeks of age and reared under similar feed and management conditions were purchased from the Livestock Farm, College of Veterinary Sciences, LUVAS, Hisar or from the local market of Hisar. These birds were slaughtered and dressed as per the standard procedure. The carcass were washed thoroughly and manually deboned after trimming of visible fat and connective tissue. Deboned meat obtained was packed in low density polythene bags and kept in deep freezer till further use.

Additives, fat, water, spices mix and condiments

Sodium chloride, sodium tripolyphosphate (STTP), spices mix (developed in the laboratory), vegetable oils, water, whole egg liquid, semolina and condiments mix were used in standardized proportion.

Pearl millet and foxtail millet flours

Pearl millet and foxtail millet grains were purchased from the local market of Hisar. These grains were washed gently with clean water and water was removed by squeezing through the muslin cloth. After that, they were dried in the hot air drier. The dried products were grinded in a fine powder. All the above material was packed in an air-tight container for further use.

Chemicals, media and standards

All the chemicals, readymade culture media and standards were procured from reputed firms like Qualigens, CDH, Hi-Media, Siga-Aldrich etc.

Preparation of control chicken rolls

For preparation of control rolls, 77 gm of minced meat was added with sodium chloride (1.75 gm), sodium tripolyphosphate (0.3 gm), spices mix (1.75 gm), condiments (3.25 gm) (ginger and garlic in ratio of 1:1), semolina flour (3 gm), ice flakes (2.7 gm) and refined oil (7 gm). A stable emulsion was formed by mixing all the ingredients with the minced meat for 4 to 5 minutes. The rolls were prepared by steam cooking the emulsion, which was placed in a beaker, covered with aluminum foil and steam-cooked for 35 minutes on low heat. After cooking, the rolls were cooled to room temperature, packaged in polyethylene bags, and stored at a refrigerated temperature of 4 $\pm$ 1°C for further study.

Preparation of treated chicken rolls

Development of chicken meat rolls by incorporating different levels of Pearl Millet and Foxtail Millet flours, both individually and in combination. The rolls containing 3%, 6%, 9% and 12% Pearl Millet Flour (PMF) and 3%, 6% and 9% Foxtail Millet (FTMF) Flour individually as well as their combination 3%FTMF + 3%PMF, 5%FTMF + 3%PMF, 3%FTMF + 5%PMF and 5%FTMF + 5%PMF to replace lean meat in formulation. Levels of pearl millet flour (PMF) and foxtail millet flour (FTMF) were selected on the basis of sensory evaluation.

Table 1: Formulation for the preparation of chicken meat emulsion (per 100 gm emulsion)

Name of ingredients	Weight (g)
Chicken lean Meat	80
Sodium chloride	1.75
Sodium tripolyphosphate	0.3
Spices mix	1.75
Egg whole liquid	3.25
Condiments	3.25
Ice flakes	2.7
Refined oil	7
Total	100

Sensory evaluation

The sensory attributes, viz., colour and appearance, flavour, texture, juiciness, and overall acceptability of the finished product was estimated by semi trained panelists, using 8-point descriptive scale, where, 1 = extremely disliked and 8 = extremely like.

pH

pH of the meat samples was determined following the method described by Trout *et al.* (1992) ^[24]. A 10-gram meat sample was blended with 50 ml of distilled water for 1 minute using a pestle and mortar. The pH was measured by immersing the electrodes of a pH meter directly into the suspension.

Emulsion stability (ES)

Stability of both control and treated raw meat emulsions was assessed using the method outlined by Baliga and Madaiah (1970). A 20-gram portion of the meat emulsion was placed in low-density polyethylene (LDPE) bags with a thickness of 150 gauges and dimensions of 11 × 10 cm. These bags were then placed in a thermostatically controlled water bath set at 80±1°C for 20 minutes. Subsequently, the bags were removed from the water bath, opened, and the cooked-out fluid (comprising fat and water-soluble solids) was drained. The mass of the cooked emulsion was weighed and expressed as a percentage.

Water holding capacity (WHC)

The water-holding capacity (WHC) was determined following the method described by Wardlaw *et al.* (1973)^[26] with minor adjustments. In a 100 ml polycarbonate centrifuge tube, a finely minced meat sample weighing 15 grams was combined with 22.5 ml of 0.6 M NaCl solution. The mixture was stirred with a glass rod and agitated for 2 minutes on a mechanical shaker. After allowing it to stand for 15 minutes at 4°C to ensure the salt's effect reached equilibrium, the meat slurry was stirred again for 1 minute on the shaker and then centrifuged at 5000 rpm for 15 minutes using a refrigerated centrifuge (Eltek refrigerated centrifuge, model MP 400 R). The volume of the supernatant was measured, and the difference between the added and decanted solution was expressed as a percentage of the weight of the meat sample.

Cooking yield (CY)

Weight of chicken meat rolls before and after cooking was recorded and yield was expressed in percentage.

Statistical analysis

Data obtained were subjected to statistical analysis using Tukey test by using SPSS-16.0 (SPSS Inc., Chicago, II USA) software to find out the significant difference at 5% significance level in the mean values.

Result and Discussion

Sensory Attributes

The sensory attributes of chicken rolls with different amounts of Pearl Millet flour (PMF) are given in Table 2. The study investigated the sensory attributes of chicken meat rolls incorporated with 3%, 6%, 9% and 12% levels of pearl millet flour (PMF). Incorporation of PMF did not significantly affect the colour scores of PMF1, PMF2, and PMF3 treatments compared to the control, indicating that up to 9% incorporation of PMF did not compromise colour acceptability. The flavour, texture, juiciness, tenderness and overall acceptability (OAA) scores were comparable in case of control and PMF1, PMF2, and PMF3 while PMF4 have significantly lower score which could be attributed to the dilution of meat pigment due to PMF addition. These observations were consistent with the study of Para and Subha (2015)^[14], who reported that there were no significant differences in colour, appearance or flavour scores among various levels of pearl millet flour (PMF) and incorporation in chicken nuggets. In conclusion, the study demonstrates that incorporating up to 9% PMF in chicken meat rolls can be a viable option to enhance nutritional value without significant compromise in sensory attributes.

Table 2: Selection of suitable level of Pearl Millet flour (PMF) in chicken meat rolls (Mean ± SD)

Treatments	Colour	Flavour	Texture	Tenderness	Juiciness	OAA
Control	7.17 ^b ±0.30	7.17 ^b ±0.30	7.08 ^b ±0.41	7.08 ^b ±0.34	7.12 ^b ±0.47	7.12 ^b ±0.34
PMF1	7.00 ^b ±0.22	6.96 ^b ±0.29	6.83 ^b ±0.34	7.04 ^b ±0.25	7.04 ^b ±0.24	7.00 ^b ±0.16
PMF2	6.96 ^b ±0.33	7.08 ^b ±0.34	6.87 ^b ±0.38	7.00 ^b ±0.22	7.00 ^b ±0.35	6.96 ^b ±0.33
PMF3	6.92 ^b ±0.26	7.12 ^b ±0.26	6.83 ^b ±0.34	7.00 ^b ±0.16	6.96 ^b ±0.29	7.04 ^b ±0.29
PMF4	6.25 ^a ±0.45	6.17 ^a ±0.44	6.12 ^a ±0.38	6.08 ^a ±0.34	6.04 ^a ±0.29	6.33 ^a ±0.49

Mean with different superscript with small letter in a column differ significantly ($P \leq 0.05$) (n=12)

Control - Chicken rolls with 3% semolina, PMF1 - Chicken rolls with 3% pearl millet flour, PMF2 - Chicken rolls with 6% pearl millet flour, PMF3 - Chicken rolls with 9% pearl millet flour, PMF4 - Chicken rolls with 12% pearl millet flour

The sensory attributes of chicken rolls with different amounts of Foxtail Millet flours (FTMF) are given in Table 3. Sensory analysis results of foxtail Millet flour illustrated that incorporation of foxtail millet flour up to 6% resulted in comparable sensory scores. Further increase in FTMF level (12%) resulted in a significant decline in colour scores. This change might be due to increased swelling of the product at higher FTMF levels, resulting in charring of the outer skin and lower colour scores. Sharp and significant decline in

flavour scores of treatments FTMF 4 was also noticed. The decrease in juiciness might be due to decreased product density at higher extension levels, leading to reduced moisture content and dilution of meaty flavour. Texture, juiciness, tenderness and OAA scores of these treatments also showed significant decline with increase in the level of FTMF incorporation. As the OAA score of treatment FTMF2 was 7.17 denoting very good acceptability and comparable with control, so treatment FTMF2 (6% level) was selected for further study. These findings are similar to the report of Reddy *et al.* (2017)^[17]. Shinde *et al.* (2019) who concluded that the sensory scores of chevon sausage slightly increased with up to 6% FTMF incorporation and then decreased non-significantly ($P > 0.05$) at 9%.

Table 3: Selection of suitable level of Foxtail Millet flour (FTMF) in chicken meat rolls (Mean $\pm$ SD)

Treatments	Colour	Flavour	Texture	Tenderness	Juiciness	OAA
Control	7.17 ^b $\pm$ 0.30	7.17 ^a $\pm$ 0.30	7.08 ^b $\pm$ 0.41	7.08 ^b $\pm$ 0.34	7.12 ^b $\pm$ 0.47	7.12 ^b $\pm$ 0.34
FTMF1	7.17 ^b $\pm$ 0.20	7.04 ^a $\pm$ 0.19	7.12 ^b $\pm$ 0.26	7.04 ^b $\pm$ 0.33	7.12 ^b $\pm$ 0.34	7.08 ^b $\pm$ 0.20
FTMF2	7.12 ^b $\pm$ 0.34	7.21 ^a $\pm$ 0.37	7.17 ^b $\pm$ 0.20	7.08 ^b $\pm$ 0.34	7.08 ^b $\pm$ 0.34	7.17 ^b $\pm$ 0.20
FTMF3	6.54 ^a $\pm$ 0.33	6.87 ^a $\pm$ 0.34	6.33 ^a $\pm$ 0.49	6.17 ^a $\pm$ 0.44	6.12 ^a $\pm$ 0.38	6.42 ^a $\pm$ 0.41

Mean with different superscript with small letter in a column differ significantly ($P \leq 0.05$) (n=12)

Control - Chicken rolls with 3% semolina, FTMF1 - Chicken rolls with 3% foxtail millet flour, FTMF2 - Chicken rolls with 6% foxtail millet flour, FTMF3 - Chicken rolls with 9% foxtail millet flour.

The sensory attributes of chicken rolls with different amounts of Pearl Millet and Foxtail Millet flours combination given in Table 4. Incorporation of pearl millet flour (PMF) and foxtail millet flour (FTMF) combination revealed similar results as those noticed when individual flour was incorporated. Treatments MF1, MF2 and MF3 having combination of pearl millet flour (PMF) and foxtail

millet flour (FTMF) had sensory scores similar to control. Significant decline in sensory scores in comparison to control was noticed in treatment MF4. These observations were consistent with the study of Verma *et al.* (2010) suggested that the decline in sensory score ratings at elevated extender levels might result from the replacement of structural meat proteins by the extender. This suggests that MF3 incorporation strikes a balance between enhancing nutritional content while maintaining sensory qualities similar to the control.

Table 4: Selection of suitable level of combination of Pearl Millet flour (PMF) and Foxtail Millet flour (FTMF) in chicken meat rolls (Mean $\pm$ SD)

Treatments	Colour	Flavour	Texture	Tenderness	Juiciness	OAA
Control	7.17 ^b $\pm$ 0.30	7.17 ^b $\pm$ 0.30	7.08 ^b $\pm$ 0.41	7.08 ^b $\pm$ 0.34	7.12 ^b $\pm$ 0.47	7.12 ^b $\pm$ 0.34
MF1	6.87 ^{ab} $\pm$ 0.26	7.00 ^b $\pm$ 0.22	6.83 ^{ab} $\pm$ 0.26	7.00 ^b $\pm$ 0.22	7.04 ^b $\pm$ 0.19	6.96 ^{ab} $\pm$ 0.19
MF2	6.92 ^{ab} $\pm$ 0.13	7.04 ^b $\pm$ 0.19	6.87 ^{ab} $\pm$ 0.34	6.96 ^{ab} $\pm$ 0.19	6.95 ^{ab} $\pm$ 0.29	7.04 ^b $\pm$ 0.29
MF3	6.96 ^{ab} $\pm$ 0.19	7.12 ^b $\pm$ 0.34	6.92 ^{ab} $\pm$ 0.30	7.00 ^b $\pm$ 0.16	7.00 ^{ab} $\pm$ 0.22	7.08 ^b $\pm$ 0.34
MF4	6.33 ^a $\pm$ 0.63	6.29 ^a $\pm$ 0.19	6.37 ^a $\pm$ 0.26	6.54 ^a $\pm$ 0.33	6.50 ^a $\pm$ 0.27	6.42 ^a $\pm$ 0.41

Mean with different superscript with small letter in a column differ significantly ($P \leq 0.05$) (n=12)

Control - Chicken rolls with 3% semolina MF1 - Chicken rolls with 3% pearl millet flour + 3% foxtail millet flour, MF2 - Chicken rolls with 3% pearl millet flour + 5% foxtail millet flour, MF3 - Chicken rolls with 5% pearl millet flour + 3% foxtail millet flour, MF4 - Chicken rolls with 5% pearl millet flour + 5% foxtail millet flour.

Physico-chemical properties

The physico-chemical parameters included pH, cooking yield and emulsion stability are represented in Table 5. pH of raw emulsion increased significantly in all treatment's comparison to control. Para and Subha (2015) [14] also observed a gradual pH increase with higher levels of incorporation, noting a significantly higher pH ($P < 0.05$) at a 20% incorporation level compared to the control. pH of cooked chicken meat rolls did not differ significantly between control and treatments T₁, T₂ and T₃. This difference was attributed to ingredient concentration in the cooked product and cooking processes affecting protein coagulation and deamination.

WHC increased significantly in all treated chicken rolls comparison to control. Higher water holding capacity in PMF and FTMF treated rolls might be due to presence of high dietary fibres in PMF and FTMF and their capacity to absorb more moisture through protein-water interactions

which contributed to increase in water holding capacity. Reddy *et al.* (2017) [17] observed a significant ($P < 0.05$) increase in water-holding capacity in sausages with added foxtail millet flour (FTMF).

Incorporation of PMF and FTMF significantly improved the emulsion stability of chicken meat rolls. This increase in emulsion stability with increasing level of PMF and FTMF addition could be attributed to the gelatinizing property of starch components upon heating, contributing to emulsion stabilization. Similar findings were reported by Reddy *et al.* (2017) who observed significantly higher emulsion stability ($P < 0.05$) at higher level of foxtail millet flour incorporation compared to the control.

Cooking yield of rolls increased significantly with incorporation of PMF and FTMF in chicken rolls compared to control. This improvement in cooking yield may be due to the solubilization and breakdown of millet proteins into smaller subunits as well as positive effects of insoluble fibre on water retention and fat absorption. Para and Subha (2015) [14] found that nuggets containing pearl millet flour had significantly ($P < 0.05$) greater cooking yield compared to the control nuggets. Gamit *et al.* (2020) [7] observed a significantly ($p < 0.05$) higher cooking yield in chicken meat cutlets with an optimized 5% level of finger millet flour compared to the control.

Table 5: Effect of incorporation of selected level of millet on physico-chemical properties (Mean $\pm$ SD)

Treatments	pH (raw emulsion)	pH (Cooked)	Water holding capacity (%)	Emulsion Stability (%)	Cooking yield (%)
Control	6.09 ^a $\pm$ 0.02	6.28 $\pm$ 0.05	38.78 ^a $\pm$ 1.17	91.68 ^a $\pm$ 1.08	88.05 ^a $\pm$ 1.55
T ₁	6.16 ^a $\pm$ 0.02	6.33 $\pm$ 0.02	48.09 ^a $\pm$ 1.38	93.65 ^b $\pm$ 0.37	92.36 ^a $\pm$ 0.45
T ₂	6.13 ^b $\pm$ 0.03	6.30 $\pm$ 0.05	44.69 ^b $\pm$ 1.54	92.78 ^{ab} $\pm$ 0.93	89.87 ^b $\pm$ 0.74
T ₃	6.14 ^{bc} $\pm$ 0.02	6.31 $\pm$ 0.06	45.13 ^b $\pm$ 0.99	92.69 ^b $\pm$ 0.74	90.58 ^b $\pm$ 0.86

Mean with different superscript with small letter in a column differ significantly ($P \leq 0.05$) (n=6)

Control - Chicken rolls with 3% semolina, T₁ - Chicken rolls with 9% pearl millet flour, T₂ - Chicken rolls with 6% foxtail millet flour, T₃ - Chicken rolls with 5% pearl millet flour + 3% foxtail millet flour.

Summary

The present study was conducted to develop functional chicken meat rolls by incorporating varying levels of Pearl Millet flour (PMF) and Foxtail Millet flour (FTMF), both individually and in combination. Based on preliminary sensory evaluation, three optimal treatments were selected for comprehensive analysis: 9% Pearl Millet flour (9PMF), 6% Foxtail Millet flour (6FTMF), and a combination of 5% PMF + 3% FTMF (MF3). These were compared against a control group containing 3% semolina. All selected treatments exhibited high consumer preference, with scores for colour, flavour, texture, tenderness, juiciness, and overall acceptability exceeding 7.0 on an 8-point descriptive scale, indicating "very good" acceptability. While the pH of the raw emulsion increased significantly in treated samples compared to the control, no significant differences were observed in the pH of the final cooked rolls. However, the incorporation of millet flours significantly enhanced the water-holding capacity (WHC), emulsion stability, and cooking yield, suggesting that millets act as effective functional extenders in comminuted meat systems.

Conclusion

The study concludes that Pearl and Foxtail millet flours can be successfully utilized to produce functional chicken meat rolls. These products maintain superior sensory attributes while improving processing yields and nutritional density, offering a cost-effective and health-conscious alternative to traditional cereal-based extenders.

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