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Effects of Foxtail Millet Flour (*Setaria italica*) on the Proximate Composition, Texture Profile, Colour Profile and Microbiological Qualities of Duck Meat Sausages

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ABSTRACT

Background: Dietary fiber can be effectively incorporated into processed meat products along with binders, extenders and fillers. Using millet in meat products can balance the enormous demand and supply for affordable, wholesome, dietary fiber enriched and healthful meat products.

Methods: The duck meat sausages were developed by incorporating three different levels of roasted foxtail millet flour (FTMF) *i.e.* 5%, 10% and 15% and coded as T_1(5%), T_2(10%) and T_3 (15%). The proximate composition, texture profile, colour profile and microbiological qualities of the control and treated sausages were estimated.

Result: The moisture, crude protein, ether extract and calorie value of the sausages declined significantly (p<0.05) with increasing levels of FTMF in the treated sausages. In the case of texture profile, a significant (p<0.05) difference was observed in the springiness, hardness, chewiness and resilience (p<0.05) of the sausages between the control and treated groups. However, no significant difference in cohesiveness was observed between the control and the treated products. The colour profile revealed no significant (p>0.01) difference in lightness (L*), redness (a*) and yellowness (b*). TVC and TVPBC showed a significantly (p<0.01) decreasing trend from control to treated products. However, the bacterial load increased during the storage for up to 15 days. No colititre, yeast, or mould were detected during the entire storage period.

Key words: Colour profile, Duck meat, Foxtail millet, Microbiological qualities, Proximate composition, Sausages, Texture profile.

INTRODUCTION

Duck meat is a crucial food source in rural areas, particularly South East Asia. In India, ducks are mainly concentrated in the Eastern, North-eastern and Southern states. Assam is one of the leading North-Eastern states in terms of duck population and meat consumption. Despite the higher demand for poultry meat compared to other animals, duck meat is significantly less consumed than chicken meat. Duck meat has a stronger gamey flavour and more fat (13.8 per cent) than chicken, therefore, it may be less popular among the consumers (Biswas *et al.*, 2019). However, the North-Eastern region of the country has a high acceptance of duck meat.

Although meat contains a high amount of nutrients, it is highly susceptible to deterioration caused by microbes and enzymatic activity unless processed into a form that can be ingested or stored. The meat can be processed into sausages, burgers and meatloaf to add value and improve shelf life. By increasing the consumption of various value-added products, rural farmers can also raise ducks with good returns. Processed food items are becoming more popular due to the shifting socio-economic conditions.

Most individuals know that a diet containing high amounts of saturated fat and cholesterol increases the risk of heart disease. The consumption of meat and meat products is hindered by health problems such as colorectal cancer, cardiovascular disorders and diabetes that are linked to consumption of meat and meat products. Health issues related to the fat content of food have received much attention and consumers are searching for no-fat or low-fat meat products. Also, many processed foods, including meat products, are deficient in dietary fiber. Fiber-fortified meat

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products may help prevent coronary heart disease, diabetes, irritable bowel disease, obesity and other diseases.

In order to enhance the shelf life of meat products, improve the quality and the nutritional profile and minimize the cost of manufacturing, a variety of plant and animal sources are widely employed as fillers, binders and extenders in comminuted meat systems. On the other hand, dietary fiber can be effectively incorporated into processed meat products such as binders, extenders and fillers. They can significantly replace the harmful fat components from the meat products and hence can increase acceptability by improving the nutritional profile, economic gain and many physicochemical parameters of the finished products.

Foxtail millet (*Setaria italica*) is one of the most significant food crops of the semiarid tropics, which is free of gluten, low in fat (4%) and high in protein (11%) and dietary fiber (6.7%) (Talukder and Sharma, 2014). In Assam, foxtail millet is called "Koni Dhan" locally. As a diabetic food, foxtail millet was recognized for its value. Numerous macro and micronutrients are found in millets, including various phytochemicals such as phytosterols, phenolic acids and lignans (Muthamilarasan *et al*., 2016). This millet has been proven to prevent constipation, lowering blood cholesterol and anti-diabetic and other metabolic disorders (Itagi, 2003). Using millet in meat products can balance the enormous demand and supply of affordable, wholesome and healthful meat items (Choi *et al*., 2005; Cade *et al*., 2007, Lang, 2020). By subjecting the foxtail millet fortified meat sausage to appropriate treatment with natural preservatives, it has the potential to emerge as an innovative product that caters to health-conscious consumers.

MATERIALS AND METHODS

Collection of raw materials

Hygienically slaughtered and de-feathered (Not Yet Dressed) carcasses of local ducks (*pati*) of the same age group were purchased from poultry meat traders of the Beltola market of Guwahati city and immediately brought to the laboratory of the LPT Department of the College of Veterinary Science, Khanapara. Afterwards, the carcasses were appropriately dressed in the laboratory and preserved at -20°C until use. Good quality foxtail millet was purchased from a supermarket. To prepare the foxtail millet flour, the purchased millet was cleaned and roasted well and then ground into fine flour with the help of a mechanical grinder.

Preparation of duck meat sausages

Deboning of the carcasses was done within three hours of slaughter. Then, liver, heart, gizzard, skin and visceral fat were harvested and packed in polyethylene bags before being put at a chilling temperature (4°C). The required quantity of lean meat was packed separately in food-grade polyethylene bags and then stored at 4±1°C temperature for 24 hours. The deboned duck meat, the heart, liver and gizzard were chopped into small cubes after 24 hours of storage before being processed in a mechanical mincer using a 4 mm pore plate. The previously melted visceral fat was separated with the help of a separating funnel, after which the recovered fat was stored for later use. The deboned meat was then thoroughly mixed with the curing ingredients (Salt @1.75% and sodium nitrite @150 ppm) and then stored at 4°C for another 24 hours to facilitate proper curing. The cured sausage mix was chopped in a bowl-chopper with the added fat, non-meat ingredients, spices and condiments and three different levels of foxtail millet flour *i.e*. 5 per cent (T_1), 10 per cent (T_2) and 15 per cent (T_3). The control group was prepared without foxtail millet flour (Table 1). The four emulsions were then stuffed into the cellulose casings with the help of a mechanical stuffer. After completion of the stuffing, the sausages from each treatment group were cooked in a cooking vat maintained at 85°C for 45 minutes. After cooking, the hot sausages were immersed in ice-cold water to prevent further cooking and to give a thermal shock to the surviving organism, if any. After cooling, the sausages were removed from the water and the excess water was drained. The chilled sausages were peeled and randomly packaged into sterilized polyethylene bags. They were then stored under refrigeration to evaluate the different qualitative traits during

Table 1: Sausage mix formulation.

Name of ingredients	Control	Treatment (%)		
		T_1	T_2	T_3
Lean meat	70	65	60	55
Fat (skin + visceral organ)	15	15	15	15
Foxtail millet (*Koni dhan*) flour	0	5	10	15
Spices	1.5	1.5	1.5	1.5
Condiments	3	3	3	3
Egg white	3	3	3	3
Ice flakes	5	5	5	5
Salt	1.75	1.75	1.75	1.75
Sugar	0.75	0.75	0.75	0.75
Sodium nitrite	150 ppm	150 ppm	150 ppm	150 ppm
Total	100	100	100	100

subsequent storage periods. Altogether, five batches of sausages were prepared and kept refrigerated (4±1°C) and different qualitative traits were evaluated.

The proximate composition of the duck meat sausages was determined as per the method of the Association of Official Analytical Chemists (AOAC, 2012). Evaluation of the total calories in the cooked duck meat sausages was done based on 100 portions utilizing the Atwater value for fat (9.00 kcal/g), protein (4.02 kcal/g) and carbohydrate (4.00 kcal/g). The colour (L*a*b*) of sausage samples was determined using Chromameter (Make: 3nh, Model: NR 110). A texture analyzer (TA-HD plus, Stable Micro Systems U.K.) was used to evaluate the sausage's texture profile (hardness, springiness, chewiness, cohesiveness, resilience). The total viable plate count, total viable psychrophilic bacterial counts and the Coliform counts of the sausage samples were enumerated using the pour plate technique in a standard plate count agar medium, as illustrated by Harrigan and McCance (1976). The yeast and mould Count of the sausage samples were enumerated using the technique illustrated by American Public Health Association (APHA, 2015).

RESULTS AND DISCUSSION

Proximate composition

The results for proximate composition of the duck meat sausages (Table 2), revealed that the sausages mixed with 15% foxtail millet flour (T3) had the lowest moisture content. This decrease in moisture could be because lean meat with higher moisture was replaced with foxtail millet flour (FTMF) in the recipe. Sharma and Nanda (2002) reported higher moisture content in chicken with a more significant percentage of meat, which might be due to more bound water. Similar findings were observed by incorporating chia flour on chicken nuggets (Barros *et al*., 2018), finger millet (*Eleusine coracana)* flour (5, 10 and 15 per cent) in chicken meat cutlets (Gamit *et al*., 2020), raw pearl millet flour on beef sausages (Adzitey *et al*., 2021).

The crude protein content of the duck meat sausages showed a significant decrease ($p<0.05$) in the treated formulations when foxtail millet flour was added. This decrease could be attributed to the carbohydrate-based nature of foxtail millet flour and the replacement of lean duck meat with foxtail millet flour (FTMF), which has a lower protein content of 12.3 g/100 g (Sharma and Niranjan, 2017). The findings from present study are consistent with those of Mishra *et al*. (2014), who observed a similar effect when adding barnyard millet flour to chicken meat rings.

With the addition of foxtail millet flour, the Ether Extract content of the duck meat sausages decreased significantly ($p<0.05$); this might be due to the replacement of duck meat with FTMF, which contains less fat (4.3 g/100 g) (Sharma and Niranjan, 2017) and high fiber content. Kumar *et al*. (2015) also found a significant ($p<0.05$) decrease in the fat content of the cooked chevon patties with the increase in the level of incorporation of FMF.

The ash content of the duck meat sausages increased significantly ($p<0.05$) with the increasing levels of foxtail millet flour. The higher ash content in treated duck meat sausages may be due to the higher mineral content in foxtail millet flour (Reddy *et al*., 2017a). The results obtained in the study are also in close agreement with the reports of Gamit *et al*. (2020), who observed the quality characteristics of chicken meat cutlets incorporated with finger millet (*Eleusine coracana*) flour.

The calorie value of the duck meat sausages prepared with different levels of foxtail millet flour (Table 2) revealed a significantly ($p<0.01$) decreasing trend from control to treated formulations. This might be a corollary to the progressively lower fat and protein content in the treated formulations compared to the control due to the increased incorporation of foxtail millet flour in the treated formulations. The findings of the present study corroborated well with Cáceres *et al*. (2004) in the reduced fat sausages with 12 per cent added fiber; Saha (2012) who developed fat-reduced pork patties enriched with dietary fiber, *i.e.* WB and OB.

Colour profile

The results of the colour profile analysis (Table 3) showed that the lightness (L*) values of duck meat sausages followed a non-significantly ($p>0.01$) decreasing trend from control to treated products. Reduction in the lightness (L*) of duck meat sausage values might be due to fat reduction, which imparts the colour of meat products by darkening (Keeton, 1994). Kumar *et al.* (2015) observed similar findings to the present study, who prepared chevon patties fortified with dietary fiber (FMF).

Table 2: Proximate composition and calorie value of control and foxtail millet flour treated duck meat sausages.

Parameters	Control	Incorporation of foxtail millet flour		
		T_1 (5%)	T_2 (10%)	T_3 (15%)
Moisture (%)	$61.56^a±0.34$	$59.58^b±0.33$	$58.47^c±0.11$	$56.82^d±0.39$
Crude protein (%)	$18.63^a±0.24$	$17.66^b±0.15$	$16.93^c±0.19$	$15.96^d±0.12$
Ether extract (%)	$15.29^a±0.23$	$13.11^b±0.10$	$11.61^c±0.13$	$10.50^d±0.10$
Ash(%)	$1.68^a±0.05$	$1.99^b±0.03$	$2.32^{cd}±0.08$	$2.62^d±0.09$
Calorie value (kcal/100 g)	$223.85^a±2.52$	$219.61^{ab}±1.34$	$215.23^b±0.19$	$215.07^b±1.38$

n=5.

Means with superscript bearing different alphabet (small) row wise differ significantly ($p<0.05$).

The redness (a*) values of duck meat sausages followed a non-significant ($p>0.01$) increasing trend from control to the treated products in the present study. Similar findings were observed by Barros *et al*. (2018), who utilized chia flour to produce a fiber-enriched chicken nugget. The yellowness (b*) values of duck meat sausages also followed a non-significantly ($p>0.01$) increasing trend from control to treated products. The findings were similar to Akesowan (2016), who added konjac flour to light pork sausages.

Texture profile analysis

The results of texture profile analysis (Table 4) revealed that the hardness of the duck meat sausages increased ($p<0.05$) significantly from the control to T_3 (15 per cent foxtail millet flour). This trend might be due to the low moisture and high fiber content in duck meat sausages prepared with high foxtail millet flour content. This result was in close agreement with the findings of Reddy *et al*. (2017b), who observed a significantly ($p<0.05$) higher hardness value in mutton nuggets extended with 9 per cent oat flour as compared with 3 per cent and 6 per cent oat flour.

The result indicated that the springiness of the duck meat sausages was highly significant ($p<0.01$) and decreased in the control to treated groups. This might result from the increase in the hardness of the product with increase in the level of foxtail millet flour (Rindhe *et al*., 2018). This observation was in close agreement with Santhi and Kalaikannan, 2014 who studied the effect of adding oat flour to low-fat chicken nuggets and found that the springiness value significantly decreased ($p<0.01$).

The cohesiveness of the duck meat sausages decreased non-significantly ($p>0.05$) from the control (0 per cent foxtail millet flour) to T_3 (15 per cent foxtail millet flour). The present finding was in close agreement with the findings of Pintado *et al*. (2016), by incorporating chia (*Salvia hispanica* L.) in frankfurters, observed a decrease in the cohesiveness parameter of frankfurters with 10 per cent chia flour addition compared to the control.

In the present study the chewiness of the duck meat sausages increased ($p<0.05$) significantly from the control to T_3 (15 per cent foxtail millet flour). This might result from the increase in the product's hardness with the increase in the level of foxtail millet flour (Rindhe *et al*., 2018). The present finding was in close agreement with the findings of Motamedi *et al*. (2015), who reported a significant increase in the chewiness of the treated products compared to control in hamburger containing lentil and chickpea flour.

Analysis of variance reveals that the resilience of the duck meat sausages decreased significantly ($p<0.05$) from the control to T_3 (15 per cent foxtail millet flour). A decrease in resilience may be attributed to an increase in hardness and a decrease in springiness values with the incorporation of FTMF (Rindhe *et al*., 2018). The present finding was in close agreement with the findings of Santhi and Kalaikannan, 2014 who, by adding oat flour to low-fat chicken nuggets, observed that as the oat flour level increased, the resilience value significantly decreased ($p<0.01$).

Microbiological qualities

Total viable count

The result of TVC (Table 5) revealed that the TVC of the duck meat sausages decreased significantly ($p<0.01$) with the increasing levels of foxtail millet flour. This might be due to the antimicrobial activity of foxtail millet flour. Protein extracts of foxtail millet effectively inhibited the growth of microbes and 23-kDa thaumatin-like proteins showed higher antimicrobial activity against *Bacillus cereus* and *Aspergillus flavus* (Viswanath *et al*., 2009). The present finding was in close agreement with the findings of Reddy *et al*. (2017a),

Table 3: Colour profile of control and foxtail millet flour treated duck meat sausages.

Storage days	Control	T_1	T_2	T_3
L*	52.68^a±0.83	49.19^a±1.99	48.72^a±1.44	44.47^a±1.98
a*	13.03^a±0.80	13.49^a±0.85	13.50^a±0.57	13.52^a±0.83
b*	19.29^a±0.73	20.35^a±0.98	20.37^a±0.63	20.57^a±0.78

n=5

Means with superscript bearing similar alphabet (small) row wise do not differ significantly ($p>0.01$).

Table 4: Texture profile of control and foxtail millet flour treated duck meat sausages.

Parameter	Control	T_1	T_2	T_3
Hardness (kg)	1.549^d±0.02	3.410^c±0.11	3.990^b±0.13	6.362^a±0.29
Springiness (mm)	0.850^a±0.05	0.834^{ab}±0.09	0.824^{bc}±0.09	0.800^c±0.07
Cohesiveness (force ratio)	0.335±0.01	0.332±0.07	0.330±0.07	0.327±0.05
Chewiness (kg)	0.438^c±0.02	0.953^b±0.05	1.089^{ab}±0.06	1.230^a±0.09
Resilience (mm)	0.147^a±0.04	0.140^{ab}±0.03	0.131^b±0.07	0.098^c±0.03

n=5.

Means with superscript bearing different alphabet (small) row wise differ significantly ($p<0.05$).

Means with superscript bearing similar alphabet (small) row wise do not differ significantly ($p>0.05$).

Table 5: Microbiological Qualities of control and foxtail millet flour treated duck meat sausages.

Treatment	Days	TVC (log10 cfu/g)	TVPBC (log10 cfu/g)
C	1	$^{A}2.51^{a}\pm0.01$	-
	5	$^{B}3.58^{a}\pm0.01$	$^{A}2.73^{a}\pm0.06$
	10	$^{C}4.84^{a}\pm0.004$	$^{B}3.57^{a}\pm0.02$
	15	$^{D}5.96^{a}\pm0.01$	$^{C}4.07^{a}\pm0.03$
T_1	1	$^{A}2.41^{a}\pm0.01$	-
	5	$^{B}3.26^{bd}\pm0.03$	$^{A}2.59^{ab}\pm0.07$
	10	$^{C}4.61^{abc}\pm0.02$	$^{B}3.30^{ab}\pm0.02$
	15	$^{D}5.83^{a}\pm0.03$	$^{C}3.97^{ab}\pm0.04$
T_2	1	$^{A}2.29^{a}\pm0.02$	-
	5	$^{B}2.82^{cd}\pm0.26$	$^{A}2.51^{ab}\pm0.12$
	10	$^{C}4.51^{bc}\pm0.02$	$^{B}3.12^{bc}\pm0.07$
	15	$^{D}5.65^{ab}\pm0.03$	$^{C}3.90^{ab}\pm0.04$
T_3	1	$^{A}1.94^{b}\pm0.07$	-
	5	$^{B}2.97^{d}\pm0.07$	$^{A}2.33^{b}\pm0.14$
	10	$^{C}4.47^{c}\pm0.06$	$^{B}2.95^{c}\pm0.07$
	15	$^{D}5.47^{b}\pm0.05$	$^{C}3.73^{b}\pm0.05$

n=5.

Means with superscript bearing different alphabet (small) row wise differ significantly ($p<0.01$).

Means with superscript bearing different alphabet (capital) column-wise differ significantly ($p<0.01$).

who prepared chevon sausages with different levels (0, 3, 6 and 9 per cent) of foxtail millet flour (FTMF). However, a gradual increase in the count of TVC with the increase in the storage period was observed. This might be due to the growth and multiplication of microorganisms exposed to the product during its preparation, handling, packaging or subsequent storage. The present finding was in close agreement with the findings of Shinde *et al*. (2019), who prepared Japanese Quail meat nuggets using different levels of Finger millet flour (*Eleusine coracana*) and observed that the Total plate count increased ($p<0.05$) significantly throughout the refrigerated(4±1°C) storage period of 20 days in both the control and the treatment groups.

Total viable psychrophilic bacterial count

No TVPBC was detected on the 1st day of refrigeration storage. A lower TVPBC (log10 cfu/g) count was recorded in the study in the treated groups on the 5th day and subsequent storage days compared to the control (Table 5). The reduction in total psychrophilic counts in FTMF-added sausages might be due to the antimicrobial activity of foxtail millet flour. The present finding was in close agreement with the findings of Reddy *et al*. (2017a), who evaluated the efficacy of different levels (0, 3, 6 and 9 per cent) of foxtail millet flour (FTMF) on quality characteristics and storage stability of functional chevon sausages and observed a significant ($p<0.05$) reduction in the total psychrophilic counts on the addition of 6 per cent FTMF. However, the TVPBC (log10 cfu/g) count increased ($p<0.01$) significantly up to the 15th day of storage for control and treated products. It might be due to the growth and multiplication of psychrophilic organisms which come in contact with the product during handling, packaging and storage. The present finding was in close agreement with the findings of Reddy *et al*. (2017a), who evaluated the efficacy of different levels (0, 3, 6 and 9 per cent) of foxtail millet flour (FTMF) on quality characteristics and storage stability of functional chevon sausages and observed a significant ($p<0.05$) reduction in the total psychrophilic counts on the addition of 6 per cent FTMF.

The study revealed an absence of colititre count, yeast and mould count in control and the treated products in the entire storage period (15 days).

CONCLUSION

Based on the results of various parameters studied in this investigation, it might be concluded that value-added, nutritionally balanced duck meat sausages can be prepared satisfactorily by replacing lean meat and incorporating foxtail millet flour up to 15 per cent without severe adverse effects on its microbial qualities and were acceptable for 15 days under aerobic packaging and refrigerated storage condition (4±1°C). In addition, foxtail millet flour also exerts antioxidant and antimicrobial activity, resulting in the substantial shelf life of the sausages of upto 15 days, with aerobic packaging under refrigerated storage (4±1°C). However, further studies with more product formulations, larger samples with more extended storage periods and improved packaging systems might be of immense value to drawing a concrete conclusion and recommending the best-suited formulation for a commercial venture.

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