DR-2326
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RESEARCH ARTICLE Asian Journal of Dairy and Food Research

Effect of Incorporation of Finger Millet Flour (Ragi Flour) on Texture Profile of Chicken Nuggets

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ABSTRACT

Background: The present study was carried out to evaluate effect of different levels of finger millet flour (ragi) on the texture profile of chicken nuggets.

Methods: The chicken nuggets were incorporated with different levels of finger millet flour *i.e.* 0, 3, 6, 9% along with other spices and condiments to the minced meat to prepare the emulsion. Hardness, cohesiveness, gumminess, springiness and chewiness were obtained using a Stable texture analyser (Microsystems Texture Analyzer;TA-XT2).

Results: Addition of finger millet (ragi) levels @ 3-6% are optimal for achieving a well-rounded texture profile for creating innovative chicken nugget formulations. However, higher ragi levels (9%) may affect the cohesiveness and elasticity of the chicken nuggets.

Key words: Chicken nuggets, Finger millet, Ragi flour, Texture profile analysis.

INTRODUCTION

Chicken nuggets, a widely popular ready-to-eat meat product, are favoured by consumers for their palatability, convenience and nutritional content (Pakseresht *et al.,* 2022). However, growing health awareness and dietary preferences are influencing consumer choices, leading to a demand for healthier and more diverse meat products. The quality of chicken nuggets is significantly affected by factors like processing, raw material and non-meat ingredients, affecting their nutritional value and consumers acceptability (Yogesh *et al.,* 2013). In this context, chicken nuggets fortified with finger millet flour could cater the market demand by providing a convenient, nutritious and functional food option. Moreover, finger millet is gluten-free, making it suitable for individuals with celiac disease or gluten sensitivity, further broadening its market appeal (Muthamilarasan and Prasad, 2015).

Finger millet (*Eleusine coracana*), commonly known as ragi, is a small-seeded cereal widely cultivated in Asia and Africa (Nagaraja *et al.,* 2022). It is known for its exceptional nutritional profile particularly calcium, iron and dietary fibre and resilience to harsh environmental conditions (Devi *et al.,* 2014; Amadou *et al.,* 2013). However, finger millet remains underutilized, largely due to limited awareness crop of its nutritional quality and health benefits (Desai and Dutta, 2023). India is a leading producer of finger millet, contributing around 2.2 million tons and the crop is well adapted to thrive in harsh agro-climatic conditions (https://www.icrisat.org/crops/finger-millet/overview) Studies have shown that the functional properties of finger millet flour, such as water-holding capacity, emulsifying properties and fat-binding ability, can significantly improve the quality of meat products (Rao *et al.,* 2018). Additionally, the fiber in finger millet can act as a natural stabilizer, improving the texture and cohesiveness of the meat emulsion, which is essential for maintaining the integrity of the nuggets during processing and cooking (Rathod and Annapure, 2017). Moreover, finger millet is relatively inexpensive compared to other grains, making it a cost-effective ingredient for food manufacturers (Belton and Taylor, 2004).

Incorporating finger millet flour into chicken nuggets can potentially offer several health benefits. The high fiber content of finger millet can aid in digestion and help maintain healthy bowel function, reducing the risk of constipation and other gastrointestinal disorders (Gull *et al.,* 2014). Finger millet are rich in antioxidants due to the presence of various polyphenols, offering several health benefits, such as reduced risk of cardiovascular diseases, cancer, diabetes and neurogenerative disorders (Nakarani *et al.,* 2021). The slow-release carbohydrates in finger millet can help regulate blood sugar levels, making it a suitable option for diabetic individuals (Shobana *et al.,* 2013).

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How to cite this article: Chandra. N., Devi. R., Verma. A.K., Shekhar. C. and Sakshi. (2025). Effect of Incorporation of Finger Millet Flour (Ragi Flour) on Texture Profile of Chicken Nuggets. Asian Journal of Dairy and Food Research. 1-4. doi: 10.18805/ajdfr.DR-2326.

Submitted: 06-03-2025 **Accepted:** 29-04-2025 **Online:** 21-06-2025

Studies have demonstrated better quality attributes of different types of finger millet flour enrobed chicken nuggets and cutlets (Akhila *et al.,* 2023; Gamit *et al.,* 2020).

However, incorporation of ragi flour into chicken nuggets may encounter challenges in sensory acceptance due to millet's lower viscoelastic properties compared to refined wheat flour, which can affect the texture and overall appeal (Siroha and Banger, 2024). The distinctive taste and color of finger millet flour can alter the flavor and appearance of the final product, which may not be acceptable to all consumers (Rao and Bhattacharya, 2013). To overcome these challenges, it is essential to optimize the level of finger millet flour used in chicken nuggets to balance its nutritional benefits with desirable sensory attributes. Based on the potential benefits and disadvantages related to sensory attributes of finger millet, we evaluated the texture profile of chicken nuggets incorporated with different levels of finger millet flour concentration for the development of nutrient rich chicken nuggets.

MATERIALS AND METHODS

This study was carried out during the period from February 2023 to January 2024 in the Livestock Product Technology department, College of Veterinary Science and UAT, Kumarganj, Ayodhya (U.P.). Fresh raw boneless meat from 6-week-old broilers was procured from nearby local meat shop and were transported to the laboratory in the polythene pouches to maintain cleanliness and hygiene. The skin, subcutaneous fat, tendons and separable connective tissue were trimmed off. The dressed meat was packed in polyethylene (HDPE- 0.93-0.97 g/cm^3) and kept at -18±1°C overnight for aging, thawed and subsequently used for product formulation.

Deboned meat, after thawing at room temperature, was cut into small pieces (around 3 cm size) and minced using a meat mincer (4 mm plate). During chopping in a bowl chopper, salt, sodium nitrite and sodium tripolyphosphate were added to the minced meat. Subsequently, refined vegetable oil, finger millet flour, condiments and spice mix were added to achieve proper emulsion. A recipe comprising lean meat, salt, spices, condiments and preservatives was followed for the preparation of chicken nuggets, as detailed in Table 1.

During chopping in a bowl chopper, salt, sodium nitrite and sodium tripolyphosphate were added to the minced meat and chopped for about 30 sec. After addition of ice flakes, it was chopped again for 1.5 min followed by incorporation of vegetable oil slowly and chopping was continued for 2 min. Condiments, spices were added and chopping continues for 2 min. Ragi flour (Finger millet) was added @ 0%, 3%, 6% and 9% to the emulsion and chopping was continued until proper emulsion was achieved, while the formulation for the control group was kept same, as detailed in Table 1.

Chicken nuggets were prepared by filling the above formulated emulsions in separate stainless steel moulds of dimensions 14 cm × 7 cm × 3 cm to achieve a proper shape and steam cooked for 35 minutes with internal core temperature maintained at 75± 2°C during cooking. After cooking and cooling to room temperature, whole nuggets were uniformly cut into 2 cm pieces. The pieces were compressed to 75% of their height for two cycles using a Stable Microsystems Texture Analyzer (TA-XT2) equipped with a 1/2° flat surface plunger. The instrument was programmed for a 40 kg load cell and a cross-head speed of 2 mm/sec. Hardness, cohesiveness, gumminess, springiness and chewiness were obtained using the available computer software attached to the texture analyser. The experiment was repeated five times with three samples in each repetition.

RESULTS AND DISCUSSION

The data in Table 2 analyzes the impact of Finger Millet Flour (ragi flour) incorporation at different levels (0%, 3%, 6% and 9%) on the texture profile of chicken nuggets. The parameters assessed include hardness, springiness, stringiness, cohesiveness, chewiness and gumminess, which collectively describe the physical and mechanical properties of the nuggets. These attributes are critical to the sensory perception of the product, as they directly influence mouthfeel, chewability and overall acceptability.

The addition of ragi flour significantly influenced the texture profile of chicken nuggets. Hardness is a measure of the force required to compress the product, indicating how firm or tough the chicken nuggets feel when bitten. Hardness progressively decreased from 11.74±0.04 N/cm² at 0% to 8.80±0.02 N/cm² at 9%, indicating a softer texture due to increased moisture retention. This softening effect can be advantageous, particularly for consumer groups that prefer less dense and easier-to-chew textures, such as children and older adults. However, excessive softness at higher Ragi levels (9%) may compromise the structural integrity and traditional bite associated with chicken nuggets, potentially reducing their appeal to consumers accustomed to firmer textures.

Springiness measures the extent to which a product returns to its original shape after being compressed, reflecting its elasticity or resilience. Springiness declined with increasing ragi flour levels, from 9.82±0.04 cm at 0% to 8.70±0.02 cm at 9% suggesting a reduction in elasticity, likely due to disruption of the protein matrix. While reduced

Table 1: Formulation for emulsion for preparation of chicken nuggets.

Ingredients	Quality % by weight
Lean meat	70
Vegetable oil	11
Ice flakes	11
Salt	1.6
Spice mix	1.5
Condiments	4.5
Sugar	0.19
Sodium nitrite	0.01
STPP (Sodium tripolyphosphate)	0.2
Total	100

elasticity can make the nuggets feel more yielding and less rubbery, excessive loss of springiness could detract from the expected textural experience, making the product feel less cohesive and more fragile during handling and consumption.

Stringiness measures the tendency of the product to form strands or fibers when pulled or bitten, which can negatively affect chewability if excessive. A decrease in stringiness from 17.02±0.02 at 0% to 14.52±0.02 at 9% was observed with increase in levels of ragi flour. This downward trend suggests that ragi flour helps reduce the fibrous or stretchy nature of the nuggets, likely by interfering with the meat protein network responsible for string formation. Reduced stringiness is generally favorable for chicken nuggets, as it improves bite quality and eliminates the undesirable sensation of fibrous or tough textures. This effect aligns well with consumer preferences, especially in products like chicken nuggets, where a smooth and cohesive bite is highly valued. Ragi Flour's ability to mitigate stringiness can enhance the mouthfeel of the product, making it more enjoyable and easier to consume.

Cohesiveness measures the internal bonding strength of the product, indicating how well it holds together when compressed. Cohesiveness also decreased from 0.95± 0.01 at 0% to 0.80±0.01 at 9%, indicating a weaker internal structure, which could impact product integrity at higher ragi levels. Lower cohesiveness at higher Ragi levels may be attributed to the dilution of meat proteins, which are responsible for the strong binding properties in chicken nuggets. While some reduction in cohesiveness can contribute to a softer texture, excessive loss may negatively affect the handling, packaging and eating experience.

Chewiness is a composite measure derived from hardness, cohesiveness and springiness, reflecting the effort required to chew the product. Chewiness showed a declining trend with increase in ragi flour levels, from 65.44±0.05 N/cm at 0% to 60.46±0.11 N/cm at 9%, making nuggets easier to chew, particularly for children and elderly consumers. However, manufacturers must ensure that the product retains enough substance to provide a satisfying bite, as overly soft textures may be perceived as unappealing by some consumers.

Gumminess reflects the stickiness or density of the product during chewing, combining elements of hardness and cohesiveness. Gumminess decreased with higher ragi levels, from 8.56±0.01 N/cm² at 0% to 7.6±0.02 N/cm² at 9%, contributing to a lighter and more enjoyable mouthfeel experience. By reducing gumminess, Ragi Flour contributes to a lighter and more enjoyable mouthfeel, making the product more appealing to a wider range of consumers.

Several studies have been conducted to study the effect of incorporation of different types of flours on the texture of chicken nuggets. A study analyzed texture profile parameter of oat flour incorporated chicken nuggets and observed significantly increased hardness values, contrarily significantly decreased springiness values for oat treated chicken nuggets (Santhi and Kalaikannan, 2014). Devatkal *et al.* (2011) showed significantly increased hardness, gumminess and chewiness values in 10% sorghum flour (SF) incorporated chicken nuggets, while 5% SF incorporated chicken nuggets did not show any significant difference from control. Kumar *et al.* (2013) also reported increased firmness, chewiness and elasticity values in chicken nuggets incorporated with 3-5% soybean skin flour.

The results demonstrate that ragi flour significantly influences the texture profile of chicken nuggets, primarily by softening the product, reducing stringiness and gumminess and making it easier to chew. These changes are particularly beneficial for creating a product that appeals to consumers seeking tender and succulent textures. However, higher ragi levels (9%) may compromise cohesiveness and elasticity, potentially reducing the structural integrity and traditional bite associated with chicken nuggets. A study by Dahriya *et al.* (2024) suggested development of functional chicken nuggets by incorporating kodo millet flour at the level of 6 %. One study indicated that incorporation of 3.5% pearl millet flour to the chicken nuggets have shown good acceptability, however, they did not go for the treatment above 3.5% pearl millet (Akhila *et al.,* 2023). Similarly, another study demonstrated that the addition of black rice flour at 1-5 % level resulted no significant changes in the physicochemical qualities of chicken nuggets (Richa *et al.,* 2024). The linear reduction in hardness and gumminess observed with increasing ragi levels reflects a

Table 2: Effect of incorporation of finger millet flour (Ragi) on texture profile of C=chicken nuggets.

Levels of finger millet flour	Texture profile analysis					
	Hardness (N/cm²)	Springiness (cm)	Stringiness	Cohesiveness (ratio)	Chewiness (N/cm)	Gumminess (N/cm²)
0%	11.74±0.04^{a}	9.82±0.02^{a}	17.02±0.02^{a}	0.95±0.01^{a}	65.44±0.05^{a}	8.56±0.01^{a}
3%	10.47±0.02^{b}	9.52±0.02^{b}	16.52±0.02^{b}	0. 90±0.01^{b}	64.0±0.10^{b}	8.20±0.02^{b}
6%	9.74±0.01^{c}	9.12±0.02^{c}	15.77±0.02^{c}	0.85±0.01^{c}	62.0±0.10^{c}	7.94±0.02^{c}
9%	8.80±0.02^{d}	8.70±0.02^{d}	14.52±0.02^{d}	0.80±0.01^{d}	60.46±0.11^{d}	7.6±0.02^{d}

Means with common superscripts did not differ significantly ($p<0.05$). Values within the same column followed by different superscript letters (a, b, c, d) are significantly different ($p<0.05$).

progressive alteration in meat matrix interactions due to starch and fiber content in ragi. Additionally, the natural binding properties of ragi may contribute to moisture retention, as evidenced by the softer texture in the 6% group. Our findings suggests that although increasing ragi levels results in significant reduction in texture attributes, however, a moderate inclusion of ragi levels (3-6%) may offer an acceptable well-rounded texture profile for creating innovative chicken nugget formulations that leverage the functional benefits of ragi flour while maintaining consumer appeal.

CONCLUSION

Our study suggested that finger millet flour (ragi flour) can be used as a replacer of refined wheat flour in preparation of chicken nuggets without compromising its texture. By incorporating ragi at controlled levels, manufacturers can offer a product that meets the demands of modern consumers for healthier, softer and more enjoyable processed meat products.

ACKNOWLEDGEMENT

The authors are grateful to College of Veterinary Science, A.N.D.U.A.T., Kumarganj, Ayodhya (U.P.) for providing facilities to complete this research.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

Akhila, V.V., Sathu, T., Sunil, B., Irshad, A., Geetha, R., Hridhya, V.C., Anjitha, J.K. and Manasa, M. (2023). Effect of different millet flours on the physico-chemical characteristics, proximate composition and sensory characteristics of enrobed chicken nuggets. Journal of Veterinary and Animal Sciences. 54(4): 898-906.

Amadou, I., Mahamadou, E.G. and Le, G.W. (2013). Millets: Nutritional composition, some health benefits and processing-A review. Emirates Journal of Food and Agriculture. 25(7): 501-508. doi: 10.9755/ejfa.v25i7.12045.

Belton, P.S. and Taylor, J.R.N. (2004). Sorghum and millets: Protein sources for Africa. Trends in Food Science and Technology. 15(2): 94-98.

Dahriya, S., Das, K., Verma, S.K. and Patyal, A. (2024). Development and evaluation of shelf life of kodo millet added chicken meat nuggets. Journal of Meat Science. 18(2): 47-53.

Desai, R.K., Dutta, S. (2023). Development of Finger Millet and Sapota based Ready-to-Reconstitute Halwa Mix. Asian Journal of Dairy and Food Research. 42(3): 380-385. doi: 10.18 805/ ajdfr.DR-2007.

Devatkal, S.R., Kadam, D.M., Naik, P.K. and Sahoo, J. (2011) Quality characteristics of gluten free chicken nuggets extended with sorghum flour. Indian Journal of Meat Science and Technology. 2(1): 132-135.

Devi, P.B., Vijayabharathi, R., Sathyabama, S., Malleshi, N.G. and Priyadarisini, V.B. (2014). Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: A review. Journal of Food Science and Technology. 51(6): 1021-1040.

Gamit, M., Gupta, S. and Savalia, C.V. (2020). Quality characteristics of chicken meat cutlets incorporated with finger millet (*Eleusine coracana* L.) flour. Journal of Animal Research. 10 (1): 111-116.

Gull, A., Jan, R., Nayik, G.A., Prasad, K. and Kumar, P. (2014). Significance of finger millet in nutrition, health and value-added products: A review. Journal of Environmental Science. Computer Science and Engineering and Technology. 3(3): 1601-1608.

Kumar, V., Biswas, A.K., Sahoo, J., Chatli, M.K. and Sivakumar, S. (2013). Quality and storability of chicken nuggets formulated with green banana and soybean hulls flours. Journal of Food Science Technology. 50(6): 1058-1068.

Mgonja, M.A., Gwata, E.T., Adugna, A. and Monyo, E.S. (2007). Improving finger millet production in East and Central Africa through breeding and improved agronomy. Development in Crop Science. 50(3): 265-270.

Muthamilarasan, M. and Prasad, M. (2015). Advances in Setaria genomics for genetic improvement of cereals and bioenergy grasses. Theoretical and Applied Genetics. 128(1): 1-14.

Nagaraja, T.E., Bhat Sujata, Nandini, C. (2025). Current Scenario of Crop Improvement of Finger Millet [*Eleusine coracana* L.] in India: A Review. Agricultural Reviews. 46(1): 13-23. doi: 10.18805/ag.R-2545.

Nakarani, U.M., Singh, D., Suthar, K.P., Karmakar, N., Faldu, Priti.,. Patil, H.E. (2021). Nutritional and phytochemical profiling of nutracereal finger millet (*Eleusine coracana* L.) genotypes. Food Chemistry. 341(2): 128271.

Pakseresht, A., Kaliji, S.A. and Canavari, M. (2022). Review of factors affecting consumer acceptance of cultured meat. Appetite. 170: 105829.

Rao, B.D., Reddy, P.S. and Anjaneyulu, A.S.R. (2018). Development of functional chicken nuggets with the addition of ragi flour. Journal of Food Science and Technology. 55(1): 369-376.

Rao, P.P. and Bhattacharya, K.R. (2013). Functional properties of rice flour and the effects of various treatments. International Journal of Food Science and Technology. 15(6): 507-513.

Rathod, R.P. and Annapure, U.S. (2017). Effect of extrusion process on antinutritional factors and protein and starch digestibility of lentil splits. LWT-Food Science and Technology. 83: 113-119.

Santhi, D. and Kalaikannan, A. (2014). The Effect of the Addition of Oat Hour in Low-Fat Chicken Nuggets. Journal of Nutrition and Food Sciences. 4: 260.

Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G. and Anjana, R.M. (2013). Finger millet (Ragi, *Eleusine coracana* L.): A review of its nutritional properties, processing and plausible health benefits. Advances in Food and Nutrition Research. 69: 1-39.

Siroha, A.K. and Bangar, S.P. (2024). Millet-based Food Products: An Overview. Current Food Science and Technology Reports. 2: 213-220.

Yogesh, K., Ahmad, T., Manpreet, G., Mangesh, K. and Das, P. (2013). Characteristics of chicken nuggets as affected by added fat and variable salt contents. Journal of Food Science and Technology. 50(1): 191-196.