

FUNCTIONAL CHICKEN NUGGETS ENRICHED WITH DIETARY FIBRE FROM KODO MILLET-AN INDIAN NUTRI CEREAL

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ABSTRACT

*The optimization of Kodo millet (*Paspalum scrobiculatum*) as a healthy alternative to refined wheat flour (RWF) in chicken nuggets was investigated to assess dietary fibre enrichment. Replacement was performed at four levels: 5% (T1), 6% (T2), 7% (T3), and 10% (T4), while control nuggets were prepared using RWF. Product quality, texture profile, sensory evaluation, and dietary fibre content were assessed. Emulsion stability and product yield remained statistically similar, with improved textural characteristics observed up to 7% replacement with Kodo millet. The product's acceptance was highly significant ($P \leq 0.01$) at 7% inclusion (7.61 ± 0.32), with dietary fibre enrichment showing a 126.49% increase over the control. The findings concluded that 7% Kodo millet flour inclusion is the optimal level for dietary fibre enhancement in functional chicken meat nuggets.*

Key words: Chicken nuggets, dietary fibre, functional food, Kodo millet

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INTRODUCTION

Readily available processed meat products like patties, balls, kebabs, sausages and nuggets attract meat loving

consumers of all ages due to their taste and nutritive value. Despite its nutritional value, misconceptions about meat contributing to lifestyle disorders have negatively influenced consumer perception. Lack of dietary fibre content in meat could be pointed as one of the major reasons for the negative impact on consumption of meat products. Public awareness and increased consciousness on health and nutrition have created a need to develop functional meat products.

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Dietary fibre plays a well-established positive role in human health, acting as a satiety agent, improving digestion, reducing total and low-density lipoprotein cholesterol levels and regulating blood pressure. Additionally, dietary fibres offer functional benefits in processed meat foods, influencing their texture, sensory attributes, and nutritional quality.

The inclusion of dietary fibre in meat products aids in creating a product with physiological benefits, enhances product yield (Zinina *et al.*, 2019), and extends the product's freshness and shelf life (Pathania and Kaur, 2022).

Incorporating non-meat ingredient sources rich in dietary fibre (Verma *et al.*, 2012) into meat enhances the functional quality of comminuted meat products, addressing the health needs of consumers. Millet grains, being a rich source of dietary fibres, are receiving increasing attention for their utilisation as food and as a functional ingredient in meat products, catering to both taste and health requirements. Kodo millet (*Paspalum scrobiculatum*), commonly known as “varagu” in tamil, is an excellent source of fibre (9%) as opposed to other cereals such as rice (0.2%) and wheat (1.2%), and is rich in dietary fibre (Deshpande *et al.*, 2015). The use of Kodo millet as a gluten-free extender, replacing refined wheat flour in processed meat products, has remained largely unexplored. Therefore, this experimental study was conducted to develop functional chicken nuggets incorporating Kodo millet to harness the dietary fibre benefits in meat products.

MATERIALS AND METHODS

Preparation of functional chicken nuggets

Frozen, deboned chicken meat was tempered ($4 \pm 1^\circ\text{C}$) and minced using a meat mincer (Model No. TS 12, Omas Food Machinery, Italy). The minced chicken meat was then mixed with various ingredients, including salt, sodium tripolyphosphate, sodium nitrite, a spice mix, green condiments and different replacement levels of refined wheat flour (0% for the control, 5% [T1], 6% [T2], 7% [T3], and 10% [T4]) with Kodo millet flour, making up 100% of the formulation (Table 1). The temperature of the emulsion was maintained between $12\text{--}16^\circ\text{C}$ using slushed ice flakes during the process of mixing. The prepared emulsion was packed into aluminum boxes ($25\text{ cm} \times 10\text{ cm} \times 10\text{ cm}$) without any air pockets, cooked at 121°C for 30 min. and the cooked loaves were cooled before being cut into nuggets (1-inch cubes). The product's textural, sensory and nutritional quality characteristics were analysed to determine the optimal level of Kodo millet incorporation in the functional chicken meat nuggets.

Product characteristics

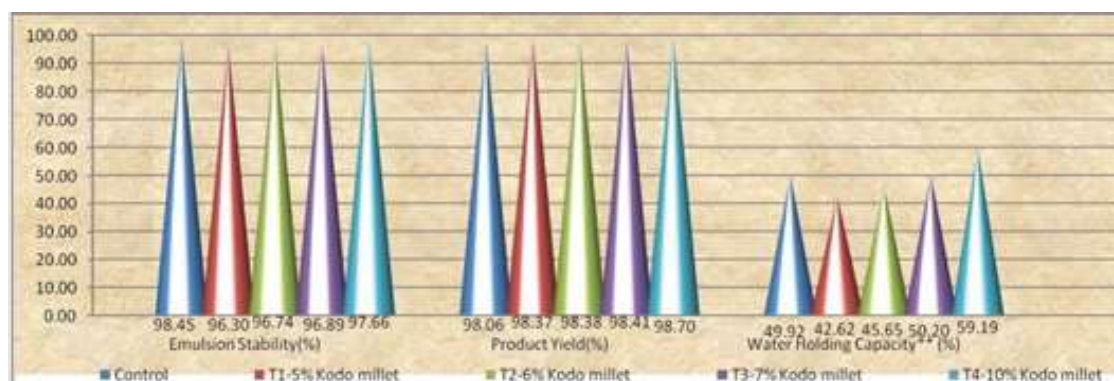
The product characteristics such as emulsion stability, product yield and water holding capacity are given in Fig. 1.

Emulsion stability (%)

Fifteen grams of prepared emulsion packed in polyethylene pouch was heated at 80°C for 20 min. in water bath and the sample was weighed after draining the released fluid

Table 1: Formulation of functional chicken nuggets

S. No	Ingredients	Percentage (w/w)				
		Control	Treatments			
			T1	T2	T3	T4
1.	Lean chicken meat	69.52	69.52	69.52	69.52	69.52
2.	Salt	1.45	1.45	1.45	1.45	1.45
3.	Sodium tripolyphosphate	0.22	0.22	0.22	0.22	0.22
4.	Sodium nitrite	0.01	0.01	0.01	0.01	0.01
5.	Oil	7.23	7.23	7.23	7.23	7.23
6.	Spice mix	1.45	1.45	1.45	1.45	1.45
7.	Condiment mix (Onion: Garlic-3:1)	2.89	2.89	2.89	2.89	2.89
8.	Ice flakes	7.23	7.23	7.23	7.23	7.23
9.	Refined wheat flour	10.00	5.00	4.00	3.00	-
10.	Kodo millet flour	-	5.00	6.00	7.00	10.00

**Fig 1. Effect of Kodo millet on the product characteristics of functional chicken meat nuggets**

(Kondaiah *et al.*, 1985). The weight of cooked emulsion divided by raw emulsion weight was expressed as emulsion stability in percentage.

Product yield (%)

Product yield was determined by dividing the weight of the cooked product by the weight of the raw emulsion, expressed as a percentage (Verma *et al.*, 2012).

Water holding capacity (%)

Twenty grams of the minced product was mixed with 30 ml of 0.6 M NaCl₂ solution for 2 min. using a mechanical shaker, then held at 4°C for 15 min. to equilibrate the salt. The mixture was stirred for 1 min. on the shaker before being immediately centrifuged at 5,000 rpm for 10 min. at 9°C in a refrigerated centrifuge (Thermo Scientific, Sorvall ST8R

Centrifuge). The volume of the supernatant was measured, and the water-holding capacity (WHC) was calculated using the equation provided by Wardlaw *et al.* (1973).

$$\frac{\text{Volume of solution taken} - \text{Volume of decanted solution after centrifugation}}{\text{Sample weight}} \times 100$$

Texture profile

Texture profile of the nuggets was assessed by compressing a 2 cm³ nugget using a cylindrical probe (P75) in a Texture Analyser (Stable Systems Ltd., England, UK; Model TX_HD Plus) with a load cell capacity of 500 kg and a crosshead speed of 50 mm/min (Bourne, 1978). The product was compressed to its 50 % height twice by the probe. Hardness (maximum force required to compress the sample), springiness (ability of the sample to recover to its original shape after the deforming force was removed), cohesiveness (extent to which the sample could be deformed prior to rupture), gumminess (force to disintegrate a semisolid meat sample) and chewiness (work to masticate the sample) were assessed in triplicate and the average was recorded.

Sensory quality characteristics

The developed nuggets were analysed for sensory characteristics such as appearance, flavour, texture, juiciness and overall acceptability by a semi trained panel of nine members using a nine-point scale (Keeton, 1983) score card. Factor analysis was performed by Principal Component method to analyse the sensory scores given by the trained panelist.

Dietary fibre

Dietary fibre was estimated by the modified enzymatic and gravimetric method prescribed by AOAC (1997). Protein and starch present in the sample were removed by gelatinizing the dried, fat free samples with heat stable α -amylase and digesting with enzymes like protease and amyloglucosidase. The soluble dietary fibre was precipitated by adding ethanol to the sample. The residue was then filtered and washed with ethanol and acetone and weighed after drying. Fifty per cent of the sample was analyzed for protein and the rest of it was washed. Total dietary fibre (TDF) is the weight of the residue less the weight of the protein and ash.

$$\text{Total dietary fibre (g/100 g)} = [R_{\text{SAMPLE}} - P_{\text{SAMPLE}} - A_{\text{SAMPLE}} - B] / \text{SW}$$

Where

R = Average residue weight (mg)

P = Average protein weight (mg)

A = Average ash weight (mg)

SW = Average sample weight (mg)

B = $R_{\text{BLANK}} - P_{\text{BLANK}} - A_{\text{BLANK}}$

Statistical analysis

The data obtained on the assessment of product characteristics, texture profile, sensory characteristics and dietary fibre were analysed statistically by one way ANOVA and the significance by DUNCANS test using the SPSS software as per the method outlined by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Figure 1 presents the results of the product characteristics, revealing a significant decrease in water-holding capacity (WHC) with increased Kodo millet replacement, while emulsion stability and product yield was found to be statistically similar between treatment and control groups which explains that Kodo millet can be incorporated at higher levels for dietary fibre enrichment in functional chicken meat nuggets. Further, the increased product yield may be attributed to the higher retention of water and fat by millet (Devatkal *et al.*, 2011). The textural characteristics (Table 2) showed a significant ($P < 0.01$) increase in hardness, springiness, gumminess and chewiness, along with a significant decrease in adhesiveness ($P < 0.05$), cohesiveness ($P < 0.01$) and resilience ($P < 0.01$) in Kodo millet-replaced nuggets (T1, T2, T3) compared to the control nuggets. The increased hardness may be attributed to the reduced fat content in millet-replaced nuggets, as observed in low-fat chicken meatballs with pearl millet and rice bran, as noted by Santhi *et al.* (2015). Springiness and chewiness were significantly lower ($P < 0.01$) in nuggets with 10% millet incorporation (T4), compared to lower inclusion levels, indicating improved textural characteristics up to 7% millet replacement. Similar improvements in texture were also reported by Jen *et al.* (1999) in beef patties incorporating soy flour.

The sensory evaluation (Fig. 2) scores given by the taste panelist's revealed highly significant increase in all the characteristics in Kodo millet incorporated nuggets with highest

scores for T3 nuggets and least scores for total replacement (T4). The high acceptance scores of RWF replaced chicken meat nuggets upto 7% (7.61 ± 0.32) in comparison to the control and treated nuggets suggests improved appearance (Vijaya Kumar *et al.*, 2010), flavor (Nirmala *et al.*, 2000), texture and juiciness due to Kodo millet. The increase in texture and juiciness scores with increase in millet replacement levels could be due to unique gritty and grainy texture of the millets and the increase in water holding capacity of products due to the presence of millet starch (Talukder and Sharma, 2013).

The ranking chart of PCA analysis of sensory evaluation scores reveals that T3 (7% Kodo millet) had the greatest influence (3.113) on the sensory characteristics followed by T2 (0.83), control (-0.083), T1 (-0.177) and T4 had the least influence on the sensory characteristic (-3.684). The results of factor analysis of the sensory scores done by Principal Component method (Table 3) showed that PCA had extracted 5 dimensions to characterize the sensory parameters. Among which, the first dimension itself explained more than 97% of variance as is reflected in the Scree plot. The results of PCA analysis in the form of component matrix illustrates the interdependence among the sensory parameters. Based on the coefficients in the component matrix for sensory parameters, PCA scores were calculated by multiplying the scores with the coefficients to rank the products based on sensory evaluations.

Dietary fibre enrichment in Kodo millet-incorporated nuggets was observed to increase

Table 2: Mean±SD of Texture profile analysis values of Kodo millet incorporated functional chicken nuggets

Groups	Hardness (N)	Adhesiveness (N)	Springiness (cm)	Cohesiveness (ratio)	Gumminess (N)	Chewiness (Ncm)
Control	20.68 ^a ±1.36	0.14 ^b ±0.02	0.53 ^a ±0.09	0.87 ^c ±0.03	17.87 ^a ±0.62	11.05 ^a ±2.83
T1-5%	29.65 ^b ±2.98	0.11 ^{ab} ±0.05	0.53 ^a ±0.08	0.84 ^{bc} ±0.03	25.54 ^b ±0.99	14.89 ^{ab} ±2.95
T2 -6%	31.54 ^b ±1.54	0.13 ^b ±0.05	0.70 ^b ±0.08	0.80 ^{bc} ±0.02	25.13 ^b ±0.74	17.80 ^b ±2.55
T3-7%	45.47 ^c ±3.31	0.13 ^b ±0.02	0.75 ^b ±0.04	0.76 ^{ab} ±0.04	34.98 ^c ±1.97	26.03 ^c ±1.23
T4-10%	53.98 ^d ±9.17	0.08 ^a ±0.01	0.66 ^b ±0.08	0.69 ^a ±0.15	37.15 ^c ±10.41	24.31 ^c ±7.56
'F' value	20.68 ^a ±1.36	0.14 ^b ±0.02	0.53 ^a ±0.09	0.87 ^c ±0.03	17.87 ^a ±0.62	11.05 ^a ±2.83

Means bearing different superscripts between columns (a,b,c,d) differ significantly ($P \leq 0.05$)

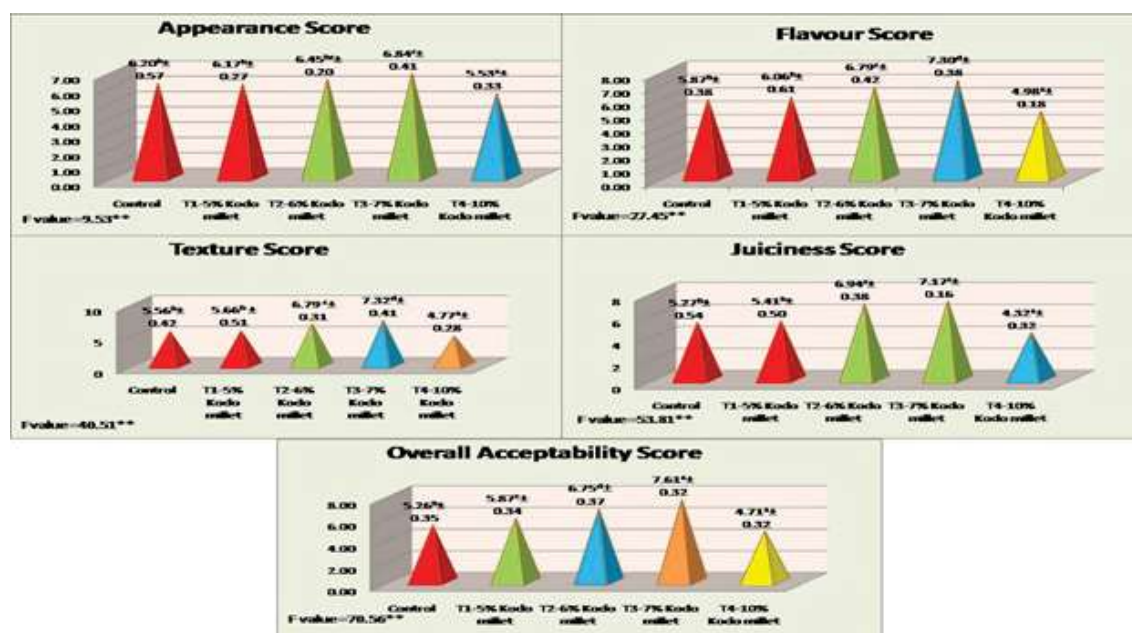
**Fig 2. Effect of Kodo millet on the sensory scores of functional chicken nuggets**

Table 3: Principal component analysis of sensory scores of trained panellist of functional chicken nuggets

Component	Total variance explained		
	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.886	97.722	97.722
2	.078	1.556	99.278
3	.032	.641	99.919
4	.004	.081	100.000
5	1.805E-17	3.610E-16	100.000

Scree Plot

Component Number	Eigenvalue
1	4.886
2	.078
3	.032
4	.004
5	1.805E-17

	PCA Co-efficient for sensory characteristics- Component Matrix				
	1	2	3	4	5
Appearance	.785	.466	.409	.009	.000
Flavour	.656	.572	.491	-.035	.000
Texture	.575	.641	.506	.050	.000
Juiciness	.539	.712	.451	-.017	.000
Acceptability	.533	.551	.642	-.003	.000

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

	Ranking of products based on PCA Score	
Control nuggets	-0.08343	
T1 (5% KMF)	-0.17742	
T2 (6% KMF)	0.83222	
T3(7% KMF)	3.11349	
T4(10% KMF)	-3.68486	

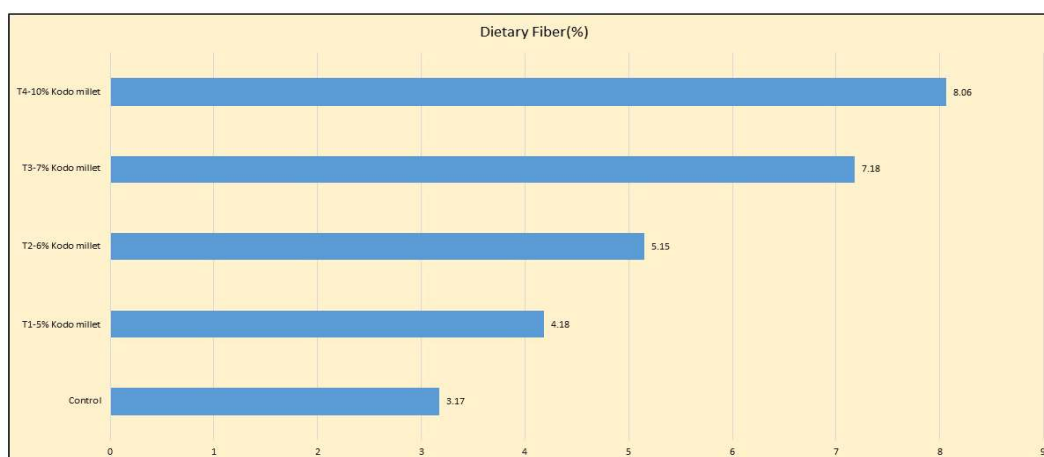


Fig 3. Dietary fibre content of Kodo millet incorporated functional chicken nuggets

by 126.49% in the treated nuggets (T3) compared to the control (Fig 3). The dietary fibre in Kodo millet undoubtedly adds to the functional value of the product. Furthermore, it increases the bulk of the product by preventing cooking loss in meat products, with minimal or no changes in textural parameters, due to its water-binding capabilities (Talukder and Sharma, 2013). This enhances the product's acceptability among trained panellists.

CONCLUSION

Kodo millet replacement for refined wheat flour is an effective approach for developing functional chicken meat nuggets. Statistical analysis of the results of this study concludes that functional chicken meat nuggets can be developed with up to 7% replacement to achieve the acceptable product development with added nutritional benefit of dietary fibre enrichment.

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CONFLICT OF INTERESTS

We certify that there is no conflict of interest among the authors and the financial organization with respect to the materials discussed in the manuscript.

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