International Journal for Scientific Research (IJSR)

IJSR

المجلة الدولية للبحوث العلمية

Vol. (4), No. (12) December 2025 الإصدار (4)، العدد (12)

Influence of Tamarind (*Tamarindus indica*) Seed Kernel Powder on Dough Rheology and Bread Quality: A Comparative Study of Local and Imported Wheat Flours

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Abstract

This study investigated the effects of tamarind seed kernel powder (TKP) incorporation (0–20%) on the rheological and quality properties of dough and bread produced from two wheat flour types: local flour (Alsayed Flour Mills) and imported Egyptian flour (Salara). Significant improvements in water absorption, dough development time, and stability were observed with increasing TKP levels, with more pronounced effects in the local flour. Water absorption increased to 66.5% (local) and 61.5% (imported) at 20% TKP, reflecting the superior protein strength and water-binding capacity of the local flour. Dough development time rose from 1.7 to 11.5 minutes (local) and from 1.4 to 5.7 minutes (imported), while stability reached 8.7 and 6.7 minutes, respectively. The gluten index was higher in local flour

https://doi.org/10.59992/IJSR.2025.v4n12p4 E-ISSN 2755-3418

(135.64) than in imported flour (93.66), though both decreased with TKP addition due to gluten dilution. Proximate analysis revealed increased protein (up to 13.51%), fiber (0.7% to 1.44%), and ash content with TKP enrichment, alongside reduced carbohydrate levels. Sensory evaluation indicated that higher TKP levels negatively affected color, aroma, taste, and texture, with overall acceptability scores declining to 5.26 (local) and 5.33 (imported) at 20% TKP. The local flour demonstrated superior gluten strength and nutritional enhancement potential.

Keywords: *Tamarindus Indica***,** Tamarind Kernel Powder, Dough, Rheology, Bread Quality.

1. Introduction

Tamarind (*Tamarindus indica* L.), a member of the family Leguminosae (Fabaceae), is native to the dry savannas of tropical Africa (Mohamed, Mohamed et al. 2015). Today, major production areas are found in South and Southeast Asia, particularly in India, Bangladesh, Sri Lanka, and Thailand, with India recognized as the world's leading producer and consumer (Havinga, Hartl et al. 2010). Tamarind is considered a multipurpose tree, as nearly all of its parts have economic or nutritional value. The fruit typically comprises approximately 55% pulp, 34% seed, and 11% shell and fiber per pod (Kumar and Bhattacharya 2008).

Among its by-products, tamarind kernel powder (TKP) has attracted attention as a low-cost, alternative source of proteins and other essential nutrients. TKP contains 4.67% moisture, 24.61% crude protein, 2.46% crude fat, 3.70% crude fiber, and 2.50% total ash, while carbohydrates account for about 62.06% of its composition, yielding a physiological energy value of 369 kcal per 100 g. It is also a rich source of calcium (145 mg/100 g) and iron (15.46 mg/100 g), although minor levels of tannic acid (0.006 mg/100 g) and phytates (0.49 mg/100 g) are present (Sarkar, Awasthi et al. 2018).

Functionally, TKP has been utilized as a natural food additive, particularly in the baking industry, where it enhances the viscosity and texture of doughs and batters.

Its application in bread and biscuit formulations has been reported to improve structural attributes such as hardness, crispness, and thickness, without negatively impacting flavor or taste.

Tamarind seeds, a by-product of the pulp industry, are often discarded in large quantities, representing both a waste management issue and a lost nutritional opportunity. Given its composition and potential as a cost-effective bread improver, TKP represents a promising ingredient for enhancing bakery products(Oluseyi and Temitayo 2015).

Accordingly, the present study was undertaken to evaluate the influence of tamarind seed kernel powder on dough rheology and bread quality. In addition, comparative analyses were performed using locally produced and imported wheat flours to assess the potential of TKP as a functional bread improver in different flour matrices.

2. Material and Methods

2.1. Chemicals:

All reagents and solvents used in this study were used as received without further purification.

2.2. Material Collection:

Mature tamarind (*Tamarindus indica*) were procured from the local market (EbinMasuod Market, Elobeid, Sudan). Two types of wheat flour were used in the study: a locally produced flour (Elsaied Flour Mills, Sudan) and an imported commercial flour (Salara, Egypt). Both flours were purchased from a certified supplier in Khartoum, Sudan.

2.3. Preparation of Tamarind Kernel Powder (TKP):

Tamarind fruits (*Tamarindus indica L.*) were immersed in water for two hours at ambient temperature (25–30 °C) to facilitate pulp separation. Seeds were subsequently manually cleaned to remove residual pulp, foreign matter, and

https://doi.org/10.59992/IJSR.2025.v4n12p4 E-ISSN 2755-3418

defective seeds, followed by thorough rinsing under running tap water. A 500 g aliquot of cleaned seeds was boiled in distilled water for 30 minutes to soften the testa. The seed coats were manually decorticated to isolate the kernels.The kernels were shade-dried at ambient temperature (25–30 °C) for 72 hours until constant weight was achieved. Dried kernels were fragmented using a mortar and pestle and subsequently ground to a fine powder using an electrical grinder. The resulting powder was sieved through a 500-µm stainless steel sieve to ensure particle size uniformity. The tamarind kernel powder (TKP) was stored in airtight polyethylene containers under refrigeration (4 °C) to minimize moisture uptake and preserve functional properties until further analysis.

2.4. Preparation of Flour Blends:

Flour blends were formulated by incorporating tamarind seed kernel powder (TKP) into wheat flour at substitution levels of 0, 5, 10, 15, and 20% (w/w). Two types of wheat flour were used: locally produced flour and standard imported flour. This resulted in ten experimental samples as follows:

Table (1): Preparation of Flour Blends

Types of Wheat Flour	The Tamarind Kernel Powder (TKP) %				
	Control	**5%**	**10%**	**15 %**	**20 %**
Local wheat flour	LF_0	LF_5	LF_{10}	LF_{15}	LF_{20}
Imported wheat flour	IF_0	IF_5	IF_{10}	IF_{15}	IF_{20}

The blends were homogenized thoroughly to ensure even distribution of TKP within each formulation and stored in airtight containers under refrigeration (4 °C) until further use.

2.5. Dough Rheological Property Analyses:

The rheological properties of the dough formulations were evaluated using a **Farinograph** according to the standard method AACC 54-21.02 (AACC 2000). Measurements were performed in triplicate for each flour blend. Parameters recorded included: Water Absorption (%): The amount of water required to center

International Journal for Scientific Research, London Vol (4), No (12), 2025
https://doi.org/10.59992/IJSR.2025.v4n12p4 E-ISSN 2755-3418

the farinograph curve on the 500 BU line. Dough Development Time (min): The time from the initial addition of water until the maximum consistency of the dough is reached. Stability (min): The time the dough consistency remains within the 500 BU ± 20 BU range, indicating tolerance to over mixing. Degree of Softening (BU): The difference in consistency between the peak and the curve measured 12 minutes after the peak.

2.6. Bread Baking Procedure:

Bread baking trials were conducted to evaluate the quality of the control and TKP-supplemented flour blends, following an adapted method from Badi, Hoseney et al. (1976). The basic formulation consisted of 250 g flour, 2.5 g yeast, 1.5 g salt, and 2.5 g sugar. TKP was incorporated at levels of 0, 5, 10, 15, and 20% (w/w), replacing an equivalent portion of wheat flour.

The water addition for each formulation was determined based on its farinograph water absorption capacity. Ingredients were mixed in a laboratory dough mixer for 5 minutes at medium speed. The resulting dough was rested for 10 minutes at 30 °C, divided into three 120 g portions, and rounded. After a 15-minute intermediate proofing period, the dough pieces were molded, panned, and subjected to final proofing in a fermentation cabinet at 35 °C and 85% relative humidity for 50–60 minutes.

The proofed doughs were baked in a Simon Rotary test oven at 220–250 °C with initial steam saturation for 20–25 minutes. The baked loaves were cooled to room temperature prior to analysis. For sensory evaluation, loaves were sliced using an electric knife, and slices were stored in polyethylene bags at ambient temperature until evaluation on the same day.

2.6.1. Evaluation of Bread Quality Parameters:

Bread quality was assessed on triplicate loaves after a one hour cooling period at ambient temperature (28 ± 2 °C). The following parameters were evaluated:

2.6.1.1. Loaf Volume (cm³): Loaf volume was determined using the seed displacement method (Pyler and Gorton 1973). Each loaf was placed in a calibrated container of known volume, which was then filled with millet seeds (*Panicum miliaceum*). The volume of seeds displaced by the loaf was recorded as the loaf volume.

2.6.1.2. Loaf Weight (g): Loaf weight was measured using an analytical balance (±0.01 g precision).

2.6.1.3. Specific Volume (cm³/g): Specific volume was calculated according to AACC Method 10-05.01 (AACC 2000) by dividing the loaf volume by its corresponding weight.

2.7. Proximate Composition Analysis:

Proximate composition of the baked bread samples was determined in triplicate according to standard AOAC methods (AOAC 2016). The following analyses were performed: Moisture content was determined by oven-drying samples at 105 ± 2 °C until constant weight was achieved (Method 925.10). Ash content was quantified by incineration in a muffle furnace at 550 °C for 6 hours (Method 923.03). Crude protein content (% N × 5.7) was determined using the Kjeldahl method (Method 992.23). Crude fat content was analyzed by solvent extraction using a Soxhlet apparatus with petroleum ether as the solvent (Method 920.39). Crude fiber was determined via the enzymatic-gravimetric method (Method 962.09). Total carbohydrate content was calculated by difference using the formula:

% Carbohydrates=100− (%Moisture+%Protein+%Fat+%Ash).

2.8. Sensory Evaluation of Bread:

The breads were sliced with an electric knife and prepared for sensory evaluation on the same day. The sensory evaluation of bread samples “aroma, taste, crumb texture, color, crumb cell uniformity and general acceptability was carried out by fifteen panelists. The evaluation depends on the range of 8 – 9 as excellent, 6 – 7 is very good, 4 – 5 is good, 2 – 3 is fair and 1 is poor

2.9. Statistical Analysis:

The data were statistically analyzed using analysis of variance and least significant differences according toSnedecor and Cochran (1987). Means were compared using Duncan's Multiple-Range Test (Duncan, 1955) with probability ($p \leq 0.05$).

3. Results And Discussion

3.1. Rheological Properties of Dough:

The farinograph properties of dough were significantly influenced by both the addition of tamarind kernel powder (TKP) and the type of wheat flour used as shown in Table 2.

Water absorption capacity increased progressively with higher TKP incorporation levels in both flour types. The local flour demonstrated a markedly higher water absorption (66.5%) compared to the imported flour (61.5%) at the 20% TKP supplementation level. This suggests that the proteins in the local flour possess a superior water-binding capacity, likely attributable to stronger gluten strength and a more favourable protein composition (Sivam, Sun-Waterhouse et al. 2010). The inherent hydrocolloid nature of TKP, rich in polysaccharides, also contributes to this enhanced water retention.A pronounced increase in dough development time was observed with escalating TKP levels. The effect was more substantial in the local flour, where development time increased from 1.7 to 11.5 minutes, compared to an increase from 1.4 to 5.7 minutes for the imported flour. This indicates that the gluten network in the local flour requires a longer mixing time to achieve optimum development, a characteristic often associated with higher-quality, stronger gluten proteins (Dewettinck, Van Bockstaele et al. 2008). The TKP fibres and proteins likely interfere with gluten hydration and formation, further prolonging the development time.The dough stability of both flours was enhanced with TKP addition, with the local flour exhibiting significantly greater stability (8.7 minutes)

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than its imported counterpart (6.7 minutes). Concurrently, the degree of softening was reduced, with the local flour showing exceptional resistance to breakdown compared to the imported flour. These results collectively demonstrate that dough formulated with local flour possesses a more robust and stable structure, exhibiting greater tolerance to overmixing. This enhanced stability can be linked to the qualitative superiority of its gluten proteins and a possible synergistic interaction with TKP components, which may reinforce the protein-starch matrix (Rosell, Rojas et al. 2001).

Table (2): Rheological Properties of Dough

Treatment		Water Absorption	Development Time	Stability	Degree of Softening10min	Degree of Softening12min
Type of flour	Local (LF)	60.58	5.72	6.16	64.4	92.4
	Imported (IF)	54.56	2.82	4.46	108.6	150.8
TKP %	0 %	52.45	1.55	2	187	209
	5 %	55.4	1.7	3.25	122	159
	10 %	56.8	3.5	5.75	72.2	133.5
	15 %	59.2	6	7.85	35.5	101
	20 %	64	8.6	7.7	24.5	112
Local flour + TKP	LF_0	54.5	1.7	2.3	152	191
	LF_5	58.1	1.7	4	98	139
	LF_{10}	60.1	5.2	7.1	48	132
	LF_{15}	63.7	8.5	8.7	11	0
	LF_{20}	66.5	11.5	8.7	13	0
Imported flour + TKP	IF_0	50.4	1.4	1.7	204	227
	IF_5	52.7	1.7	2.5	146	179
	IF_{10}	53.5	1.8	4.4	97	135
	IF_{15}	54.7	3.5	7	60	101
	IF_{20}	61.5	5.7	6.7	36	112

3.2. Gluten Properties:

The gluten characteristics of the doughs were significantly influenced by the addition of tamarind kernel powder (TKP) and the inherent quality of the wheat flours, as detailed in Table 3.

A stark contrast in gluten index was observed between the flour types. The local flour exhibited a substantially higher gluten index (135.64) compared to the imported flour (93.66) in the control samples. This result signifies a superior gluten strength, elasticity, and gas retention capacity in the local flour, which is a critical determinant of final bread volume and texture (Wieser 2007). However, the gluten index exhibited a concentration-dependent decrease with TKP supplementation in both flours, declining to 93.47 at the 20% inclusion level. This reduction is directly attributable to a dilution effect; as TKP, which is inherently gluten-free, replaces a portion of the wheat flour, the overall proportion and continuity of the vital gluten network are diminished (Gómez, Ronda et al. 2003).

Conversely, both wet and dry gluten content were initially higher in the imported flour. These values demonstrated a gradual but consistent decline with increasing TKP concentration in both flour types. This trend corroborates the dilution effect, whereby the non-gluten components of TKP directly reduce the absolute quantity of gluten available for network formation. This reduction can potentially lead to a weaker dough structure at higher inclusion levels, which may subsequently compromise bread volume and crumb softness (Dexter, Preston et al. 1994). Despite this decline, the gluten content values remained within a technologically acceptable range for bread-making at incorporation levels up to 15% TKP. This suggests that TKP can be added at moderate levels without critically impairing the functional properties of the dough, highlighting its potential as a fibre- and protein-enriching ingredient.

Table (3): Gluten Properties

Treatment		Gluten Index	Dry Gluten	Wet Gluten
Typeof flour	Local (LF)	135.64	6.49	25.92
	Imported (IF)	93.66	7.18	26.31
TKP %	0 %	93.92	7.67	27.08
	5 %	94.46	6.87	26.26
	10 %	93.7	6.74	26.1
	15 %	93.475	6.79	25.95
	20 %	197.69	6.135	25.19
Local flour + TKP	LF_0	94.8	6.4	26.19
	LF_5	93.86	6.45	25.92
	LF_{10}	93.36	6.59	25.38
	LF_{15}	301.27	6.26	25.05
	LF_{20}	94.8	6.4	26.19

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Imported flour + TKP	IF_0	92.91	8.56	27.07
	IF_5	94.12	7.34	26.34
	IF_{10}	93.55	7.03	26.28
	IF_{15}	93.59	6.98	26.51
	IF_{20}	94.12	6.01	25.34

3.3. Proximate Analysis:

The proximate composition of the baked bread was significantly influenced by both the flour type and the level of tamarind kernel powder (TKP) supplementation, revealing a clear trend of nutritional enhancement.

A primary finding was the consistent increase in protein content with escalating TKP levels, reaching maximum values of 13.51% and 13.14% (dry basis) at the 20% incorporation level for the local and imported flour breads, respectively. This demonstrates the efficacy of TKP, which is rich in protein, as a functional ingredient for protein fortification in baked goods (Bhatta, Krishnamoorthy et al. 2001). The higher protein content in breads made from local flour across all treatments suggests a superior initial protein quality or a synergistic interaction with TKP.

Similarly, the crude fiber content exhibited a substantial increase from 0.7% in the control to 1.44% at the highest TKP level. This enhancement is nutritionally significant, as increased dietary fiber intake is associated with improved digestive health and a reduced glycemic response (Dodevska, Djordjevic et al. 2013). The ash content, an indicator of total mineral content, also rose progressively with TKP addition and was consistently higher in breads formulated with the local flour. This suggests that TKP is a valuable source of minerals and that the local flour may inherently contain a higher mineral density than its imported counterpart.

Conversely, the total carbohydrate content displayed a corresponding decrease as TKP levels increased. This is a direct result of the partial replacement of wheat flour (a carbohydrate-rich matrix) with TKP, which has a different nutritional profile. The moisture content remained within acceptable technological limits for bread across all samples, indicating that the enhanced water absorption capacity (Table 4) did not negatively impact the final product's shelf-life regarding microbial stability.

Collectively, these results indicate that the strategic incorporation of TKP, particularly at moderate levels (10-15%), successfully improves the nutritional profile of bread by boosting protein, fiber, and mineral content, while only marginally reducing its carbohydrate density. This positions TKP as a promising functional ingredient for developing value-added baked products.

Table (4): Proximate analysis

Treatment		Moisture	Protein	Fat	Fiber	Ash	Carbohydrate
Typeof flour	Local (LF)	13.41	12.74	0.99	1.23	1.19	70.4
	Imported (IF)	13.23	12.93	0.99	1.05	0.76	70.96
TKP %	0 %	12.77	12.13	0.7	0.7	0.7	72.65
	5 %	13.06	12.43	0.79	1.09	0.78	71.82
	10 %	13.69	13.3	1	1.27	1.2	69.54
	15 %	13.43	13.2	1.33	1.24	1.08	69.84
	20 %	13.64	13.14	1.14	1.39	1.1	69.55
Local flour + TKP	LF_0	12.53	12.2	0.67	0.75	0.76	73.13
	LF_5	13.24	12.09	0.81	1.39	0.85	71.6
	LF_{10}	13.51	13.09	0.82	1.33	1.63	69.59
	LF_{15}	13.88	12.84	1.43	1.23	1.36	69.12
	LF_{20}	13.88	13.51	1.2	1.44	1.36	68.58
Imported flour + TKP	IF_0	13.02	12.06	0.73	0.65	0.65	72.17
	IF_5	12.88	12.77	0.77	0.79	0.71	72.03
	IF_{10}	13.88	13.51	1.18	1.21	0.78	69.5
	IF_{15}	12.98	13.56	1.22	1.24	0.8	70.56
	IF_{20}	13.41	12.77	1.07	1.35	0.84	70.53

3.4. Sensory Evaluation:

Sensory evaluation revealed that both flour type and tamarind kernel powder (TKP) concentration significantly influenced the organoleptic properties of the bread, including color, aroma, taste, texture, crumb structure, and overall acceptability.

The control samples (0% TKP) consistently received the highest hedonic scores for overall acceptability, with the imported flour bread achieving a marginally higher score (7.06) than the local flour variant (6.93). This suggests that the baseline sensory profile of the standard imported flour was slightly preferred by panelists, potentially due to its more familiar or refined functional properties in the baked product.

A clear, concentration-dependent decline in all sensory attributes was observed with increasing TKP incorporation. The most pronounced negative impact was recorded at the 20% supplementation level, which yielded the lowest overall acceptability scores (5.33 for imported and 5.26 for local flour). This deterioration in sensory quality is likely attributable to several factors inherent to TKP. The introduction of non-wheat components can dilute the gluten network, leading to a denser crumb structure and altered texture (Gómez, Ronda et al. 2003). Furthermore, TKP may impart distinctive, and potentially less preferred, notes in color, flavor, and aroma that deviate from the expected profile of conventional wheat bread, resulting in lower consumer acceptance at high inclusion levels (Lu, Liu et al. 2017).

Notably, while the absolute scores decreased, the sensory performance of breads made from local and imported flours remained closely aligned across all TKP levels. This indicates that the impact of TKP supplementation was a dominant factor over the initial, minor differences in flour type.

These findings underscore a critical trade-off between nutritional enhancement and sensory appeal. While TKP effectively improves nutritional value (Section 4.3), its incorporation above 10-15% significantly compromises product acceptability. Therefore, optimizing TKP levels is essential to achieve a balance between creating a nutritionally fortified product and maintaining desirable sensory characteristics that ensure consumer adoption.

https://doi.org/10.59992/IJSR.2025.v4n12p4
E-ISSN 2755-3418

Table (5): Sensory Evaluation

Treatment		Color	Odor	Taste	Texture	Crumb	Prefer
Typeof flour	Local (LF)	6.16	5.76	5.97	5.8	5.65	5.86
	Imported (IF)	6.54	6.08	6.96	6.13	5.84	6.29
TKP %	0 %	7.23	6.76	6.73	7.33	6.43	6.93
	5 %	6.5	6.03	6.2	6.46	6.23	6.36
	10 %	5.93	5.66	5.76	5.16	5.43	5.9
	15 %	6.56	5.93	6.1	5.6	5.86	5.9
	20 %	5.53	5.2	5.3	5.26	4.76	5.3
Local flour + TKP	LF_0	6.86	6.93	6.66	6.6	5.8	6.8
	LF_5	6.2	5.73	5.4	6.46	6.13	6.13
	LF_{10}	5.86	4.73	5.73	4.73	5	5.2
	LF_{15}	6.86	6.13	6.33	5.73	6.53	5.93
	LF_{20}	5	5.26	5.73	5.46	4.8	5.26
Imported flour + TKP	IF_0	6.86	6.6	6.8	6.6	7.06	7.06
	IF_5	6.2	6.33	7	6.46	6.33	6.6
	IF_{10}	5.86	6.6	5.8	4.73	5.86	6.6
	IF_{15}	6.86	5.73	5.86	5.73	5.2	5.86
	IF_{20}	5	5.13	4.86	5.46	4.73	5.33

4. Conclusion

Present findings suggest that moderate tamarind seed kernel powder (TKP) incorporation can improve nutritional profile while maintaining acceptable sensory properties, with local flour offering better technological performance for fortified bread production.

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