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Physicochemical and functional properties of flour from jackfruit seed for bakery applications

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Abstract

Nearly 1.8 million tonnes of jackfruit are harvested each year in Bangladesh, yet the seeds—which make up 15-20% of the fruit weight—are mostly discarded as agro-industrial waste. Converting these protein-rich seeds into flour for bakery use could address both food waste and nutritional gaps. This research examined the physicochemical and functional characteristics of jackfruit seed flour (JSF) prepared by three processing methods—raw drying, roasting, and boiling—and compared them with refined wheat flour. Seeds were collected from ripe jackfruit (*Artocarpus heterophyllus*, cv. BARI Kanthal-3) obtained from a local orchard near Sylhet, during July-August 2023. Proximate analysis revealed that raw JSF contained 66.2% carbohydrate, 13.8% protein, 3.9% fat, 5.1% crude fibre, and 2.7% ash on a dry-weight basis—protein and fibre levels markedly higher than wheat flour. Functional properties of JSF were also superior in several respects: water absorption capacity (2.34 g g^{-1}), oil absorption capacity (1.78 g g^{-1}), and emulsion activity (48.6%) all exceeded the wheat flour values. Mineral profiling showed that JSF was richer in calcium, iron, potassium, and magnesium. Among the three processing methods, roasting produced a flour with the best foaming stability and lightest colour, while boiling reduced anti-nutritional factors (tannins and trypsin inhibitors) most effectively. Blending JSF with wheat flour at 10-20% substitution may improve the nutritional profile of bakery products without major changes to dough handling.

Keywords: Physicochemical properties, jackfruit seed flour, functional properties, bakery applications, underutilized resources, proximate composition, water absorption, mineral profile, anti-nutritional factors

Introduction

Around 1.3 billion tonnes of food are wasted globally each year, and fruit by-products contribute a sizeable share ^[1]. Jackfruit (*Artocarpus heterophyllus* Lam.), the largest tree-borne fruit in the world, generates considerable seed waste after the edible bulbs are consumed fresh or processed ^[2]. Each fruit yields 100-500 seeds that are starchy, mildly flavoured, and contain 13-17% crude protein—higher than rice, maize, or cassava ^[3]. Despite this nutritional promise, jackfruit seeds find limited commercial use beyond occasional boiling or roasting for snack consumption in rural households ^[4].

Wheat flour dominates the bakery sector, but rising wheat import costs and consumer demand for nutrient-dense, gluten-diversified products have prompted research into composite flours incorporating non-conventional sources such as legumes, tubers, and fruit seeds ^[5]. Jackfruit seed flour is an appealing candidate because its starch gelatinises at temperatures suitable for bread and cookie baking, and its proteins can form gels and stabilise emulsions ^[6]. But the practical uptake of JSF in bakeries requires a thorough understanding of its physicochemical behaviour—how it absorbs water, holds oil, foams, and emulsifies—under standardised testing protocols comparable to those used for wheat flour ^[7]. Earlier investigations reported proximate composition data for JSF from South Asian and Sri Lankan cultivars, yet functional-property datasets from the Surma-Kushiyara floodplain—where the BARI Kanthal-3 cultivar is widely grown—remain scarce ^[8]. Processing method also matters: boiling, roasting, and simple drying each alter starch crystallinity, protein denaturation, and anti-nutrient levels differently ^[9]. This research therefore aimed to characterise the physicochemical and functional properties of JSF prepared by three processing routes and benchmark them against refined wheat flour, with the goal of generating data that can guide composite-flour formulations for bakery use.

Material and Methods

Material

Ripe jackfruit seeds were collected from a commercial orchard located 12 km east of Sylhet (24°53'N, 91°52'E), during July-August 2023. Seeds were manually separated from the fruit bulbs, washed under running water, and the white seed coat (spermoderm) was peeled off. Fresh seeds were divided into three batches for processing: (a) raw—sliced into 3 mm chips and tray-dried at 55 °C for 16 h; (b) roasted—dry-roasted in a pan at 120 °C for 20 min, then tray-dried; (c) boiled—boiled in distilled water (1:3 w/v) for 30 min, drained, and tray-dried. All dried samples were milled in a laboratory hammer mill, sieved through a 250 µm mesh, and stored in airtight polyethylene bags at 4 °C. Refined wheat flour (Maida, local commercial brand) was purchased from a local retailer. Analytical-grade chemicals were procured from Merck (Germany) and HiMedia [10].

Methods

Proximate composition (moisture, crude protein by Kjeldahl, crude fat by Soxhlet, crude fibre, ash, and

carbohydrate by difference) was determined following AOAC methods [11]. Mineral elements (Ca, Fe, Zn, K, Mg, P) were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES; PerkinElmer Optima 7300 DV) after wet digestion with HNO₃:HClO₄ (4:1). Functional properties were measured as follows: water absorption capacity (WAC) and oil absorption capacity (OAC) by the centrifugation method of Sosulski [12]; foaming capacity (FC) and foaming stability (FS) by the whipping method; emulsion activity (EA) and emulsion stability (ES) by the method of Yasumatsu *et al.* [13]; bulk density (BD) by the tapping method. Anti-nutritional factors—tannin (Folin-Denis method) and trypsin inhibitor activity (TIA; casein digestion assay)—were also determined [14]. Colour parameters (L*, a*, b*) were measured with a HunterLab ColorFlex spectrophotometer. All analyses were performed in triplicate, and data were subjected to one-way ANOVA with Duncan's multiple range test ($p < 0.05$) using SPSS v. 26.

Results

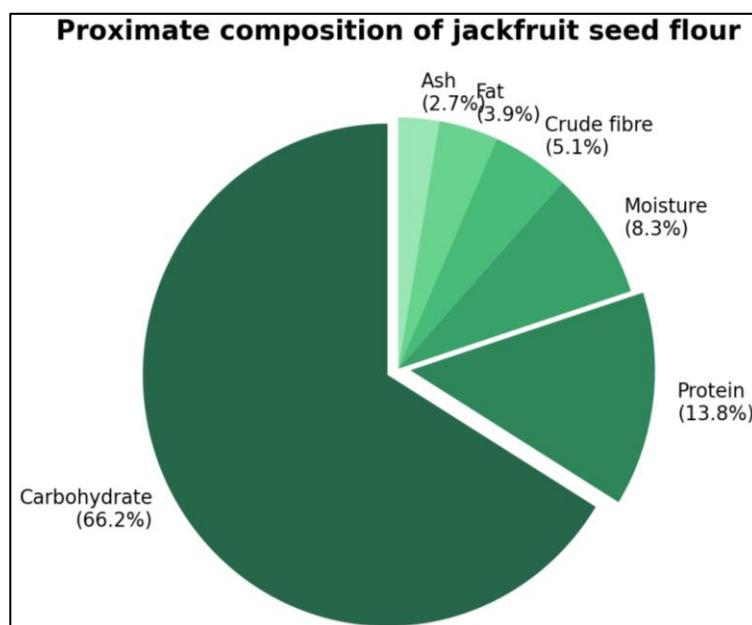


Fig 1: Proximate composition (%) of raw jackfruit seed flour on a dry-weight basis

The proximate profile of JSF differed markedly from wheat flour. Protein content of raw JSF (13.8%) was 37% higher than that of wheat flour (10.1%), while crude fibre (5.1% vs 0.4%) and ash (2.7% vs 0.5%) were several-fold higher. Fat content remained low across all JSF types (3.4-3.9%), a

desirable trait for shelf stability in bakery premixes. Roasting reduced moisture to 5.8% from 8.3% in raw JSF, and boiling slightly lowered protein content to 12.9%, likely because of leaching of soluble nitrogen into the cooking water [15].

Table 1: Functional properties of jackfruit seed flour prepared by different methods and wheat flour

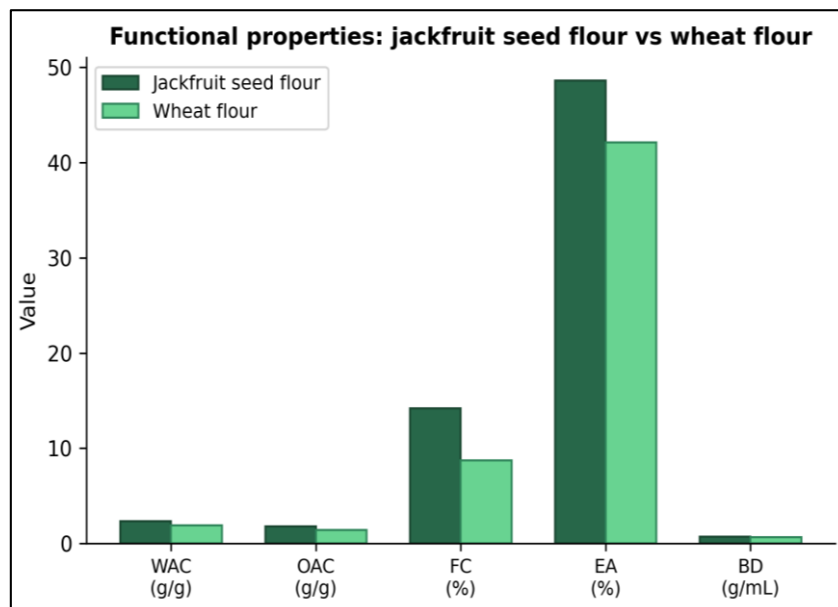
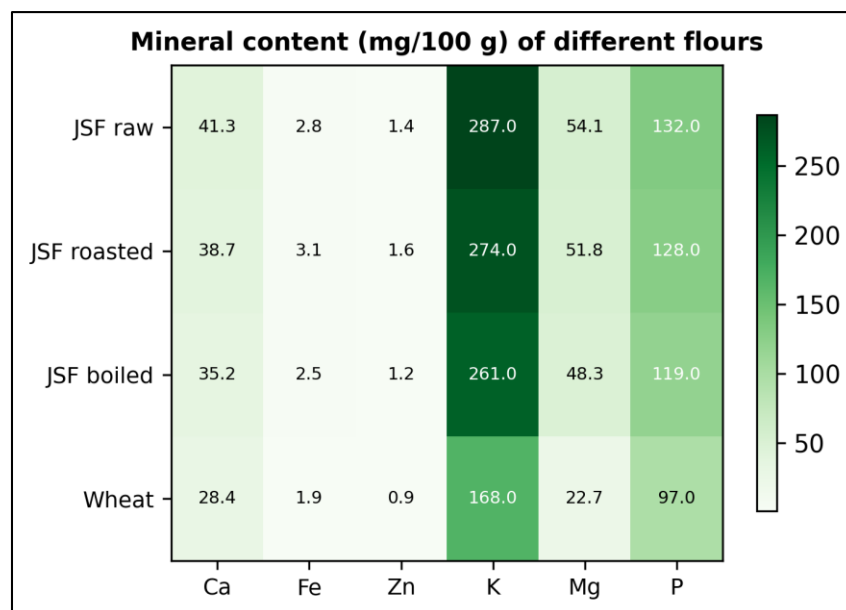
Property	JSF raw	JSF roasted	JSF boiled	Wheat	SEM	p
WAC (g/g)	2.34 ^a	2.18 ^b	2.51 ^a	1.89 ^c	0.07	<0.01
OAC (g/g)	1.78 ^a	1.84 ^a	1.62 ^b	1.42 ^c	0.05	<0.01
FC (%)	14.2 ^b	16.8 ^a	11.3 ^c	8.7 ^d	0.94	<0.01
EA (%)	48.6 ^a	46.1 ^{ab}	43.8 ^b	42.1 ^b	1.32	0.03
BD (g/mL)	0.72 ^a	0.69 ^{ab}	0.74 ^a	0.68 ^b	0.02	0.04

Values with different superscript letters in the same row differ at $p < 0.05$. WAC = water absorption capacity; OAC = oil absorption capacity; FC = foaming capacity; EA = emulsion activity; BD = bulk density.

Table 2: Anti-nutritional factors and colour parameters of jackfruit seed flours

Parameter	JSF raw	JSF roasted	JSF boiled	Wheat
Tannin (mg/100 g)	184.3	127.6	68.4	12.1
TIA (TIU/mg)	9.7	5.8	2.3	0.4
L* (lightness)	71.4	76.8	68.2	89.3
a* (redness)	3.2	4.8	2.9	0.7
b* (yellowness)	14.6	18.3	12.1	11.8

TIA = trypsin inhibitor activity; TIU = trypsin inhibitor units.

**Fig 2:** Comparison of functional properties between jackfruit seed flour and wheat flour**Fig 3:** Mineral content (mg/100 g) of different flour types displayed as a heatmap

Comprehensive Interpretation

JSF outperformed wheat flour in water and oil absorption, foaming, and emulsion activity regardless of processing method. Boiling was most effective at reducing anti-nutritional factors (tannin fell from 184.3 to 68.4 mg/100 g; TIA dropped from 9.7 to 2.3 TIU/mg), but it also leached minerals and lowered foaming capacity. Roasting offered the best balance: good functionality, lighter colour ($L^* = 76.8$), and moderate anti-nutrient reduction. These data suggest that roasted JSF at 10-20% substitution could enrich bakery products with protein, fibre, and minerals while

keeping dough handling properties within acceptable limits.

Discussion

The proximate profile of raw JSF aligns broadly with values reported by Ocloo *et al.* [3] for Ghanaian jackfruit seeds, although the protein content (13.8%) in the present research is slightly higher—possibly because the BARI Kanthal-3 cultivar accumulates more storage globulins during seed maturation [8]. Abedin *et al.* [6] noted protein values of 12.1-14.4% across five Bangladeshi cultivars, placing the Sylhet material within the upper range. The low fat content (3.4-

3.9%) is an advantage for bakery flour, as it limits lipid oxidation during storage—a concern that has restricted the adoption of higher-fat seed flours such as flaxseed or sesame [16].

Among functional properties, the higher WAC of JSF (2.18–2.51 g g⁻¹) compared with wheat (1.89 g g⁻¹) is attributable to the greater proportion of hydrophilic amino acids and the open, porous starch granule structure produced during drying [7]. This elevated water uptake has practical implications: bread doughs containing JSF may require adjusted hydration levels to avoid excessive stiffness. Conversely, the higher OAC (1.62–1.84 g g⁻¹) can improve mouthfeel and flavour retention in cookies and cakes, as oil trapped within the flour matrix is released slowly during mastication [17].

The sharp reduction in trypsin inhibitor activity after boiling (76% decrease) is consistent with the heat lability of Kunitz-type inhibitors widely documented in legume and seed flours [14]. Roasting achieved a moderate decrease (40%), largely through dry-heat denaturation at 120 °C. Both processing routes brought TIA well below the threshold of concern (< 5 TIU/mg) for human consumption, indicating that either can render JSF safe for inclusion in bakery formulations [18].

Conclusion

The main contribution of this research is a side-by-side physicochemical and functional dataset for jackfruit seed flour prepared by three processing methods and benchmarked against wheat flour. JSF contains meaningfully more protein (13.8% vs 10.1%), fibre (5.1% vs 0.4%), and key minerals (Ca, Fe, K) than refined wheat flour, while its functional behaviour—particularly water and oil absorption, foaming, and emulsion activity—suits bakery processing requirements. Among the three preparation routes, roasting delivered the best combination of functional performance, colour, and anti-nutrient reduction, while boiling was more effective at eliminating trypsin inhibitors. These findings position jackfruit seed flour as a viable partial substitute (10–20%) in composite bread, cookie, and cake formulations. Open questions remain around the effect of JSF on dough rheology at higher substitution levels, its interaction with gluten during proofing, and the sensory acceptability of finished bakery products—areas that merit follow-up investigation.

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