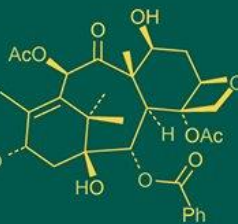
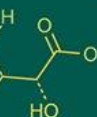
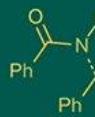


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Nutritional composition, sensory acceptability, and shelf-life stability of Jhar Ber (*Ziziphus nummularia*) powder-fortified khakhra and biscuits

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Abstract

Jhar Ber is a resilient, drought-resistant fruit found across the arid tracts of Rajasthan, yet it lacks any organized processing pathway into finished food products. This work responds to that gap by examining how consumers perceive, and how well storage preserves, two products built around Jhar Ber fruit powder. Khakhra and Biscuits were each formulated at graded powder-inclusion levels alongside a plain control. A 30-member semi-trained panel scored all variants on a nine-point hedonic scale, and the results pointed to 10% inclusion as the preferred level for Khakhra and 15% for Biscuits — both comfortably ahead of their controls and of the more heavily fortified variants on every attribute assessed (color, appearance, texture, flavor, taste, and overall liking). These two winning formulations were then sealed in polyethylene pouches and tracked for a month under ordinary room conditions. Across that period, liking scores drifted down only slightly and never fell below 7.5, moisture pickup stayed within acceptable bounds, and microbial load climbed from an initial zero to levels still inside the permissible range by day thirty. Taken together, the results show that Jhar Ber-fortified Khakhra and Biscuits hold up well in taste and safety for at least a month of simple ambient storage, pointing to real commercial promise for this underused desert fruit as a functional-food ingredient.

Keywords: *Ziziphus nummularia*, Jhar Ber, underutilized fruit, sensory evaluation, hedonic scale; shelf-life, storage stability, functional food

1. Introduction

Feeding a fast-expanding population safely and adequately remains one of the world's toughest challenges. India in particular, home to an enormous population living on comparatively limited arable land, continues to struggle with delivering nutrient-rich food safely to its people ^[1]. Interest in plant-derived, nutrient-dense foods with added health value has surged in recent years, a trend that gained further momentum after the COVID-19 pandemic ^[2]. India's fruit acreage is dominated by a handful of familiar crops — mango, banana, citrus, guava, apple — leaving indigenous and lesser-known fruit species to occupy only a marginal share of cultivated land, despite often yielding well ^[3]. Fruits native to dry and semi-dry ecological zones are particularly promising for boosting both dietary variety and food security, since they tolerate drought, heat, salinity, and poor soil, and frequently pack more minerals, antioxidants, and phytonutrients than the fruits grown at scale ^[4, 5].

One such underused species is Jhar Ber, a spiny, drought-adapted shrub of the Rhamnaceae family that carries both ecological and dietary weight in Rajasthan's Thar Desert ^[6, 7]. Reports place its calcium content as high as 428 mg and iron as high as 9.66 mg per 100 g fresh weight, alongside notable dietary fibre, vitamin C, and antioxidant flavonoids and phenolics ^[8]. Even its seeds — usually discarded — have been found to carry up to 38.7% protein, hinting at potential for zero-waste use ^[9, 10]. Yet despite this nutritional promise and a growing body of research into the plant's antioxidant, anti-inflammatory, antidiabetic, and antimicrobial effects ^[11-13], no published work has yet taken the step of developing, standardizing, and quality-testing actual food products from this fruit. Fresh Jhar Ber spoils quickly, and rural Rajasthan's limited cold-chain infrastructure confines its use largely to brief, subsistence-level consumption during the short winter harvest ^[14]. Related species — *Ziziphus jujuba* and *Ziziphus mauritiana* — have already been turned into powders and

baked goods with longer shelf lives and retained bioactive compounds [2, 15, 16], offering a proven approach that has simply not yet been tried with Jhar Ber.

Drawing on this established nutritional groundwork, the present study set out to formulate Khakhra and Biscuits containing Jhar Ber powder at increasing inclusion levels, and to assess how well the resulting products performed in terms of sensory quality and shelf-life stability.

2. Materials and Methods

2.1 Locale and procurement of raw material

Experimental work took place in the laboratories of College of Community and Applied Sciences, and College of Dairy and Food Technology, Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, Rajasthan, over the period from 2025-2026. Ripe, disease-free Jhar Ber fruit was sourced from local markets in Udaipur district during the main harvest window, and all other ingredients were also bought locally.

2.2 Preparation of Jhar Ber powder

Five kilograms of fresh fruit went through sorting, washing, and spreading on clean cloth for sun-drying under hygienic conditions until moisture was fully removed. The dried material was then run through a pulverizer, with seeds separated out from the pulp and skin during this grinding step; the resulting material was sieved down to a fine, seed-free powder and sealed into airtight containers (Figure 1).

2.3 Development and standardization of value-added products

Both Khakhra and Biscuits were built around three variants each: an unfortified control plus two levels of Jhar Ber powder inclusion, arrived at through preliminary trial batches. For Khakhra, jowar flour, whole wheat flour, and besan were combined with Jhar Ber powder at 10 g and 15 g per 100 g of flour blend; the dough was mixed, rested, rolled into thin rounds, and roasted on a hot griddle. Biscuits followed a creaming-method preparation using whole wheat flour, oat flour, butter, and jaggery, with Jhar Ber powder worked in at 15 g and 20 g per batch, then baked at 80-100 °C for 45 minutes.

2.4 Sensory evaluation

A nine-point hedonic scale was used to rate the attributes including color, appearance, texture, flavor, taste, and overall acceptability. Thirty semi-trained panelists tasted all three variants of each product, presented in random, coded order, and the variant scoring highest on overall acceptability was designated the best-accepted treatment for each product.

2.5 Physicochemical and proximate analysis

Titrate acidity, total soluble solids, and pH of the powder were measured through standard titration, refractometry, and pH-meter methods respectively. Proximate values — for both the raw powder and the best-accepted product formulations against their controls — followed established procedures [17]: oven-drying for moisture, muffle-furnace ashing for ash content, micro-Kjeldahl digestion for crude protein, Soxhlet extraction for crude fat, and acid-alkali digestion for crude fibre. Carbohydrate content was derived by difference, and energy value was calculated from standard fuel-factor conversions.

2.6 Mineral, vitamin and antioxidant estimation

Iron and calcium levels were measured via Atomic Absorption Spectrophotometry after wet-ashing. Vitamin C was quantified using the dichlorophenol-indophenol titration method [18], and beta-carotene was measured spectrophotometrically [19]. A radical-scavenging assay captured antioxidant activity (reported as percent inhibition and IC₅₀), while total flavonoid content was determined via the aluminium chloride colorimetric method.

2.7 Shelf-life assessment

The best-accepted formulations were sealed into airtight polyethylene pouches and kept at room temperature for 30 days, with samples pulled at 0, 10, 20, and 30 days to check moisture content, sensory acceptability, and Total Viable Count (via pour plate method).

2.8 Statistical analysis

Every measurement was run in triplicate, or across the full sensory panel where applicable, with results reported as mean ± SD. Sensory scores were compared using one-way ANOVA with Critical Difference set at the 5% level, while proximate, mineral, vitamin, and antioxidant differences between best-accepted treatments and their controls were tested via independent-samples t-tests, taking $P \leq 0.05$ as significant.

3. Results

For context, the raw Jhar Ber powder feeding into product development had already been profiled for its physicochemical, proximate, mineral, vitamin, and antioxidant makeup (Table 1); those figures aren't repeated here, since this section is centered on how the finished products performed through sensorial examination, and held up in storage.

Among Khakhra variants, the 10%-inclusion version came out on top, scoring notably higher on overall acceptability than either the plain control or the heavier 15% version. A parallel pattern emerged for Biscuits, where the 15%-inclusion variant clearly beat out both its control and the 20% version.

Beyond taste, the winning formulations of both products also came out nutritionally ahead of their controls — higher in fibre, iron, calcium, vitamin C, and antioxidant activity (Table 2, Table 3) — showing that better flavor didn't come at the expense of nutritional quality.

Across the 30-day ambient storage trial, overall liking eased downward gradually but stayed above the 7.5 mark for all three products (Figure 4); moisture uptake rose slightly but remained within safe thresholds (Figure 5); and microbial counts, starting from zero, climbed steadily yet stayed within acceptable limits through day thirty (Figure 3).

4. Discussion

The raw Jhar Ber powder's physicochemical and nutritional profile — established here as background context — reaffirmed the fruit's status as a mineral- and antioxidant-rich raw material well suited to fortifying functional foods, in line with earlier findings on the species [6, 8, 20-25]. That profile formed the foundation for building Khakhra and Biscuits at graded inclusion levels, whose sensory and storage performance are examined below.

As inclusion levels rose, both products lost ground on sensory scores — likely a result of darker browning, a

firmer dough texture (since higher fibre and tannin content compete with gluten for available water), and a more pronounced astringent aftertaste. This mirrors texture and flavor shifts documented in other Ziziphus powder-fortified baked goods^[16, 26]. At the same time, the best-accepted formulations showed clear nutritional gains — more fibre, iron, calcium, vitamin C, and antioxidant activity — underscoring Jhar Ber powder's fortification value, with enough ascorbic acid surviving the heat of baking to remain detectable despite its known heat sensitivity^[27].

The mild, non-disqualifying dip in sensory scores seen over the storage period lines up with patterns reported for other fruit-fortified baked products^[28], and the steady but capped rise in microbial counts reflects the gradual increase in water activity that comes with slight moisture gain — together pointing to microbiological safety being maintained across all three products for at least a month of simple ambient storage.

Table 1: Nutritional composition of Jhar Ber fruit powder (per 100 g fresh weight)

Category	Parameter	Value (Mean ± SD)	Unit
Proximate composition	Moisture	12.33 ± 2.53	g/100 g
	Ash	6.86 ± 1.59	g/100 g
	Crude protein	2.35 ± 0.02	g/100 g
	Crude fat	0.32 ± 0.04	g/100 g
	Crude fibre	4.06 ± 1.90	g/100 g
	Total carbohydrate	73.68 ± 1.73	g/100 g
	Energy	306.11 ± 0.78	kcal/100 g
Minerals	Iron	8.94 ± 0.21	mg/100 g
	Calcium	412.65 ± 2.18	mg/100 g
Vitamins	Vitamin C	27.84 ± 0.62	mg/100 g
	Beta-carotene	35.71 ± 1.11	µg/100 g
Antioxidant properties	DPPH inhibition	65.31 ± 1.74	%
	IC ₅₀ value	67.03 ± 1.04	µg/mL
	Total flavonoid content	76.02 ± 1.55	mg QE/100 g

All values are mean ± standard deviation of three observations

Table 2: Nutritional composition of best-accepted Jhar Ber Khakhra (T1) versus control (per 100 g)

Parameter	Control	T1 (10%)	t-value
Moisture (g)	4.78 ± 0.07	9.68 ± 0.12	61.25**
Ash (g)	7.29 ± 2.03	7.86 ± 7.73	NS
Crude protein (g)	2.50 ± 0.02	2.29 ± 0.02	12.88**
Crude fat (g)	9.17 ± 2.77	3.45 ± 0.82	3.42*
Crude fibre (g)	1.30 ± 1.88	4.06 ± 1.17	NS
Carbohydrate (g)	73.21 ± 2.83	74.34 ± 8.49	NS
Energy (kcal)	332.60 ± 6.86	352.42 ± 16.43	NS
Iron (mg)	5.05 ± 0.09	5.46 ± 0.10	6.10**
Calcium (mg)	55.18 ± 0.97	88.78 ± 1.56	31.68**
Vitamin C (mg)	0.11 ± 0.00	0.39 ± 0.01	48.50**
DPPH inhibition (%)	18.42 ± 0.32	38.67 ± 0.68	46.67**
IC ₅₀ (µg/mL)	312.45 ± 5.49	187.32 ± 3.29	33.86**

All values are (Mean ± SD) of three observations

SE- Standard Error, NS- non- significant, **- Significant at 1 per-cent level;*-Significant at 5 per-cent level

Table 3: Nutritional composition of best-accepted Jhar Ber Biscuits (T1) versus control (per 100 g)

Parameter	Control	T1 (15%)	t-value
Moisture (g)	3.43 ± 0.08	3.95 ± 0.07	8.52**
Ash (g)	5.44 ± 3.94	6.52 ± 7.13	NS
Crude protein (g)	1.66 ± 0.02	1.90 ± 0.02	15.00**
Crude fat (g)	19.50 ± 1.38	17.24 ± 5.84	NS
Crude fibre (g)	2.11 ± 0.77	3.17 ± 0.82	NS
Carbohydrate (g)	66.71 ± 6.23	68.20 ± 2.64	NS
Energy (kcal)	452.24 ± 43.23	419.08 ± 81.84	NS
Iron (mg)	2.80 ± 0.05	3.92 ± 0.07	22.55**
Calcium (mg)	74.29 ± 1.30	128.46 ± 2.26	35.99**
Vitamin C (mg)	0.20 ± 0.00	0.78 ± 0.01	96.67**
DPPH inhibition (%)	15.83 ± 0.28	32.14 ± 0.56	45.12**
IC ₅₀ (µg/mL)	348.92 ± 6.13	214.67 ± 3.77	32.31**

All values are (Mean ± SD) of three observations

SE- Standard Error, NS- non- significant, **- Significant at 1 per-cent level

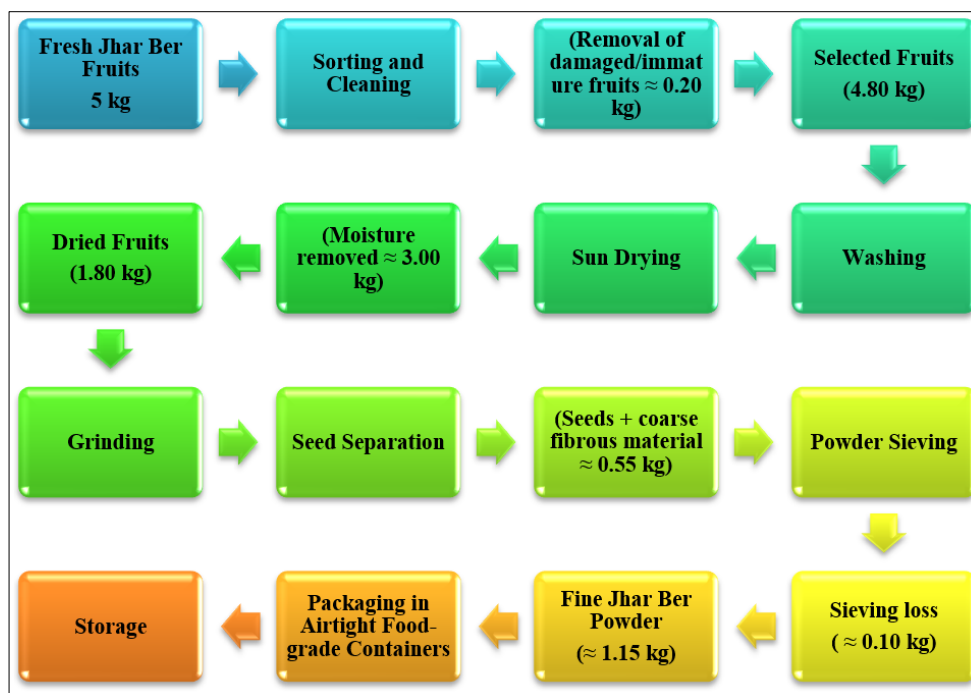


Fig 1: Flow diagram for preparation of Jhar Ber powder

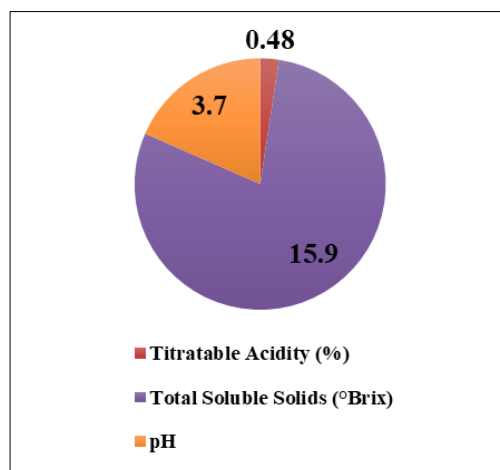
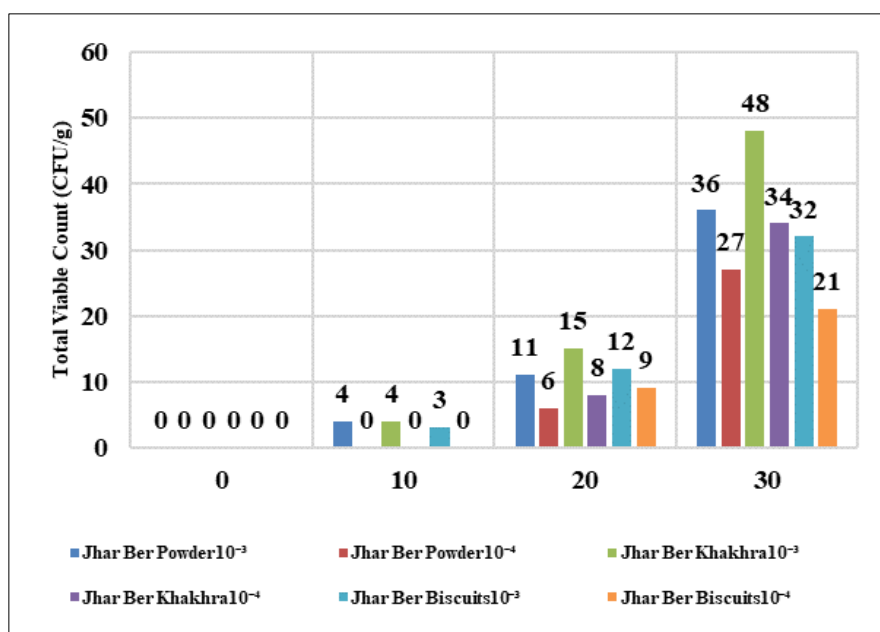


Fig 2: Physico-chemical properties of Jhar Ber fruit powder

Fig 3: Total Viable Count (CFU/g) of the products during 30-day storage period
~ 1519 ~

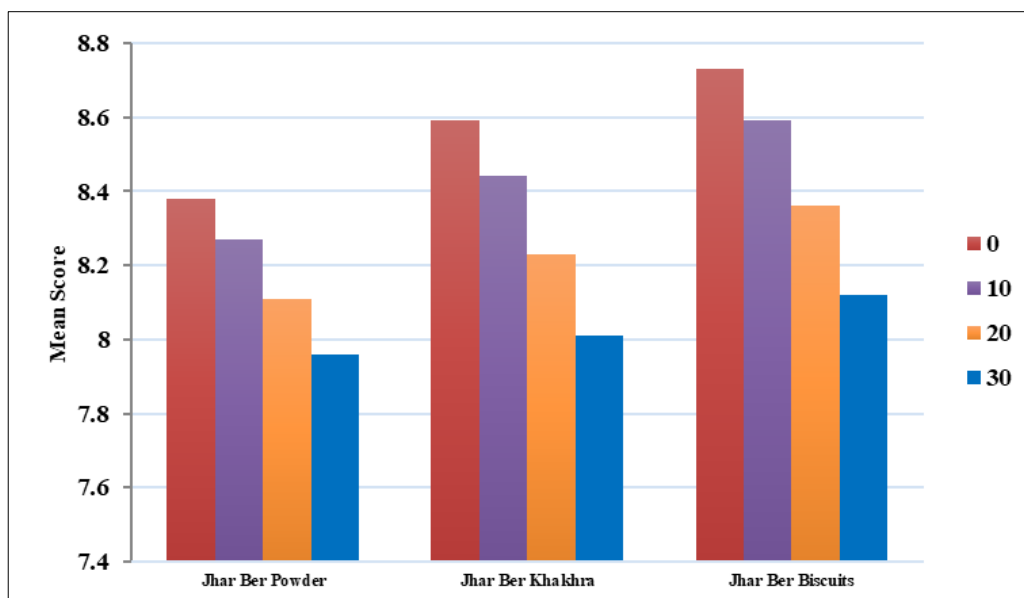


Fig 4: Changes in overall acceptability score during 30-day storage period

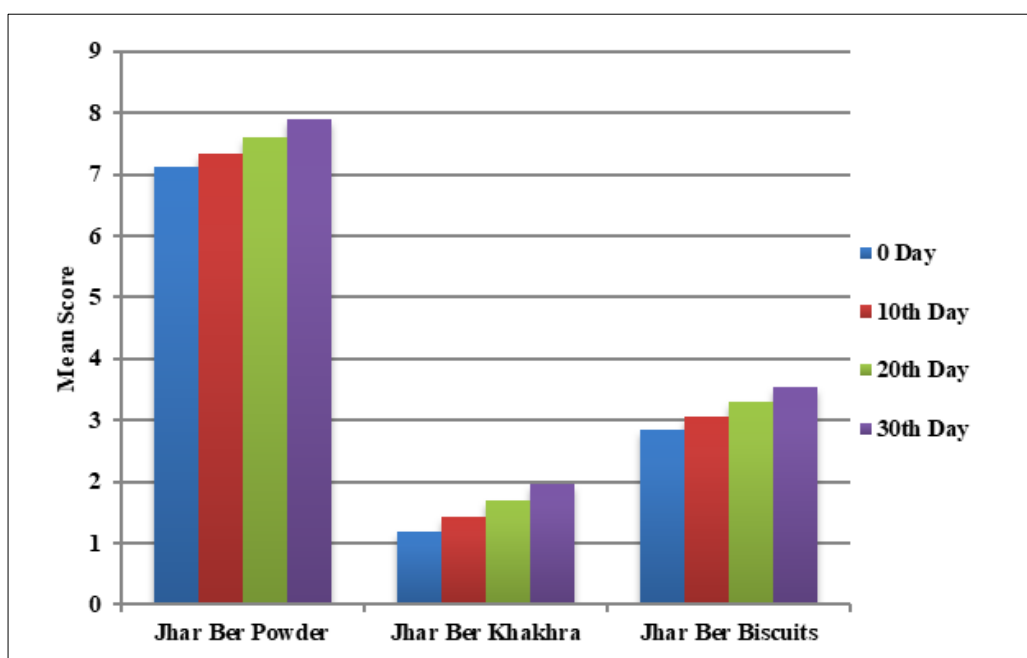


Fig 5: Changes in Moisture content during 30-day storage period

5. Conclusion

This study set out to gauge the sensory quality and shelf-life performance of Khakhra and Biscuits fortified with Jhar Ber (*Ziziphus nummularia*) powder at graded levels. Products fortified at 10% (Khakhra) and 15% (Biscuits) came out on top in panelist acceptability among all variants tested, with no trade-off in product quality. Both formulations stayed acceptable to taste, chemically stable, and microbiologically safe across a full month of simple ambient storage. Altogether, the findings position Jhar Ber-fortified Khakhra and Biscuits as viable, shelf-stable functional foods — evidence that supports the commercial potential of this indigenous desert fruit and its capacity to open new income avenues in Rajasthan's arid regions.

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