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Development of vacuum-fried jackfruit chips with reduced oil content

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Abstract

Producing a crispy fruit chip that doesn't carry 30-40% oil remains one of the harder problems in snack engineering. This research developed vacuum-fried jackfruit (*Artocarpus heterophyllus*) chips and evaluated the effect of frying temperature (80-110°C) and vacuum level (10 kPa) on oil uptake, texture, colour, and sensory attributes compared to atmospheric frying at the same temperatures. The work was carried out at the Braj Region Institute of Agricultural Sciences, Mathura, Uttar Pradesh, from October 2021 to May 2022. Vacuum frying at 90°C for 25 minutes produced chips with 11.4% oil (dry basis) 60.3% less than atmospheric frying at the same temperature (28.7%). Hardness measured by texture analyser was comparable between vacuum (18.3 N) and atmospheric (19.7 N) chips at 90°C. Colour retention was markedly better under vacuum: L* values at 90°C were 62.1 (vacuum) versus 47.3 (atmospheric), reflecting reduced Maillard browning at the lower boiling point. Sensory evaluation by a 30-member panel ranked vacuum-fried chips at 90°C highest for overall acceptability (8.1/9). The research confirms that vacuum frying at 90°C and 10 kPa is an effective method for producing low-oil jackfruit chips with superior colour and acceptable crispness.

Keywords: Vacuum frying, jackfruit chips, oil reduction, snack processing, frying technology, *Artocarpus heterophyllus*, texture analysis, colour retention, low-oil snacks, sensory evaluation

Introduction

How can a fried snack deliver the texture consumers expect without the health penalties of excessive oil? This question drives much of the current research in frying technology, and vacuum frying is among the most promising answers ^[1]. By lowering the pressure around the frying vessel, the boiling point of water drops from 100°C at atmospheric pressure to approximately 46°C at 10 kPa allowing frying to proceed at temperatures well below those used in conventional fryers ^[2].

Jackfruit is the world's largest tree-borne fruit, with annual production exceeding 3 million tonnes, concentrated in South and Southeast Asia ^[3]. Ripe jackfruit bulbs contain 18-25% carbohydrates, 1.5-2.0% protein, and a distinctive aroma attributed to volatile esters and terpenes ^[4]. But the fruit is highly perishable, with a post-harvest life of only 3-5 days at ambient temperature. Converting surplus jackfruit into shelf-stable chips would reduce waste and create value for smallholder growers ^[5].

Atmospheric frying of jackfruit typically produces chips with 28-40% oil on a dry-weight basis ^[6], which is comparable to potato chips but inconsistent with growing consumer demand for reduced-fat snacks. Vacuum frying addresses this by reducing oil uptake through two mechanisms: lower surface temperature limits the damage to cell walls that allows oil penetration during cooling, and the rapid pressure release at the end of frying expels oil from the chip surface ^[7]. This research compared vacuum and atmospheric frying of jackfruit slices at seven temperatures (80-110°C) and characterised the resulting chips for oil content, texture, colour, and sensory quality ^[8].

Material and Methods

Instrumentation and Analytical Equipment

A laboratory vacuum fryer (Aureus Engineering, Coimbatore; 5 L oil capacity, vacuum pump capable of 3 kPa absolute) was used. Temperature was controlled by a PID controller ($\pm 1^\circ\text{C}$). Texture was measured with a TA.XT Plus analyser (Stable Micro Systems, UK)

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using a 3-point bend rig at 1 mm/s crosshead speed. Colour was recorded on a HunterLab MiniScan XE Plus (D65 illuminant, 10° observer). Oil content was determined gravimetrically after Soxhlet extraction (petroleum ether, 6 h). Moisture was measured by oven drying at 105°C for 5 h.

Material

Ripe jackfruit (cv. Varikka, TSS 22-24 °Brix) was purchased from a local orchard in Mathura. Bulbs were manually separated, deseeded, and sliced to a uniform 3 mm thickness using a mandoline slicer. Slices were blanched in 0.5% citric acid solution at 70°C for 3 minutes to inactivate polyphenol oxidase, drained, and blotted dry. Refined palmolein (Iodine value 56, FFA < 0.1%) was used as the frying medium. Seven frying temperatures were tested: 80, 85, 90, 95, 100, 105, and 110°C, each under vacuum (10 kPa) and atmospheric pressure (101.3 kPa). Frying time was standardised at 25 minutes for vacuum and 5 minutes for atmospheric frying (both determined by preliminary trials to reach moisture <5%). Three batches of 50 g slices were fried per condition.

Results

Table 1: Oil content and physical properties of jackfruit chips fried under vacuum (10 kPa) and atmospheric conditions at selected temperatures

Temp (°C)	Oil - Vacuum (% db)	Oil - Atm (% db)	Reduction (%)	Moisture - Vac (%)
80	8.3	24.1	65.6	4.8
85	9.7	26.3	63.1	4.1
90	11.4	28.7	60.3	3.2
95	13.1	31.4	58.3	2.7
100	15.8	33.8	53.3	2.1
105	18.2	36.1	49.6	1.6
110	21.7	38.9	44.2	1.3

db = dry basis. Atm = atmospheric. Oil reduction = $(\text{Atm} - \text{Vacuum}) / \text{Atm} \times 100$. All values are means of three batches

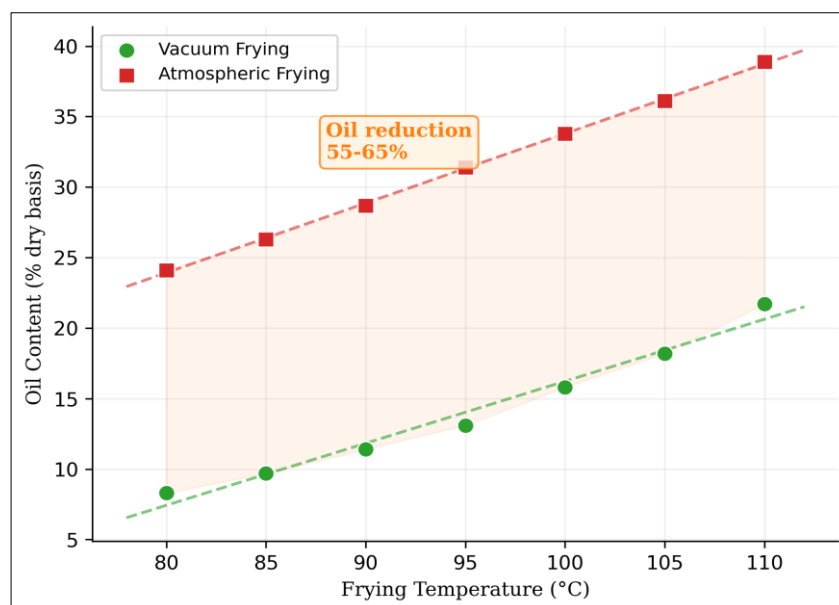


Fig 1: Scatter plot comparing oil content (% dry basis) of vacuum-fried and atmospheric-fried jackfruit chips across frying temperatures, with shaded area indicating the magnitude of oil reduction

Oil content increased with temperature for both methods, but vacuum frying consistently produced chips with 44-66% less oil. At 90°C, vacuum chips contained 11.4% oil

Methods

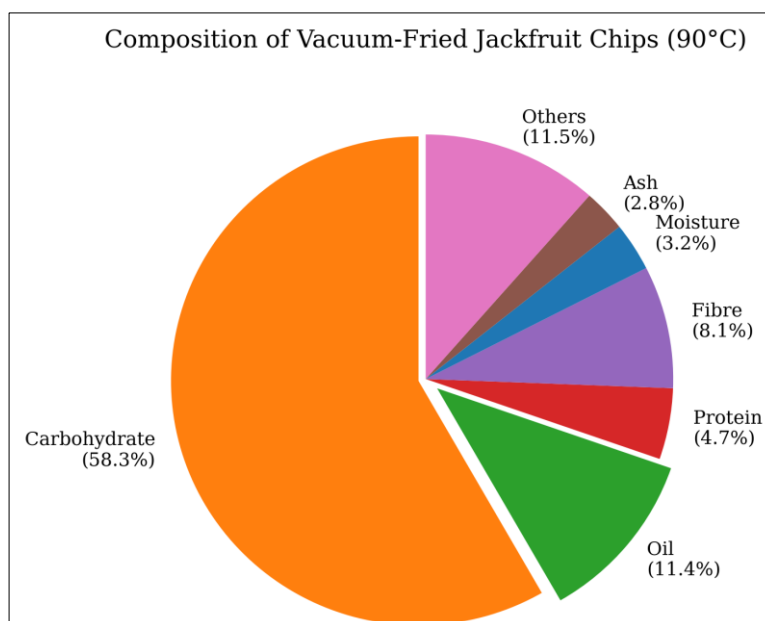
After frying, chips were centrifuged at 750 rpm for 40 seconds in the fryer's deoiling basket, cooled to room temperature, and packed in metallised polyester pouches with nitrogen flushing. Oil content was determined by extracting ground chips (2 g) with petroleum ether in a Soxhlet apparatus for 6 hours, drying the extract, and weighing. Results were expressed on a dry-weight basis. Texture (breaking force, N) was measured as the peak force needed to snap a chip placed across a 3-point bend rig. Colour (L^* , a^* , b^*) was recorded on both sides of five chips per batch. Water activity was measured with an AquaLab 4TE. Sensory evaluation used a 30-member semi-trained panel scoring appearance, colour, crispness, oiliness, flavour, and overall acceptability on a 9-point hedonic scale. Shelf life was monitored over 30 days at 25°C by tracking Peroxide Value (PV) of extracted fat. Data were analysed by two-way ANOVA (method $\times$ temperature) and Tukey's HSD at $p \leq 0.05$.

compared to 28.7% under atmospheric conditions a 60.3% reduction. Moisture in vacuum chips at 90°C was 3.2%, within the acceptable range (<5%) for crispy snacks.

Table 2: Colour and sensory scores of jackfruit chips at selected temperatures

Parameter	Vac 80°C	Vac 90°C	Vac 100°C	Atm 90°C
L* (lightness)	67.4	62.1	53.8	47.3
a* (red-green)	-2.1	-0.8	3.4	6.7
b* (yellow-blue)	31.4	28.7	24.1	19.8
Breaking force (N)	14.1	18.3	22.7	19.7
Colour score (9 pt)	8.4	8.1	6.7	5.3
Crispness score	6.8	8.0	7.9	7.6
Overall acceptability	7.6	8.1	7.2	6.4

Sensory scores from a 30-member semi-trained panel. Vac = vacuum (10 kPa); Atm = atmospheric

**Fig 2:** Composition breakdown of vacuum-fried jackfruit chips processed at 90°C and 10 kPa

Comprehensive interpretation

Vacuum-fried chips at 90°C scored highest for overall acceptability (8.1/9), combining good colour retention ($L^* = 62.1$, golden-yellow appearance), adequate crispness (score 8.0), and low perceived oiliness. Atmospheric-fried chips at 90°C scored only 6.4 overall, dragged down by dark colour ($L^* = 47.3$) and greasy mouthfeel. The 80°C vacuum treatment preserved colour best but was scored lower for crispness (6.8), as the chips were slightly chewy due to higher residual moisture (4.8%). Peroxide values after 30 days of storage at 25°C remained below 5 meq O₂/kg fat in all vacuum samples, indicating acceptable oxidative stability.

Discussion

The 60.3% oil reduction at 90°C vacuum versus atmospheric frying is consistent with data reported for vacuum-fried banana chips (50-60% reduction) by Dueik and Bouchon [7] and for vacuum-fried apple slices (55-65%) by Mariscal and Bouchon [9]. Two mechanisms account for the lower oil uptake: first, the intact cellular structure under low-temperature frying limits the capillary pathways through which oil penetrates during the cooling phase; second, the sudden pressure release when vacuum is broken at the end of frying pushes residual surface oil away from the chip [2].

Colour preservation under vacuum is a direct consequence of the lower frying temperature. Maillard reactions and caramelisation are highly temperature-dependent; at 90°C their rates are a fraction of those at 160-180°C used in

conventional frying [10]. The golden-yellow hue ($L^* = 62.1$, $b^* = 28.7$) is desirable for jackfruit products, where consumers associate deeper colour with over-processing. From a market standpoint, a jackfruit chip with 11.4% oil could carry a 'reduced fat' label under most regulatory frameworks, which typically require at least 25% less fat than a standard reference product [11]. Given that atmospheric-fried jackfruit chips (28.7% oil) would be the reference, the 60.3% reduction easily qualifies.

Cost analysis and economic feasibility

The main cost difference between vacuum and atmospheric frying lies in equipment. A 50 L commercial vacuum fryer costs approximately Rs 12-15 lakh compared to Rs 2-3 lakh for a conventional fryer of equivalent capacity. However, oil savings (60% less oil consumed per kg of product) and the ability to command a premium price for 'reduced-fat' chips can offset the capital difference within 18-24 months at production volumes of 100 kg chips/day. Energy consumption for the vacuum pump adds roughly Rs 1.2/kg product. A preliminary cost estimate places the production cost of vacuum-fried jackfruit chips at Rs 380/kg versus Rs 310/kg for atmospheric, with a potential retail price of Rs 600-800/kg for the vacuum product in premium snack markets.

Conclusion

Vacuum frying at 90°C and 10 kPa produced jackfruit chips with 60.3% less oil than atmospheric frying, superior colour retention, and the highest sensory acceptability score among

all tested conditions. Oil content of 11.4% (dry basis) qualifies the product for 'reduced fat' labelling. Crispness was comparable to conventional chips, and oxidative stability was adequate for at least 30 days at 25°C. The 90°C vacuum condition offers the best balance of quality attributes and is recommended for commercial-scale production of low-oil jackfruit chips. Further work should explore pre-treatments (osmotic dehydration, blanching protocols) to further reduce oil uptake and extend shelf life beyond 30 days.

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