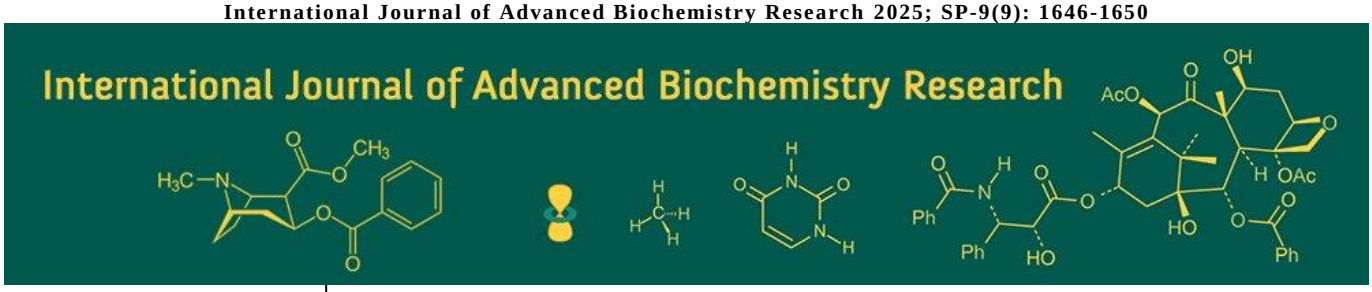

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Dr. Shruti Nayak
Assistant Professor, College of Agricultural Sciences, Iruvakki, Shivamogga, Karnataka, India

Dr. Maruthesh AM
Professor and Head, AHRS, Ullal, Mangalore, Karnataka, India

Dr. Sateesha N
Assistant Professor, College of Forestry, Ponnampet, Karnataka, India

Pratibha H Devaramane
Ph.D., Scholar Human Development &Family Studies, UAS Dharwad, Karnataka, India

Corresponding Author:
Dr. Shruti Nayak
Assistant Professor, College of Agricultural Sciences, Iruvakki, Shivamogga, Karnataka, India

Development and evaluation of biscuits enriched with jackfruit seed flour

Shruti Nayak, Maruthesh AM, Satheesha N and Pratibha H Devaramane

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Abstract
The present study was conducted to evaluate the effect of incorporating jackfruit seed flour (JSF) on the proximate composition, sugar content, and sensory attributes of biscuits. Biscuits were prepared with five different levels of JSF substitution (10%, 15%, 20%, 25%, and 30%) and compared to a control made entirely from 100% refined wheat flour. The proximate analysis revealed that increasing JSF levels led to an enhancement in moisture, fat, ash, crude fibre, and caloric content, while protein and carbohydrate content decreased slightly, indicating an overall improvement in the nutritional profile of the biscuits. Total sugars, reducing sugars, and soluble solids (°Brix) showed a gradual decline with higher JSF incorporation, reflecting a slight reduction in perceived sweetness. Sensory evaluation indicated that biscuits containing up to 25% JSF maintained acceptable colour, taste, flavour, texture, and overall acceptability. However, biscuits with 30% JSF recorded lower scores, attributed to bitterness, darker colour, and grittiness, suggesting limitations in consumer acceptability at higher substitution levels. These results demonstrate that JSF can serve as a functional ingredient to produce nutritionally enriched biscuits with increased fibre, minerals, fat, and energy. The study concludes that incorporation of JSF up to 25% is optimal for enhancing nutritional value without compromising sensory quality, providing a healthier and value-added alternative to conventional wheat flour biscuits. This research highlights the potential of utilizing underexploited jackfruit seeds in bakery products, contributing to waste reduction and the development of functional foods.

Keywords: Jackfruit seed, seed flour, biscuits, nutrition, sensory evaluation

Introduction
Jackfruit (*Artocarpus heterophyllus Lam.*) is a tropical fruit valued for its sweet, fleshy bulbs and nutrient-rich seeds, which are often underutilized despite containing significant amounts of protein, carbohydrates, dietary fibre, and essential minerals. The seeds are frequently discarded, leading to nutritional and economic losses, yet they hold potential as a functional ingredient in value-added food products. Biscuits, as widely consumed ready-to-eat baked goods, are typically prepared from refined wheat flour, sugar, and fat, and are low in fibre, minerals, and bioactive compounds. Incorporating jackfruit seed flour (JSF) into biscuits offers an opportunity to enhance their nutritional profile by increasing protein, dietary fibre, ash, and energy content. Previous studies indicate that while higher JSF levels improve proximate composition, they may negatively affect sensory characteristics such as taste, texture, and colour, making optimization of substitution levels important. This study evaluated the effects of different JSF incorporation levels (10-30%) on the proximate composition, total and reducing sugars, soluble solids, and sensory attributes of biscuits. Results demonstrated that moisture, fat, ash, crude fibre, and caloric content increased with higher JSF levels, while protein and carbohydrate content decreased slightly. Total and reducing sugars, as well as soluble solids, showed a gradual decline with increasing JSF. Sensory evaluation revealed that biscuits containing up to 25% JSF maintained acceptable colour, taste, flavour, texture, and overall acceptability, whereas 30% JSF negatively impacted these attributes. Overall, JSF can be effectively used as a functional ingredient to produce nutritionally enriched biscuits with improved fibre, minerals, and energy while retaining consumer acceptability at moderate substitution levels.

Jackfruit seed flour thus represents a sustainable and cost-effective alternative to conventional wheat flour in bakery applications. Its incorporation not only reduces post-harvest seed waste but also promotes value addition to jackfruit, a fruit abundantly available in tropical regions. The development of biscuits enriched with JSF aligns with current consumer demand for healthier and functional foods, particularly products with higher fibre, mineral, and energy content. Furthermore, optimizing the level of JSF substitution is crucial to balance nutritional improvements with sensory quality, ensuring that the final product is both nutritious and organoleptically acceptable.

Materials and Methods

Mature jackfruits were procured from the local market, and the seeds were separated, cleaned, boiled, peeled, sliced, and dried under controlled conditions. The dried seeds were then ground into fine jackfruit seed flour (JSF) and stored in airtight containers. Biscuits were prepared with five levels of JSF substitution (10%, 15%, 20%, 25%, and 30%) along with a 100% wheat flour control; the 100% JSF biscuit was not used due to its bitter taste. Ingredients were mixed, shaped, and baked under standardized conditions. The biscuits were evaluated for sensory attributes including colour, taste, flavour, texture, and overall acceptability using a 9-point hedonic scale by a trained panel. Proximate composition and sugar content, including moisture, protein, fat, ash, crude fibre, carbohydrate, total sugar, reducing sugar, and soluble solids, were analyzed using standard AOAC methods. Data collected after pre-testing were analyzed statistically using percentage, mean, standard deviation, t-test, chi-square test, correlation, and regression to determine the effects of JSF on the nutritional and sensory properties of the biscuits.

Results and Discussion

Physical composition of jackfruit Table 1 shows, the weight of the jackfruit ranged from 4.22 kg to 14.10 kg, with an average weight of 6.92 kg, which is significantly lower than the 11.4 kg reported by Xess (2021). The mean weight of the fleshy bulbs per fruit was 2.6 kg, also lower than the 4.71 kg reported by Xess (2021), likely due to smaller bulb size, higher flake content, and greater non-edible portions in some fruits. The average seed weight was 1.03 kg, which is close to the 1.32 kg reported by Xess (2021), although seed weight varied considerably among fruits, possibly due to smaller seed sizes. Non-edible portions, including rind and rachis, contributed approximately 47.5% of the total fruit weight, comparable to 48.86% reported by Xess (2021) (Suzihaque *et al*., 2022). The pulp-to-seed ratio was calculated as 2.61, lower than the 3.51 recorded by Xess (2021). The average total number of seeds per fruit was 161.6, with 17.92 seeds per 100 g of fruit.

Table 1: Physical composition of jackfruit

S. No	Parameters	Mean Values
1	Weight of the fruit (Kg)	6.92 ± 3332.5
2	Weight of the bulbs (Kg)	2.60 ± 1325.9
3	Weight of the seeds (Kg)	1.03 ± 618.4
4	Weight of the non-edible part (Kg)	3.29 ± 1441.5
5	Pulp: Seed ratio	2.61 ± 0.45
6	Total number of seeds in a fruit	161.6 ± 82.2
7	Total number of seeds per 100g	17.92 ± 4.24

Table 2: Proximate composition of jackfruit seeds

S. No	Parameter (g%)	JSF	RWF
1	Moisture	6.14 ± 3.07	13.30±0.10
2	Protein	11.43±0.12	11.00±1.00
3	Fat	1.82±0.08	0.90±0.10
4	Ash	1.33±0.06	0.60±0.10
5	Crude fibre	2.51±0.10	0.30±0.10
6	Carbohydrate	76.77±1.50	73.90±0.20
7	Energy (k cal)	369±1.73	348±0.60

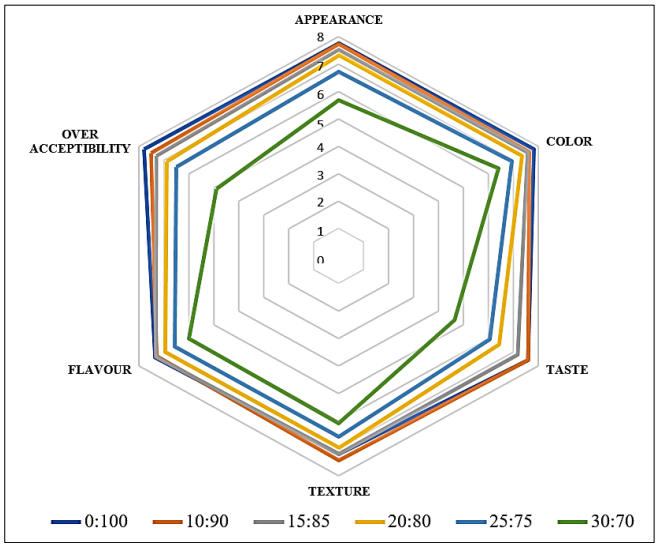

Fig 1: Sensory evaluation of the jackfruit seed flour biscuits

Proximate composition of jackfruit seeds

Table 2 shows, the proximate composition of jackfruit seed flour (JSF) indicates that the moisture content was 6.2%, which is close to the 6.3-6.5% reported by Maibam (2016) [9], Palamthodi *et al*. (2021) [16], Arefin *et al*. (2022), and Royees and Pandey (2022) [17], but lower than the 7.8% reported by Nabubuya *et al*. (2022) [14] and much lower than the 9.5-24.08% reported for other jackfruit clones and species by Azeez *et al*. (2015), Maskey *et al*. (2020) [11], and Ngwere and Mongi (2021) [13]; it was slightly higher than the 6.09% reported by Ocloo *et al*. (2010) [15]. Lower moisture content indicates improved shelf stability and flour quality Protein content of JSF was 11.4%, higher than the 10.1% reported by Nabubuya *et al*. (2022) [14] and comparable to values of 12.25-16.80% reported by Meethal *et al*. (2017) [12], Maurya (2017) [10], Yazid *et al*. (2019) [22], Sateeshan *et al*. (2019) [18], Maskey *et al*. (2020) [11], Ngwere and Mongi (2021) [13], Arefin *et al*. (2022), and Royees and Pande (2022) [17], but higher than some recognized species like Artocarpus altilis (8.12%), Artocarpus odoratissimus (8.78%), and Mastura cultivar (9.78%) (Tukura and Obliva, 2015; Masri *et al*., 2017; Zuwariah *et al*., 2018) [21, 24]. Fat content was low at 1.8%, similar to 1.77% reported by Islam *et al*. (2015) [8], higher than 0.13-y)

Proximate composition of jack fruit seed flour incorporated biscuits

Table 3 shows the proximate composition of biscuits prepared with different levels of jackfruit seed flour (JSF). The data indicate that increasing JSF substitution influenced both the nutritional and sensory attributes of the biscuits. Moisture content increased from 5.09% in the control to 6.20% in 30% JSF biscuits, while protein content ranged from 6.94% (10% JSF) to 6.70% (30% JSF), higher than the control (6.00%). Fat content increased from 19.01% to

22.74% with higher JSF levels, and ash content ranged from 0.77% to 0.85%. Crude fibre also increased from 0.26% to 0.49%, whereas carbohydrate content decreased from 66.53% (10% JSF) to 63.02% (30% JSF). The caloric value of biscuits rose from 474 to 484 Kcal/100g as JSF proportion increased. Overall, higher JSF levels enhanced moisture, fat, fibre, ash, and energy but reduced protein, carbohydrate, and sensory acceptability, with 30% JSF biscuits receiving the lowest sensory scores. This shows that biscuits containing up to 25% JSF can maintain acceptable proximate composition and sensory qualities. Overall, the results indicate that the substitution of wheat flour with JSF enhances certain nutritional qualities, such as fibre, ash, fat, and energy, while reducing carbohydrate content slightly. offering a balance between enhanced nutritional value and acceptable organoleptic properties.

Sensory evaluation of the jackfruit seed biscuits

The sensory evaluation of biscuits, as presented in Figure 1, revealed that the incorporation of jackfruit seed flour (JSF) influenced all measured attributes, including colour, taste, flavour, texture, and overall acceptability. The control biscuits made with 100% refined wheat flour received the highest colour and appearance score of 7.8 for their very good visual appeal. Biscuits containing 10% and 15% JSF scored slightly lower at 7.7 and 7.6, respectively, indicating that low-level substitution did not significantly affect appearance, while 25% and 30% JSF biscuits showed a modest decline but were still rated as good. Taste evaluation showed that 10-15% JSF biscuits were comparable to the control (7.6), reflecting moderate acceptance; however, higher levels of JSF (20-30%) led to lower taste scores of 6-4 due to increased bitterness. Texture was similarly affected, with control and 10% JSF biscuits scoring highest (7.4) for their smooth and elastic feel, while biscuits with 25-30% JSF were rated 6.6-6.1, likely due to reduced gluten content and increased grittiness. Flavour scores also decreased with increasing JSF, with the control at 7.4 and 30% JSF biscuits at 6.0, showing a decline in aromatic and palatable qualities. Overall acceptability followed the same trend, being highest for the control and 10% JSF (7.8 and 7.5) and lowest for 30% JSF (4.9), indicating that low-level JSF incorporation (up to 15%) can produce biscuits with acceptable sensory

Chemical composition of the jack seed flour biscuits

Table 4 shows the effect of different jackfruit seed flour (JSF) blends on the total sugar content of biscuits. Total sugars decreased slightly with increasing JSF, ranging from 13.73% in 10% JSF biscuits to 13.56% in 30% JSF biscuits, compared to 13.90% in the control. Reducing sugar content was highest in the 30% JSF biscuit (1.66%) and lower in the control, while the lowest reducing sugar (0.60%) was observed in the 70% rice flour + 30% JSF treatment. For another set of formulations, the control biscuit had 5.67% reducing sugar, the 10:90 JSF sample had 5.57%, and the 30:70 JSF biscuit had the lowest at 4.00%. Soluble solids, measured as °Brix, decreased gradually with increasing JSF proportion, from 9.60°Brix in the control to 8.50°Brix in the 30:70 JSF biscuit, indicating that higher JSF incorporation slightly reduces sugar content and soluble solids in biscuits. These results suggest that JSF substitution lowers total and reducing sugars while maintaining acceptable sweetness and texture in the final product reducing sugar, the 10:90 JSF sample had 5.57%, and the 30:70 JSF biscuit had the lowest at 4.00%. Soluble solids, measured as °Brix, decreased gradually with increasing JSF proportion, from 9.60°Brix in the control to 8.50°Brix in the 30:70 JSF biscuit, indicating that higher JSF incorporation slightly reduces sugar content and soluble solids in biscuits.

Lower total and reducing sugars while maintaining acceptable sweetness and texture in the final products.

Table 3: Proximate composition of jack fruit seed flour incorporated biscuits

S. No	JSF: RWF Blend	Proximate composition (g%)						
		Moisture	Protein	Fat	Ash	Crude Fibre	CHO	Energy (Kcal)
1	0:100	5.09	6.00	19.01	0.74	0.15	69.01	471
2	10:90	5.45	6.94	20.05	0.77	0.26	66.53	474
3	15:85	5.62	6.92	21.27	0.80	0.32	65.07	479
4	20:80	5.82	6.88	21.99	0.81	0.38	64.12	482
5	25:75	6.01	6.76	22.01	0.83	0.43	63.96	481
6	30:70	6.20	6.70	22.74	0.85	0.49	63.02	484
	Mean	5.70	6.70	21.18	0.80	0.34	65.29	478
	SED	0.08	0.16	0.11	0.02	0.01	0.27	0.92
	C.D	0.16	0.35	0.25	0.04	0.02	0.59	2.00
	C.V	0.15	0.59	0.09	0.06	0.04	0.17	0.27
	S.D	0.38	0.37	1.32	0.04	0.12	2.07	4.66
	Lowest Range	5.09	6.00	19.01	0.74	0.15	63.02	471

Table 4: Chemical composition of jackfruit seed flour biscuits

S. No	JSF: RWF blend	Chemical parameters		
		Total sugars (%)	Reducing sugars (%)	TSS (0 Brix)
1	0:100	13.90±0.04	5.67±0.01	9.6±0.20
2	10:90	13.73±0.07	5.57±0.02	9.4±0.12
3	15:85	13.68±0.02	5.46±0.01	9.3±0.10
4	20:80	13.63±0.01	5.33±0.01	8.9±0.05
5	25:75	13.58±0.02	5.26±0.01	8.7±0.10
6	30:70	13.56±0.02	4.00±0.07	8.5±0.10
	Mean	13.68	5.21	9.07
	SED	0.03	0.03	0.12
	C.D	0.06	0.06	0.26
	C.V	0.01	0.02	0.23
	Lowest Range	13.56	4.00	8.50
	Highest Range	13.90	5.67	9.60

Summary and Conclusion

The study evaluated the effect of incorporating jackfruit seed flour (JSF) into biscuits on their proximate composition, sugar content, and sensory attributes. Results showed that increasing JSF levels enhanced moisture, fat, ash, crude fibre, and caloric content, while protein and carbohydrate content decreased slightly, indicating an overall improvement in nutritional quality. Total sugars and reducing sugars decreased modestly with higher JSF incorporation, and soluble solids (°Brix) declined from 9.60° in the control to 8.50° in 30% JSF biscuits, reflecting a slight reduction in sweetness. Sensory evaluation revealed that biscuits with up to 25% JSF maintained whereas 30% JSF led to lower scores due to bitterness, darker colour, and grittiness. Overall, the findings suggest that JSF can be effectively used as a functional ingredient to produce nutritionally enriched biscuits with increased fibre, minerals, fat, and energy, while maintaining good sensory quality at moderate substitution levels. It is concluded that incorporation of JSF up to 25% is optimal for enhancing the nutritional value of biscuits without compromising sensory acceptability, providing a healthier and functional alternative to conventional wheat flour biscuits.

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