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A Comparative Analysis of the Influence of Various Processing Techniques on Quality Attributes of Jackfruit Seed Flour (JSF) from Different Cultivars

Sreejaya U [a*], Krishnaja U [b], Suma Divakar [a], and Pratheesh P Gopinath [c]

[a] Department of Community Science (Food and Nutrition) College of Agriculture, Vellayani, Kerala Agricultural University, Thrissur, Kerala, India.
[b] Department of Community Science (Food and Nutrition) College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala, India.
[c] Department of Agricultural Statistics College of Agriculture, Vellayani, Kerala Agricultural University, Thrissur, Kerala, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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**Corresponding author: Email: sreejuak1@gmail.com;*

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ABSTRACT

Despite the fact that jackfruit seeds have been shown to have a number of beneficial nutrients and bioactive components that provide significant value to meals, they are widely neglected. The study was aimed at investigating the effect of processing on the functional properties, proximate composition and storage stability of jackfruit seed flour from different cultivars. The jackfruit seeds of cultivars *Koozha* and *Varikka* were selected for the study. The water absorption capacity (WAC), oil absorption capacity (OAC), solubility index (SI), swelling power (SP) and bulk density (BD) of the JSF ranged between 194.6-200.1ml/100g, 84.19-85.06ml/100g, 1.12-1.20%, 3.12-3.51g/g and 0.67-0.71g/cm^3, respectively. The moisture, ash, crude fat, protein, crude fiber and carbohydrate contents varied from 4.86-5.11%, 2.40-2.60%, 1.68-1.76%, 12.22-12.79g/100g, 2.82-2.98% and 72.01- 72.45g/100g, respectively. Microbial analysis of jackfruit seed flour was performed to determine its shelf life and showed favorable results. Jackfruit seed flour produced from different processing techniques is found to have good storage stability. The jackfruit seed flour thus processed can be employed as a key ingredient to create a wide range of nutrient-dense food products.

Keywords: Jackfruit seed; Koozha; Varikka; flour; tray drying; roasting; functional properties.

1. INTRODUCTION

“Research in recent years has emphasized the need to identify lesser-known and underutilised crops, many of which are useful in human nutrition. The jackfruit, *Artocarpus heterophyllus* is native to India and is a member of the mulberry family. It is widely distributed in the Western Ghats, which has a variety of wildlife” [1]. “Despite comprising 10% to 15% of the fruit's weight and providing significant nutritional value, jackfruit seeds are frequently disregarded and undervalued” [2]. “Due to a lack of knowledge about effective ways of usage, a lack of post-harvest technology, and weaknesses in the supply chain networks, jackfruit is said to be an underutilised fruit. The seeds of the jackfruit are an excellent source of protein, fiber, and carbohydrates. Additionally, jackfruit is rich in various minerals such as N, P, K, Ca, Mg, S, Zn, and Cu” [3]. “Lack of awareness on nutrient contents and decent technologies for utilization of jackfruit seeds in food formulations are greatly responsible for such wastes of this fruit seeds” [4]. The storage life of the seeds can be refined by storing at cool, moist conditions and wielding processing techniques such as roasting. The dried seeds can be ground into flour and incorporated to various food products to increase their value and enhance the shelf life. The objective of this study therefore is to determine the effects of various processing methods on the functional properties, proximate composition and storage stability of jackfruit seed flour.

2 MATERIALS AND METHODS

2.1 Raw Materials

The jackfruit cultivars *Koozha* (k) and *Varikka* (v), which are extensively available in Kerala, were selected for the study. Ripened jackfruits were purchased from Instructional farm, college of Agriculture, Vellayani, Trivandrum.

2.1.1 Processing of Jackfruit seed flour

The seeds of both cultivars were manually cleansed, the white arils (seed coat) were peeled off, and the brown spermoderm was removed using a stainless-steel knife. The seeds were rinsed and washed with running water. Then it was gelatinized at 65°C for 10 minutes. After gelatinization the seeds were sliced and dehydrated using the following techniques such as tray drying (D_1) and roasting (D_2).

Seeds from both cultivars were dried using the above-mentioned techniques. The drying time and temperature were standardized as 12 hours at 110 °C for tray drying and 1 hour at 100 °C for roasting. After dehydration seeds from both cultivars were ground to powder and sieved through a fine wire mesh (150 micron), then the samples were packed in polyethylene pouches and used for further analysis.

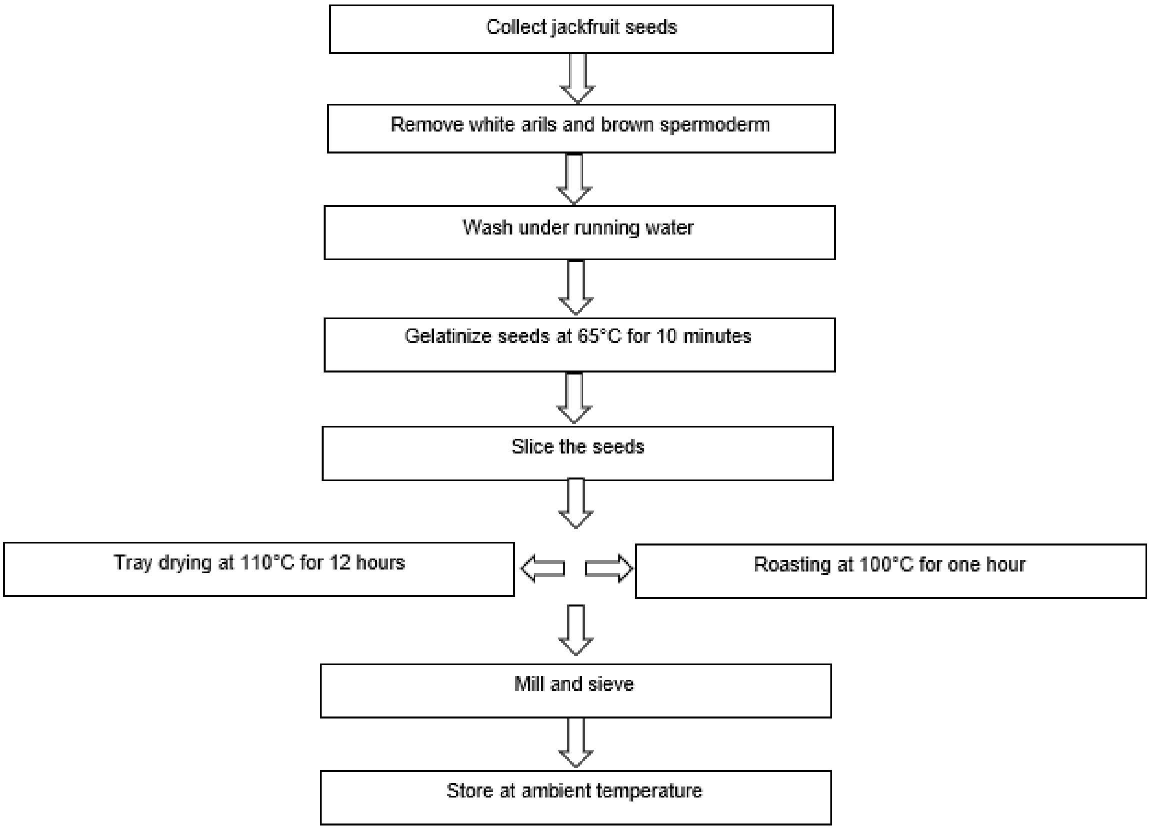

Fig. 1. Preparation of Jackfruit seed flour (Flow chart)

2.2 Analytical Methods

2.2.1 Determination of functional properties of Jackfruit seed flour

"Functional properties are very critical to the quality of food. The elements of food, particularly the carbohydrates, proteins, fats and oils, moisture, fiber, and ash, as well as the structures of these elements, have an impact on the functional qualities of foods and flours" [5]. Water absorption capacity and oil absorption capacity of the jackfruit seed flour was determined by the method of Niba et al.,[6] and Beuchat [7]. Solubility index and swelling power were determined according to the method of Oladele and Aina [8]**.** Bulk density was determined by the method suggested by Okaka and Potter [9].

2.3 Determination of Proximate composition of Jackfruit Seed Flour

"Moisture, ash and crude protein and crude fat of the samples were determined by the AOAC [10] method. Crude fiber content was estimated by the method of AOAC" [11]. The carbohydrate content was calculated by difference, (100- sum of the values for moisture, crude protein, crude fiber, crude fat and crude ash). The difference approach provides a standardized way to estimate carbohydrate content across various food samples, making it easier to compare results; it is more efficient and cost-effective.

2.4 Determination of Storage Stability of Jackfruit Seed Flour

"Microbial population analysis in developed food products is significant since it determines food quality and safety. Food safety is guaranteed by eliminating pathogenic microorganisms and inhibiting their proliferation using all conceivable measures. The moisture intake, Total viable count (TVC), Total fungal count (TFC), and Total coliform count (TCC) CFU/g of the jackfruit seed flour samples were measured at 0 days (initial) and after three months (90 days) of storage to assess its storage properties. The bacterial, fungal, and coliform growth was examined using Nutrient agar, Rose Bengal agar, and Eosin methylene blue (EMB), respectively. The evaluation was done by serial dilution of samples followed by pour plating technique suggested" [12]. The technique was used to detect the presence of microbes.

2.5 Statistical Analysis

All data obtained from various analyses were pooled and subjected to Completely Randomized Design (One-way ANOVA) using KAU-GRAPES software.

3. RESULTS AND DISCUSSION

3.1 Functional properties of Jackfruit seed flour

The functional properties of the jackfruit seed flour samples are presented in Table 1.

The water absorption capacity of a food material reflects the ability of the material to associate with water under conditions of limited water, and hence its ability to bind the water [13]. In the present investigation water absorption capacity of the jackfruit seed flour ranged between 194.6-200.1 ml/100g. Water absorption capacity was significantly higher for the cultivar *Varikka* (VD_1 - 200.1 ml/100 g and VD2-198.6 ml/100 g); it could be attributed to the presence of a higher amount of carbohydrates (starch) and fiber in this cultivar. A high WAC value can be linked to several hydrophilic components included in foods, such as carbohydrate (particularly polysaccharides), proteins, notably polar amino acid residues, which have a high affinity for water molecules [14]. The findings abide by the study done by Reddy et al [15] and Borghi and Bharathi [16], who reported the water absorption capacity of jackfruit seed flour as 184.27 ml/100g and 201.37 ml/100g, respectively.

Oil absorption is an important property in food formulations because fat improve the flavour and mouth feel of food. Oil absorption capability is mostly due to the physical trapping of oils. It represents the rate at which protein binds to fat in food compositions [13]. The oil absorption capacity obtained for the seed flour samples in this study ranged from 84.19- 85.06 ml/100g. Oil absorption capacity was found to be higher for the seed flour samples processed using the roasting method (VD_2- 85.06 ml/100 g and KD_2-84.88 ml/100 g). The results are comparable with the values obtained by Islam et al [17] and Borghi and Bharathi [16], who reported oil absorption capacity of jackfruit seed flour as 86.00 ml/100g and 89.93 ml/100g, respectively.

Solubility in foods is a chemical and functional quality that refers to a food substance's capacity to dissolve in a solvent, most commonly water or oil. A substance's solubility is essentially determined by the chemical and physical properties of the solvent and solute, as well as pressure, pH, temperature, and the presence of additional substances in the solution [18]. The solubility index of the jackfruit seed flour samples ranged from 1.12 – 1.20%. The highest solubility index was observed for the cultivar *Varikka* (VD_1 -1.20% and VD_2 1.17%). The solubility index of the cultivar *Koozha* seed flour was found to be on par across different processing techniques. The obtained values are comparable with the values reported by Akter and Haque [4] 1.80% and Islam et al [17] 2.31%.

The swelling power is the measure of the starch ability to absorb water and swell, and also reflects the extent of associative forces in the starch granules. It is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the α amylose and amylopectin ratios [1]. The swelling power obtained for the seed flour samples in this investigation ranged from 3.12 g/g – 3.51g/g. It was observed that the cultivar *Varikka* exhibited highest swelling power (VD_1 – 3.51 g/g and VD_2 – 3.41 g/g) than the cultivar *Koozha*. This could be linked to the high starch content of the cultivar *Varikka.* According to Awuchi et al., [5] increased starch content enhances the swelling capacity (index) of foods and flours, particularly in starches with a higher amount of the branched amylopectin. The obtained values are similar with the values reported by Akter and Haque [4] 3.62g/g and Ocloo et al [19] 4.77g/g.

Bulk density represents the relative volume or capacity of the needed packaging material. The higher the bulk density of the flour, the denser the amount of packaging material required. It reflects the porosity of a food product, which effects the design of the package and can be used to determine the type of packing material necessary [20]. The bulk density of jackfruit seed flour samples ranged between 0.67- 0.71 g/cm^3, it was discovered that the cultivar *Varikka* had a higher bulk density (VD_1- 0.71 g/cm^3 and VD_2-0.70 g/cm^3) than the cultivar *Koozha*. The variation in bulk density could be attributable to the increased starch content of the cultivar *Varikka*. Iwe et al., [20] reported that the variation in bulk density of foods could be as due to the variation in starch content of the foods. The higher the starch content the more likely the increase in bulk density. The findings abide by the study done by Odoemelam [21] 0.61 g/cm^3 and Reddy et al [15] 0.73 g/cm^3.

Table 1. Functional properties of Jackfruit seed flour

Treatments	WAC (ml/100g)	OAC (ml/100g)	SI (%)	SP (g/g)	BD (g/cm^3)
VD_1	200.1^a	84.51^b	1.20^a	3.51^a	0.71^a
KD_1	196.8^c	84.19^c	1.12^c	3.12^d	0.68^c
VD_2	198.6^b	85.06^a	1.17^b	3.41^b	0.70^b
KD_2	194.6^d	84.88^a	1.12^c	3.13^c	0.67^d
±SE(m)	0.083	0.078	0.004	0.004	0.003
CV %	0073	0.16	0.612	0.215	0.72

Values are means of triplicates. Values with different superscripts (a,b,c,d) within the same column are significantly different ($P \leq 0.05$). VD_1- Varikka Tray dried jackfruit seed flour, KD_1- Koozha Tray dried jackfruit Seed flour, VD_2- Varikka Roasted jackfruit seed flour, KD_2-Koozha Roasted jackfruit Seed flour. WAC= Water absorption capacity, OAC= Oil absorption capacity, SI= Solubility index, SP= Swelling power, BD = Bulk density.

3.2 Proximate Composition of Jackfruit Seed Flour

The proximate composition of jackfruit seed flour samples is depicted in Table 2.

In the present investigation ash content of jackfruit seed flour ranged from 2.40 – 2.60%. It was discovered that the ash content was found to be significantly higher for tray-dried seed flour samples (VD_1-2.60% and KD_1-2.57%). According to Eke-Ejiofor et al. [22], the ash content of dried jackfruit seed flour is 2.46%, whereas that of roasted jackfruit seed flour is 2.45%. Another study conducted by Nabubuya et al [23] reported the ash content of jackfruit seed flour as 2.60%. The obtained values correspond to the reported values.

In the current study the fat content of jackfruit seed flour ranged from 1.68 – 1.76%. The fat content was found to be substantially higher in the cultivar *Varikka* (VD_1- 1.71% and VD_2- 1.76%). Jackfruit seed flour contains a negligible amount of fat, which prevents rancidity issues and prolongs the flour's shelf life. The results are consistent with the findings of [17] and [24], who reported the fat content of jackfruit seed flour as 1.77% and 1.44%, respectively.

Protein is one of the most important nutrients required by the body to carry out a wide range of functions essential for the maintenance of life. The Protein content of jackfruit seed flour ranged from 12.22 g/100g to 12.79 g/100g. The protein content was found to be significantly higher in the cultivar *Varikka* (VD_1- 12.67 g/100g and VD_2- 12.79 g/100g). The results are comparable with the values obtained by [19] 13.50g/100g and [24] 13.9g/100g.

The crude fiber content of the jackfruit seed flour samples ranged between 2.82% - 2.98%. The crude fiber content of seed flour samples was found to be substantially higher in cultivar *Varikka* (VD_1-2.98% and VD_2-2.91%). The findings abide by the study done by Ocloo et al. [19], who reported the crude fiber content of jackfruit seed flour as 3.19%. The crude fiber content of autoclaved jackfruit seed flour was found to be higher, at 6.17%, according to [22].

Carbohydrates are one of the most abundant and widespread organic substance in nature. The carbohydrate content of the jackfruit seed flour samples ranged from 72.01 g/100g to 72.45 g/100g. It was found that based on the processing techniques, tray dried seed flour samples had more carbohydrates than roasted seed flour samples (VD_1-72.45 g/100 g and KD_1-72.11 g/100 g). The findings are comparable with the values reported by Islam et al. [17] and Juárez-Barrientos et al [25], who reported 71.46 g/100 g and 73.44 g/100 g of carbohydrate content in jackfruit seed flour, respectively.

3.3 Storage Stability of Jackfruit Seed Flour

The microbial analysis report of jackfruit seed flour is depicted in the Table 3. Moisture gives an indication of how much water and total solid matter are present in the seed flour samples. It is also a measure of the flour's storability. Reduced moisture content implies better shelf life and stability [22]. Initially, the moisture content of jackfruit seed flour ranged between 4.86 and 5.11%. In terms of processing methods, tray drying had significantly higher moisture content compared to roasting; it can be attributed to the slower drying process and lower temperature in tray drying. The airflow in tray drying is gentle and may not be as intense as in roasting. Insufficient air flow can lead to uneven drying and more moisture retention. After a period of three months, it was noted that the jackfruit seed flour moisture content had risen constantly while remaining within the acceptable range of 5.21 to 5.71 percent. The findings are consistent with the study of Morshed et al. [26], who reported that the moisture content of jackfruit seed flour during the storage period was between 5.43 and 5.70%.

The study examined the distribution and number of microorganisms in jackfruit seed flour over a three-month (90-days) storage period. The results demonstrated that the storage time had a substantial impact on the total viable count (TVC) in the seed flour, with the count increasing from day 30 to day 90. However, the counts were within the permissible limits. Initially, there was no presence of fungal colonies for up to two months (60 days) in the processed seed flour. After two months (60 days), the existence of fungal colonies was detected in the seed flour; nonetheless, the total fungal count remained below acceptable limits. There were no coliform colonies found in the jackfruit seed flour during the storage period. A study conducted by Borgis et al [27] reported that pan roasted and unprocessed jackfruit seed flour contain significantly lower bacterial and fungal colonies. Morshed et al. [26] reported that for the first 96 days of storage, jackfruit seed flour was free of microbes.

Table 2. Proximate composition of Jackfruit seed flour

Treatments	Ash (%)	Fat (%)	Protein (g/100g)	Crude fiber (%)	Carbohydrate (g/100g)
VD_1	2.60^a	1.71^b	12.67^b	2.98^a	72.45^a
KD_1	2.57^b	1.69^c	12.22^d	2.82^d	72.11^b
VD_2	2.45^c	1.76^a	12.79^a	2.91^b	72.01^d
KD_2	2.40^d	1.68^d	12.27^c	2.84^c	72.04^c
±SE(m)	0.003	0.003	0.007	0.006	0.004
CV%	0.23	0.337	0.095	0.346	0.01

Values are means of triplicates. Values with different superscripts (a,b,c,d) within the same column are significantly different (P≤0.05). VD_1- Varikka Tray dried jackfruit seed flour, KD_1- Koozha Tray dried jackfruit Seed flour, VD_2- Varikka Roasted jackfruit seed flour, KD_2-Koozha Roasted jackfruit Seed flour

Table 3. Storage stability of jackfruit seed flour

Treatments	Storage period	Moisture (%)	TVC (CFU/gram of sample)	TFC (CFU/gram of sample)	TCC (CFU/gram of sample)
VD_1	Initial count	5.04^k	2.0×10^2	ND	ND
	30 days	5.19^h	4.0×10^2	ND	ND
	60 days	5.46^c	8.0×10^2	ND	ND
	90 days	5.71^a	12.1×10^2	1.8×10^2	ND
KD_1	Initial count	5.11^i	2.1×10^2	ND	ND
	30 days	5.25^f	4.5×10^2	ND	ND
	60 days	5.44^d	8.3×10^2	ND	ND
	90 days	5.67^b	12.0×10^2	2.0×10^2	ND
VD_2	Initial count	4.86^m	1.5×10^2	ND	ND
	30 days	4.97^i	3.5×10^2	ND	ND
	60 days	5.09^j	7.6×10^2	ND	ND
	90 days	5.21^g	12.5×10^2	2.2×10^2	ND
KD_2	Initial count	4.97^i	1.6×10^2	ND	ND
	30 days	5.12^i	3.6×10^2	ND	ND
	60 days	5.19^h	7.6×10^2	ND	ND
	90 days	5.31^e	12.6×10^2	2.1×10^2	ND
±SE(m)		0.004	0.024	0.048	_
CV (%)		0.143	0.621	15.984	_

Values are means of triplicates. Values with different superscripts (a,b,c,d) within the same column are significantly different (P≤0.05). TVC- Total viable count, TFC- Total fungal count, TCC- Total coliform count, ND – Not Detected. VD_1- Varikka Tray dried jackfruit seed flour, KD_1- Koozha Tray dried jackfruit Seed flour, VD_2- Varikka Roasted jackfruit seed flour, KD_2-Koozha Roasted jackfruit Seed flour

4. CONCLUSION

The purpose of the study was to assess the impact of processing methods on functional qualities, proximate composition and storage stability of jackfruit seed flour from different cultivars. This study used tray drying and roasting as the primary processing techniques for the production of the jackfruit seed flour. The functional properties of two different cultivars of jackfruit seed flour were found to vary significantly. The cultivar *Varikka* had higher WAC, OAC, SI, SP and BD than cultivar *Koozha.* Quality analysis revealed that jackfruit seed flour is excellent source of carbohydrate and protein and they are also good source of fiber. Jackfruit seed flour had negligible amount of fat. Less fat allows for the prevention of rancidity issues and longer shelf life of the flour. From microbial analysis it is evident that the jackfruit seed flour can be stored up to three months (90 days) without any microbial spoilage. This method allows you to preserve jackfruit seeds by converting them into flour and extending their shelf life. The findings revealed that jackfruit seed flour can be employed as a key ingredient to create a wide range of nutrient-dense food products.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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