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Influence of drying temperature on nutritional composition, functional characteristics, and sensory quality of germinated jackfruit seed flour

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Abstract

Jackfruit, an underutilized crop, possesses seeds that are a valuable source of nutrients and phytonutrients that may offer various health benefits. The seeds are abundant in fibers, minerals, and vitamins that could lower the risk of heart disease, aid digestion, and aid weight loss. The seeds also contain numerous phytonutrients that could support human health, including lignans, saponins, and isoflavones. Jackfruit seeds also contain resistant starch, which can help control blood sugar levels and improve gut health. The drying temperature, however, had a significant effect on the physicochemical, sensorial, and functional properties of the jackfruit seed flours. The cabinet drying at 70°C for 6 hours was recorded as the best treatment based on the sensorial attribute for germinated jackfruit seed flour. Standardized germinated jackfruit seed flour exhibited upgraded nutritional and quality parameters against its raw form. This flour as an ingredient not only provides an alternative healthy option to refined wheat flour in many bakery and confectionery products but is also a functional raw material in developing a variety of traditional food products.

Keywords: Pretreatment, germinated jackfruit seed flour, sensory, drying treatment, nutritional value

1. Introduction

Jackfruit, which is believed to have originated from the Western Ghats in southwest India, is a large tropical fruit that belongs to the Moraceae family. It is widely cultivated in countries such as Malaysia, Indonesia, Thailand, the Philippines, and India, as well as in South America, Africa, and other parts of Asia. The ideal climate for jackfruit tree growth is warm and humid. At present, it is mainly grown in Bangladesh, Burma, India, Malaysia, Indonesia, the Philippines, Thailand, Sri Lanka, and to a lesser extent in Brazil and Australia. However, jackfruit seeds are often discarded as waste, while the ripe fruit is either consumed fresh or processed into various products. (Zuwariah *et al.*, 2018) ^[14].

Jackfruit is a nutrient-rich fruit that provides both macronutrients, such as protein, carbohydrates, and starch, as well as micronutrients like potassium, calcium, and thiamine. It is a high-energy food that can be beneficial for athletes, individuals experiencing physical or mental exhaustion, or those with weakened muscles. Jackfruit has been found to possess antimicrobial, anti-diabetic, anti-inflammatory, antioxidant, and anti-helminthic properties. The seeds, due to their high fiber content, can help reduce the risk of heart disease, promote regular bowel movements, aid in weight loss, and are a good source of B-complex vitamins. Additionally, they contain resistant starch, which helps regulate blood sugar levels and maintain gut health (Waghmare *et al.*, 2019) ^[13]. Various processing techniques such as canning, freezing, drying, and product transformation are used to preserve jackfruit. However, due to their perishable nature, jackfruit seeds are usually considered waste (Pinchu *et al.*, 2020) ^[9]. The germination process as pretreatment leads to the up gradation of the nutritional value of jackfruit and other seeds. Additionally, it is an efficient technique that improves nutrient absorption in conjunction with physiologically active chemicals with antioxidant potential. Enzymatic activity encourages the breakdown of starch into simple sugars and other alterations in the nutritional components during germination. Drying is one of the processes to extend the shelf life of jackfruit seeds by limiting microbial spoilage and oxidation processes by reducing their moisture content. The time and temperature at which seeds are dried can significantly affect their nutritional composition and overall properties.

The relationships between process variables and food qualities in food processing are vital to consider. There are various techniques available for drying jackfruit, including freeze-drying, immediate controlled pressure drop-assisted freeze-drying, hot air drying, drum drying, Osmo-convective drying, freeze-drying, and convection oven drying, which can also be combined to produce jackfruit chips. Recently, the efficiency of drying jackfruit has been improved with reflection window technology (Swami *et al.*, 2016) [12].

Jackfruit seeds are often overlooked and underrated despite their significant nutritional benefits and potential as a functional food ingredient. These seeds are rich in antioxidants, macronutrients, and micronutrients. By processing the seeds through germination and drying, they can be transformed into a powdered form that extends their shelf life and allows them to be used in a variety of products, including bakery items, confectionery, macaroni, and traditional foods. The resulting flour provides added nutritional benefits without significantly affecting taste or texture. This study aims to develop a processing technology for germinated jackfruit seed flour, evaluate quality parameters such as nutrition, sensory aspects, and texture, and assess its shelf life. Germinated jackfruit seed flour has great potential as a functional ingredient and a low-cost alternative to other protein sources, particularly in developing countries where protein malnutrition is a major health concern.

2. Material and methodology

2.1 Material

Jackfruit seeds were procured from Cape Comorin Traders located in Padanthalumoodu, Tamil Nadu. The laboratory at the MIT School of Food Technology Pune was equipped with analytical grade glassware and chemicals for use in the Food Process and Product Technology (FPPT) / Food Safety, Quality and Nutrition (FSQN) research project.

2.2 Germinated jackfruit seed flour processing technology

The process of producing flour from jackfruit seeds involved several steps, including seed selection, cleaning, germination, and drying. The seeds were carefully examined for damage before being soaked in lukewarm water for 12 hours at room temperature. After that, the seeds were allowed to germinate for seven days, with a regular sprinkling of water and cloth covering. Once the sprouted seeds were ready, they were dried at different temperatures (50, 60, 70, and 80°C) for six hours. After that, small chips were produced from the dried sprouted seeds, and the chips were further dried. The next step involved grinding the dried chips into flour, which was pre-processed using 60-mesh size sieves. This methodical approach ensured the production of high-quality jackfruit seed flour.

2.3 Proximate analysis

Proximate parameters such as moisture, fat, protein, ash, carbohydrate and micronutrients were determined (AOAC, 2019) [1].

3. Result and Discussion

3.1 Physical parameters of jackfruit seeds

The physical parameters of raw and germinated jackfruit seeds are presented in Table 1.

Table 1: Physical parameters of jackfruit seeds

Parameter	Raw jackfruit seed	Germinated jackfruit seed
Length (mm)	38.25±3.52	38.74±2.05
Width (mm)	11.42±1.01	12.20±1.50
Thickness (mm)	23.11±2.47	23.16±2.28
Weight (gm)	5.47±0.70	6.39±0.51

*Each value represents the average of ten determinations

The impact of the germination process on the physical parameter (length, width, thickness, and weight) of raw jackfruit seeds and germinated jackfruit seeds are presented in the table. The length, width, thickness, and weight were found to be increased by 0.49%, 0.78%, 0.05%, and 0.92% respectively in germinated seeds. A similar increasing trend in germination was also observed by Arya *et al.*, (2020) [2]. The rise in length (0.49%) of jackfruit seed on germination is due to the growth of the shoot and root system within the seed. The 0.78% increase in the width of jackfruit seeds on germination is attributed to cell division and elongation. The increase of thickness by 0.05% in germinated jackfruit seeds after germination is due to the growth and expansion of the embryo inside the seed. The 0.92% increase in weight of germinated jackfruit seeds is due to the absorption of moisture during the germination process. This is supported by the findings of Divekar *et al.*, (2017) [4].

3.2 Effect of drying treatment on organoleptic parameters of non-germinated and germinated jackfruit seed flours

A semi-trained panel evaluated the organoleptic characteristics of jackfruit seed flour (GJSF) based on color, texture, flavor, taste, mouthfeel, and overall acceptability, using a 9-point hedonic scale. The results of the evaluation are presented in Figure 1.

Germinated jackfruit flour has potential as a wheat flour substitute in certain applications, but its distinct flavor and aroma may affect the taste and texture of baked goods. The nutritional profile of germinated jackfruit flour may be enhanced by sprouting and grinding the seeds into fine flour, with an increase in protein and vitamins. The color of the flour is an important factor affecting consumer acceptance. The color score of the jackfruit flours developed in this study was found to be desirable, ranging from 7.47 to 8.13. The highest color score was observed in the T2 sample treated at 70°C, while the lowest was found in the T3 sample treated at 80°C. The reduction in color score may be due to the breakdown of chlorophyll pigments and Maillard browning reactions caused by increased temperature. The texture of a food product is also an important sensory attribute. The texture score of the germinated jackfruit flours decreased from 7.57 to 7.43 as temperature increased from 50°C to 80°C, which may be due to the gelatinization of starch granules at high temperatures. This may also contribute to the slight grittiness of the germinated jackfruit seed flours. The sensory attributes of taste and mouth feel are crucial for consumer acceptance. The germinated jackfruit seed flour dried at 70°C received the highest scores for both taste (7.73) and mouthfeel (7.73) among all temperature treatments. Additionally, the overall acceptability score of T2 was the highest (8.13) compared to other samples. These results suggest that germinated and dried jackfruit seed flours have the potential to be a high-quality ingredient in food products.

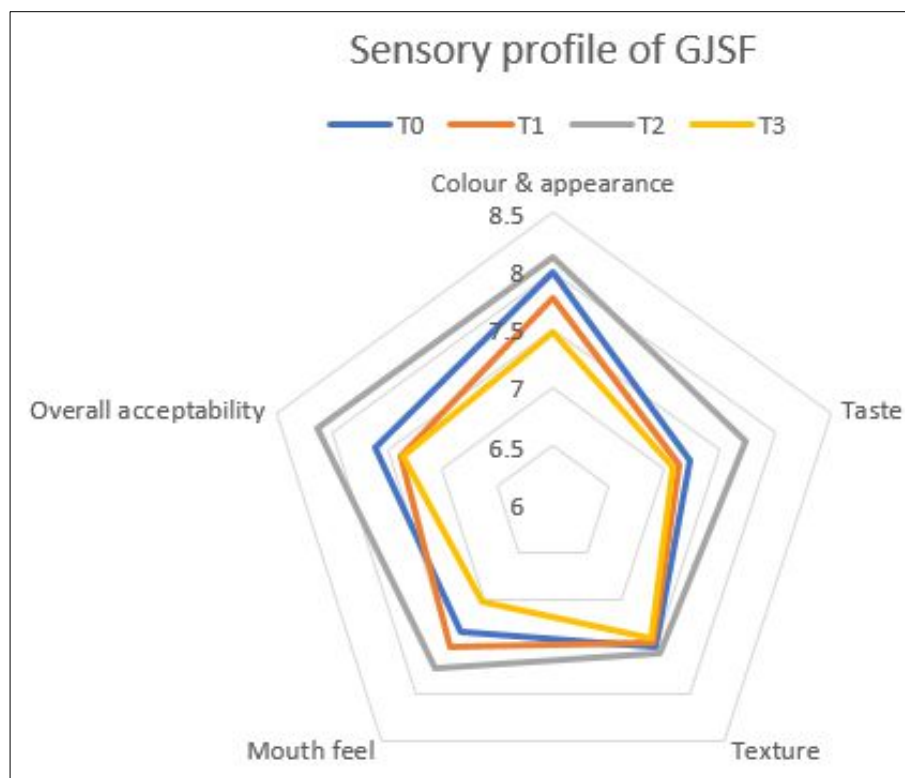


Fig 1: Sensory profile of germinated jackfruit seed flours

Where

T₀=Non-germinated seed flour dried at 50°C (Non-germinated)

T₁=Germinated seed flour dried at 60°C (Germinated)

T₂=Germinated seed flour dried at 70°C (Germinated)

T₃=Germinated seed flour dried at 80°C (Germinated)

3.3 Selective nutrient parameters of germinated jackfruit seed flours

Table 2: Selective nutrient parameters of germinated jackfruit seed flours

Parameters	T ₀	T ₁	T ₂	T ₃
Moisture (%)	10.25±0.59	10.03±0.34	9.95±0.95	9.25±0.95
Protein (%)	9.56±1.15	14.61±0.74	13.64±1.03	12.71±0.87
Fat (%)	2.74±0.97	1.53±0.48	1.26±0.98	1.17±0.02
Total ash on a dry basis (%)	5.26±0.56	4.98±0.34	4.20±1.04	3.96±0.50
Crude fiber (%)	3.20±0.59	3.32±1.12	3.77±0.97	3.98±0.51
Carbohydrate (%)	69.00±0.99	65.53±1.04	67.18±0.98	68.93±1.03
Total sugar (%)	9.67±0.93	8.71±0.45	8.12±0.95	7.83±0.67
Reducing sugar (%)	5.24±0.87	5.14±0.55	4.64±1.02	4.31±1.18

*Average of the three values (n=3)

T₀=Non-germinated seed flour dried at 50°C

T₁=Germinated seed flour dried at 60°C

T₂=Germinated seed flour dried at 70°C

T₃=Germinated seed flour dried at 80°C

Moisture content influences product shelf life. The moisture content of jackfruit seed flour was observed in between 9.25 to 10.25%. This is attributed to the heat treatment of seeds. The protein content of jackfruit seed flour ranged from 9.56% to 14.61%. The highest protein content (14.61%) was found in germinated jackfruit seeds dried at 60°C, while the lowest protein content (9.56%) was found in raw jackfruit seeds dried at 50 °C. It might be due to the germination process, seed reserves undergo a breakdown process, leading to a reduction in overall dry matter and an increase

in enzymatic activity, resulting in higher protein content. The increase in protein content may also be due to the release of nitrogen storage to produce protein for embryo formation. Similar protein content of germinated jackfruit seeds was reported by Eke-Ejiofor *et al.*, (2014) [5]. The fat content of raw jackfruit seed flour was higher than that of germinated seed flour dried at 80°C, with values of 2.74% and 1.17%, respectively. It was observed that the fat content decreased as the drying temperature increased from 50°C to 80°C, which may be attributed to fat oxidation. This decrease in fat content could potentially enhance the shelf life of the flour by reducing the risk of rancidity and unpleasant flavors. The ash content of the jackfruit seed flour decreased as the temperature increased from 50°C to 80°C. The non-germinated seed flour treated at 50°C showed the highest ash content (5.26%), whereas the germinated seed flour treated at 80°C exhibited the lowest ash content (3.96%). This decrease may be due to the leaching of minerals into the water during the heating process. Our findings are consistent with the results of Eke- Ejiofor *et al.*, (2014) [5], indicating the reliability of our findings.

The highest fiber content of 3.98% was observed in germinated seed flour treated at 80°C, while the lowest fiber content of 3.20% was found in raw seed flour treated at 50°C. The increase in fiber content during dry processing could be attributed to the formation of resistant starch and dextrins. According to the observations, the carbohydrate content of germinated jackfruit seed flours ranged from 65.53% to 69%. This slight decrease in carbohydrate content may be due to the increased activity of amylolytic enzymes such as α -amylase. The high temperatures used during drying can cause complex carbohydrates to break down into simpler sugars, resulting in a reduction in the total carbohydrate content. These findings suggest that controlling the temperature during the drying process can help maintain the carbohydrate content of jackfruit seed flour. The results obtained for the carbohydrate content of

the sample are consistent with those reported in previous studies by Ocloo *et al.*, (2010).

The taste profile of jackfruit seed flour is directly influenced by its sugar composition. The study found that there was a decreasing trend in the total sugar content of the flour, with values decreasing from 9.67% to 7.83%. Additionally, the reduced sugar content in germinated jackfruit seed flour also exhibited a decreasing trend, with values from 5.24% to 4.31%. The decrease in total and reducing sugars may be attributed to the hydrolysis of polysaccharides into

monosaccharides and various reactions that generate glyceraldehyde, hydroxymethyl furfural (HMF), and melanoidin. These findings are consistent with those reported in previous studies. The results obtained for the total sugar and reduced sugar content of jackfruit seed flour agree with previous studies by Swami *et al.*, 2016^[12].

3.4 Assessment of phenolic compound, vitamin C, and antioxidant of germinated jackfruit seed flours

Table 3: Effect of drying temperature on the phenolic compound, vitamin C, and antioxidant

Parameters	T ₀	T ₁	T ₂	T ₃
Phenolic compound as gallic acid mg/100g	5.02±0.50	4.80±0.41	4.50±1.05	4.13±0.48
Ascorbic acid (Vit C) mg/100g	51.03±2.04	49.51±0.66	47.31±1.03	44.05±1.53
Antioxidant (mg/100g)	16.68±1.54	14.50±1.32	14.00±1.00	12.08±0.87

*Average of the three values (n=3)

T₀=Non-germinated seed flour dried at 50°C

T₁=Germinated seed flour dried at 60°C

T₂=Germinated seed flour dried at 70°C

T₃=Germinated seed flour dried at 80°C

Phenolic compounds are known for their antioxidant and anti-inflammatory properties and have been linked to various health benefits, including reducing the risk of chronic diseases such as cancer, diabetes, and cardiovascular disease. The study analysed the phenolic content of jackfruit flour and found that it decreased from 5.02 to 4.13mg/100g. The sample treated at 80°C (T₃) had the lowest phenolic content (5.02mg/100g), while the non-germinated seed flour treated at 50°C had the highest content. The decrease in phenolic content may be due to degradation, oxidation, or polymerization reactions, as well as the formation of complexes with proteins and carbohydrates. These results are consistent with previous studies that have also reported a reduction in phenolic content due to processing and storage. Vitamin C, which is also referred to as ascorbic acid, is a type of water-soluble nutrient is particularly vulnerable to degradation. The raw jackfruit flour was found to contain the highest vitamin C (51.03mg/100g) followed by T₁ (49.51mg/100g), T₂ (47.31mg/100g), and T₃ (44.05mg/100g). The decreasing trend of Vitamin C was observed (51.03 mg/100g to 44.05 mg/100g) with an increase in temperature (50°C to 80°C) may be attributed to the degradation caused by exposure of

seeds to heat, light, and oxygen during the germination process. Additionally, the breakdown of stored nutrients in the seed to support growth can result in a decrease in Vitamin C content. Furthermore, the presence of alkali compounds can further exacerbate the degradation of Vitamin C, resulting in its loss during food dehydration and the results of Vitamin C analysis are consistent with this degradation mechanism.

Jackfruit flour contains antioxidants that help protect cells from damage caused by free radicals. These compounds can also reduce inflammation, support immune function, and promote healthy aging. The study found that the germinated jackfruit flour had a decreasing trend in antioxidant activity, with values decreasing from 16.68 to 12.08mg/100g. This decrease was attributed to the leaching of some antioxidant compounds from the flour into the water during heat treatment. Consequently, the concentration of these compounds in the flour decreased, resulting in a reduction in its antioxidant activity.

3.5 Process-aligned functional properties of germinated jackfruit seed flours

The functional properties of jackfruit seed flour were evaluated based on its water absorption capacity, oil absorption capacity, and swelling power. Table 4 summarizes the results of this analysis, providing a comprehensive overview of the functional properties of jackfruit seed flour.

Table 4: Process-aligned functional properties of germinated jackfruit seed flours

Parameter	T ₀	T ₁	T ₂	T ₃
Water absorption capacity (%)	24.65±1.48	25.35±0.81	28.53±1.43	29.73±1.04
Oil absorption capacity (%)	19.95±2.24	20.49±0.62	21.42±0.96	22.36±0.93
Swelling power (g/g)	3.94±0.34	3.67±0.34	3.42±0.62	3.25±0.61

*Average of the three values (n=3)

T₀=Non-germinated seed flour dried at 50°C

T₁=Germinated seed flour dried at 60°C

T₂=Germinated seed flour dried at 70°C

T₃=Germinated seed flour dried at 80°C

Water absorption is an important parameter to analyze in jackfruit flour as it determines the amount of water that the flour can absorb, and how it affects the texture, viscosity, and other properties of the final product. The water absorption capacity values of jackfruit seed flours were

observed to be increased from 24.65% to 29.73% with an increase in drying temperature (50°C to 80°C). This may be attributed to the disruption of intermolecular bonds of starch during heating lead to enhanced access to water resulted in increased water absorption by the starch molecule (Kumar and Saini, 2016)^[6].

The analysis of swelling power is a measure of the hydration capacity of flour, which is represented by the weight of swollen starch granules and their entrapped water important in determining the amount of water that flour can absorb and

the extent to which it swells. This information is particularly significant in the development of food products that require specific water-holding and swelling properties, such as soups, sauces, and baked goods according to Nazeer *et al.*, (2013). The highest swelling power was recorded in germinated jackfruit seed flour (3.94%) and raw (3.25%), according to observations decreasing trend is found. This swelling phenomenon takes place as amylopectin molecules come together to form crystals, with low crystallization leading to greater stability of starch granules and therefore a decrease in swelling power, and the results are found like by Nabubuya *et al.*, in 2022 ^[7].

Oil absorption capacity, a quality governing parameter is an indicator of flour's ability to absorb oil during food processing. Temperature increase from 50°C to 80°C The processing method led to a notable rise in the oil absorption capacity of jackfruit seed flours, with an increase of 19.95% to 22.36%. The raw jackfruit seed flour recorded a lower oil absorption capacity (19.95%) whereas germinated jackfruit flour treated at 80°C recorded the highest oil absorption capacity (22.36%). This increase may be ascribed to drying temperature rise (50°C to 80°C) which results in swelling and rupture of starch granules during heating causing the release of amylose and amylopectin molecules. These molecules then form a complex matrix with the proteins present in the flour, which increases the oil absorption capacity of the flour. The oil absorption capacity values obtained in this study are consistent with those reported by previous studies, which have also shown that higher processing temperatures lead to increased oil absorption capacity Ejiofor *et al.*, 2019.

4. Conclusion

The study demonstrated that drying temperature significantly influences the nutritional, functional, and sensory qualities of germinated jackfruit seed flour. Moderate drying temperatures were found to be most effective in retaining key nutrients such as protein and fiber while preserving desirable functional properties like water absorption, swelling capacity, and bulk density. Higher temperatures (above 70°C) led to noticeable degradation of heat-sensitive nutrients and reduced sensory acceptability due to darker coloration and altered flavor profiles. Overall, drying at moderate temperatures offers an optimal balance (70°C) between nutrient preservation, functionality, and consumer acceptability. These findings support the potential of germinated jackfruit seed flour as a sustainable, nutritious ingredient for use in health-oriented and gluten-free food formulations. Future research may focus on product development and shelf-life assessment to broaden its application in the food industry.

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