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Protocol optimisation for extraction of jackfruit seed milk: A nutritious plant-based alternative

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Abstract
The lifestyle of the modern era has led to a drift in the dietary pattern focusing on vegan diets through the uptrend usage of plant-based or non-dairy milk to accommodate the population with different dietary restrictions including people with conditions like lactose intolerance, food poisoning and heart diseases. When people are exploring cost effective sources as food substitutes, jackfruit seeds of high nutritional importance are considered as industrial waste. In this context, jackfruit seeds can be explored as an alternative source of carbohydrates and protein for industrial applications in the production of dairy analogues. Jackfruit seed milk extraction is a process that involves preparing and blending jackfruit seeds with water to obtain creamy and flavorful plant-based milk. This article provides a concise description of the extraction process, highlighting the best treatment to extract jackfruit seed milk. The best method for extraction of Jackfruit seed milk is selected according to the yield ratio, sensory attributes and curd setting properties. The extracted milk can be stored in the refrigerator for a few days for further processing, if required. Incorporating jackfruit seed milk into the diet offers a nutritious and sustainable alternative to dairy milk, adding a unique twist to culinary creations.

Keywords: Jackfruit, jackfruit seed milk, Varikka, Koozha, fully ripe, fully matured

Introduction
As the demand for plant-based alternatives continues to rise, jackfruit seed milk has emerged as a promising option due to its nutritional value and versatile applications. The jackfruit is rich in phytochemicals, particularly phenolic compounds, and offers the potential to create various value-added products, such as nutraceuticals, that can enhance its health benefits (Umesh *et al.,* 2010) [6]. Jackfruit seeds are edible and can be consumed either raw or cooked in various dishes. In spite of their potential for consumption and use, these seeds underutilized due to their increased moisture content. Although they are not widely recognized and utilized by the public, jackfruit seeds offer better nutritional benefits and can serve as a valuable component in nutraceuticals. Furthermore, the seeds are an excellent source of fiber, vitamins, carbohydrates, and proteins. Jacalin, an important protein derived from seeds of jackfruit, has been found for possessing an immunological character. Additionally, chemicals and food additives that is natural can also be seen in jackfruit seeds. The seeds offer significant nutritional benefits and can be processed into flour for easier handling and preservation. Jackfruit seeds, for example, contain approximately 11-14 percent moisture, 60-70 percent carbohydrates, 9-12 percent crude protein, 1 percent fat, 2-3 percent crude fiber, and 2-3 percent total mineral matter. They also provide a value of calorie 320-360 kcal/100 g (Islam *et al.,* 2015) [3].

In the present era, milk from seeds and nuts is employed in traditional and innovative products to increase their value. Jackfruit seed milk is a source of manganese and magnesium. Additionally, it contains fiber, potassium, calcium, and salt. Incorporating jackfruit seed milk in products enhances their nutritional profile, resulting in higher customer acceptance. Extracted from the seeds of the jackfruit, this milk offers a creamy texture, subtle nutty flavour, and a range of health benefits. This article explores the extraction process of jackfruit seed milk, highlighting its nutritional composition and potential uses. Extracted from the seeds of the jackfruit, this milk offers a creamy texture and a subtle nutty flavour that makes it a versatile ingredient in various culinary creations. The extraction process of jackfruit seed milk involves several steps, including seed preparation, soaking, blending, straining and storage. The resulting milk is not only delicious but also packed with essential nutrients. With its numerous health benefits and potential uses, jackfruit seed milk can become a popular choice for those seeking a dairy-free and plant-based alternative.

Materials and Methods

Selection of fruits for seed collection

Selecting the right jackfruits for seed collection is essential to ensure high-quality seeds that yield nutritious and tasty milk. The two most commonly seen cultivars of jackfruit in Kerala are *Varikka cv* and *Koozha cv*. For *Varikka cv* variety, it is suggested to select jackfruits that have a yellowish-green skin with a smooth surface and oval shape. The seeds should be extracted when the fruit is ripe and starts to crack. For *Koozha* variety, it is suggested to select jackfruits that have a brownish-green skin with a rough surface and round shape. The seeds should be extracted when the fruit is fully ripe. Selecting the right variety and maturity stage of jackfruits for seed collection is crucial for producing high-quality jackfruit seed milk that meets consumers' expectations and demand.
Jackfruit cultivars *Koozha* and *Varikka* were selected for the study, jackfruits was purchased from local markets.

v_1= *Varikka*
v_2= *Koozha*

Stage of fruit maturity

The stage of fruit maturity is an important factor to consider when collecting jackfruit seeds for milk production. The maturity stage of jackfruit affects the quality and yield of the seeds. For jackfruit seed milk production, the fruit should be harvested when it is fully ripe (Swami *et al.*, 2012) [5]. At this stage, the pulp of the fruit becomes soft and easily separable from the seed. For this study seeds from fully ripe and fully matured fruits of both the cultivars were selected for the study.

- m_1- Fully ripe
- m_2 - Fully matured

Pre-processing techniques

The seeds from both varieties were cleaned manually under running water to remove any dirt or debris and the white arils (seed coat) were peeled off manually using a stainless-steel knife before further processing. The brown inner skin coat was also removed manually after soaking the seed for 24 hours to obtain the pure white milk.

Soaking Media

Seeds of both cultivars with the different maturity indices were treated with the distinct soaking media. Soaking time was standardized to identify the best medium for the optimum milk yield. The different soaking media used to treat the seeds before milk extraction were as follows:

- s_1= Water
- s_2= 2% Sodium bi carbonate
- s_3= 3% Sodium hydroxide
- s_4= 2% Salt water (NaCl)

Heat Treatments

To extract jackfruit seed milk, various heat treatments can be employed, each offering a unique approach and outcome. One common method is boiling the jackfruit seeds in water. In this process, the seeds were first removed from the fruit, washed, and then boiled in water until they become soft and tender. The softened seeds are then blended with water to create a creamy milk-like consistency.
Both v_1 and v_2 with the different maturity indices were subjected to the following heat treatments.

- h_1= Steaming
- h_2= Pressure cooking

The pre-treated seeds were cleaned under running water, and the skin was peeled off before further processing.

Extraction of Jackfruit seed milk

The pre-processed and washed jackfruit seeds were weighed, and blended with water (ratio 1:1.5 w/v) until they formed a smooth and creamy mixture. The mixture was then strained through a fine mesh strainer and a cheese cloth to remove any unground remaining chunks or pieces of skin. The resulting liquid which was rich and creamy was then transferred into a glass jar and stored in refrigerator at 4°C until further processing.

Screening of best treatment

Jackfruit seed milk obtained from the above mentioned 24 treatments was tested for yield ratio, sensory attributes and curd setting properties.

Yield ratio: The developed milk was analyzed for yield ratio using the formula

$$\text{Yield Ratio} = \frac{\text{Final weight of product (g)}}{\text{Weight of ingredient (g)}}$$ (Krishnaja, 2014)

Sensory analysis

Sensory evaluation is a scientific method used to measure and analyse human responses to sensory stimuli (Chua *et al.*, 2015) [1]. It provides valuable insights into the sensory attributes of a product and helps determine consumer preferences and acceptability. In this study, the sensory attributes like colour and appearance, taste, texture, flavour and overall acceptability of the jackfruit seed milk was evaluated by a panel of 10 trained members. This step is crucial to understand how well the jackfruit seed milk performs in terms of sensory characteristics compared to other milk alternatives.

Curd setting properties

Setting curd using jackfruit seed milk involves a traditional fermentation process that transforms the milk into a thick, tangy, and nutritious curd. To initiate the curd-setting process, the milk was first extracted from the jackfruit seeds. The milk was then boiled to 90 degrees Celsius and then cooled to a suitable temperature, usually around 40-45 degrees Celsius, to create an ideal environment for bacterial fermentation and kept overnight to set the curd. The set curd was scored by trained panelist for color and appearance, taste, texture, and overall acceptability to determine the best formed curd.

Results and Discussion

The most suitable cultivar, the right stage of maturity and the correct pre-processing techniques to be involved leads to the identification of the best combinations for the extraction of jackfruit seed milk. And the best treatment combination was selected based on the yield ratio, curd setting properties, and sensory attributes of the jackfruit milk extracted.

Yield ratio: Yield ratio of the 24 treatments were calculated as per the procedure quoted in screening of best treatment. The results of yield ratio are depicted in the table 01 and 02.

Table 1: Yield ratio of jackfruit seed milk in different soaking media

Soaking treatments	Yield ratio
$v_1m_1s_1$	0.67[a]
$v_2m_1s_1$	0.63[a]
$v_1m_1s_2$	0.64[a]
$v_2m_1s_2$	0.61[b]
$v_1m_1s_3$	0.65[a]
$v_2m_1s_3$	0.64[a]
$v_1m_1s_4$	0.65[a]
$v_2m_1s_4$	0.60[b]
$v_1m_2s_1$	0.59[b]
$v_2m_2s_1$	0.61[b]
$v_1m_2s_2$	0.57[ab]
$v_2m_2s_2$	0.65[a]
$v_1m_2s_3$	0.59[b]
$v_2m_2s_3$	0.54[ab]
$v_1m_2s_4$	0.63[b]
$v_2m_2s_4$	0.61[b]
±SE(m)	0.002
CV (%)	1.927

Treatments with same letters are not significantly different.

The yield ratio of plant-based milk refers to the proportion of milk obtained from a given quantity of seeds during the extraction process. Studies have explored the impact of different soaking media on the yield ratio of plant-based milk. For instance, research conducted by Singh *et al.* (2019) [4] investigated the effects of various soaking media, such as water, and salt solution. They found that the yield ratio of plant-based milk differed significantly, on soaking in water overnight resulting in higher milk yields.

The table 01 represents yield ratio of two varieties of jackfruit seed samples which were soaked in different soaking media. From the above table it is clear that treatment $v_1m_1s_1$ (*varikka* fully ripe soaked in water) had the highest yield ratio (0.67) and $v_2m_2s_3$ (*koozha* fully matured soaked in sodium hydroxide) (0.54) had the least value. However, it can be noted that statistically, there are treatments on par with the highest value.

Table 2: Yield ratio of jackfruit seed milk with different heat treatments

Heat treatments	Yield ratio
$v_1m_1h_1$	0.63[a]
$v_2m_1h_1$	0.56[b]
$v_1m_2h_1$	0.55[b]
$v_2m_2h_1$	0.54[b]
$v_1m_1h_2$	0.61[a]
$v_2m_1h_2$	0.60[a]
$v_1m_2h_2$	0.61[a]
$v_2m_2h_2$	0.59[b]
±SE(m)	0.003
CV (%)	1.251

Treatments with same letters are not significantly different.

The table 02 represents yield ratio of two varieties of jack fruit seed samples which are subjected to different heat treatments. From the above table it is clear that treatment $v_1m_1h_1$ (*varikka* fully ripe in steaming) had the highest yield ratio (0.63) and $v_2m_2h_1$ (*koozha* fully matured in steaming) had the least value (0.54).

Curd setting properties

The curd setting properties of the milk samples were analyzed by keeping the extracted milk overnight to ferment. The curd setting properties were assessed using sensory studies and the results are shown in table 03.

Table 3: Curd setting properties of the extracted jackfruit seed milk samples in different soaking media

Treatments	Color and appearance	Taste	Texture & consistency	Flavour	Overall acceptability
$v_1m_1s_1$	7.7[abc]	7.0[abi]	7.3[a]	7.3[a]	7.325[a]
$v_2m_1s_1$	7.4[abcdefgi]	7.4[abi]	6.5[bcdefg]	6.6[abfhijkl]	7.025[ab]
$v_1m_1s_2$	7.1[bcdfghi]	6.3[abcdeg]	6.2[bcdeg]	5.5[cdegj]	6.125[deghi]
$v_2m_1s_2$	6.7[fh]	6.2[abcdg]	5.5[bcdeg]	5.1[ceghj]	5.921[deghi]
$v_1m_1s_3$	6.2[fh]	3.7[h]	5.3[bcde]	4.3[cd]	4.825[cd]
$v_2m_1s_3$	6.5[fh]	3.5[h]	5.7[c]	3.1[d]	4.776[cd]
$v_1m_1s_4$	6.5[fh]	6.2[abcdg]	6.3[abdfg]	7.0[abfikl]	6.112[abfgk]
$v_2m_1s_4$	6.3[fh]	5.9[abcdg]	6.4[af]	5.6[efhijkl]	6.350[fghijk]
$v_1m_2s_1$	7.6[abcegi]	6.1[abci]	6.1[bcdeg]	6.0[efhijkl]	6.450[fghijk]
$v_2m_2s_1$	7.2[bcdfghi]	4.9[hi]	6.1[cde]	5.1[cdeg]	5.365[cdei]
$v_1m_2s_2$	6.3[cdefghi]	4.7[hi]	6.3[abdefg]	4.9[cdg]	5.568[cdei]
$v_2m_2s_2$	7.1[bcdfghi]	6.1[abcdg]	6.5[abdfg]	6.3[afhijkl]	6.611[afghjk]
$v_1m_2s_3$	5.6[abcdei]	5.7[abci]	4.1[cd]	4.1[cdg]	5.237[cdei]
$v_2m_2s_3$	5.3[abcdei]	4.9[abcdefgj]	5.3[c]	3.7[d]	4.586[cd]
$v_1m_2s_4$	6.4[h]	7.1[abi]	6.3[bcdefg]	6.2[abfhijkl]	6.481[fghjk]
$v_2m_2s_4$	6.7[fh]	5.9[abc]	7.0[ab]	5.7[efghijk]	6.431[fghik]
$\chi 2$	47.58	98.128	56.135	96.112	93.721
p-value	0.002	0	0	0	0

Treatments combination with same letter are not significantly different

The curd setting properties of jackfruit seed milk was based on knowledge about the principles of curdling plant-based milks and the recommended practices for jackfruit seed milk.

From the table 03, it is clear that treatment $v_1m_1s_1$ (*varikka* fully ripe soaked in water) (7.325) had the highest overall acceptability and $v_2m_2s_3$ (*koozha* fully ripe soaked in sodium hydroxide) (4.586) had the least value when tested for the curd setting properties of the extracted milk samples and the results of mean values are significantly different to each other. The treatment $v_2m_2s_3$ (*koozha* fully ripe soaked in sodium hydroxide) had the least overall acceptability because of change in color and off flavour, but it was found that $v_1m_1s_1$ (*varikka* fully ripe soaked in water) had better curd setting properties, good flavour and appearance during the sensory analysis by the trained panelist.

Table 4: Curd setting properties of the extracted jackfruit seed milk samples in different Heat treatments

Treatment	Color and appearance	Taste	Texture	Flavour	Overall acceptability
$v_1m_1h_1$	7.6[a]	7.0[bdeg]	6.9[ab]	7.0[a]	7.075[a]
$v_2m_1h_1$	7.4[abcdef]	7.4[a]	6.5[bcdefg]	6.6[abfh]	7.025[abf]
$v_1m_2h_1$	7.9[a]	6.0[abc]	6.4[bcdefg]	5.8[efh]	6.525[afgh]
$v_2m_2h_1$	6.7[dfgh]	4.8[h]	6.3[bcdefg]	4.1[cdg]	5.400[cdeh]
$v_1m_1h_2$	6.7[dfh]	6.5[abcdg]	7.1[af]	5.9[efh]	6.550[afgh]
$v_2m_1h_2$	7.4[a]	7.1[bdeg]	7.0[af]	6.9[abfh]	7.010[b]
$v_1m_2h_2$	7.4[a]	6.5[bcdg]	7.4[ab]	6.6[abfh]	7.025[abf]
$v_2m_2h_2$	6.5[dfgh]	6.9[bcfg]	6.7[abdfg]	7.0[a]	6.775[abfg]
$\chi 2$	11.723	26.13	14.218	21.125	27.135
CV (%)	0.012	0	0.001	0	0

Treatments with same letters are not significantly different

The table 04 represents curd setting properties of the two varieties of jack fruit seed samples which were subjected to different heat treatments. From the above table it is clear that treatment $v_1m_1h_1$ (*varikka* fully ripe steaming) had the highest sensory attributes (7.075) and $v_2m_2h_1$ (*koozha* fully matured in

steaming) (5.400) had the least value for overall acceptability. However, the treatment $v_1m_1h_2$ (*varikka* fully ripe in pressure cooking) had good taste, flavour and appearance on sensory analysis making it the best treatment for curd setting and $v_2m_2h_1$ (*koozha* fully matured in steaming) had the least acceptability due to its least acceptance of texture, taste, color and the overall acceptability.

Sensory attributes

The sensory attributes of the milk samples were evaluated to select the treatment with highest overall acceptability as the best milk for further processing. The sensory attributes of the 24 samples (soaking and heat treatments) are depicted in table 05and 06.

Table 5: Sensory attributes of the extracted jackfruit seed milk samples in different soaking media

Sample	Color and appearance	Taste	Texture	Flavour	Overall acceptability
$v_1m_1s_1$	7.7^{abi}	7.9^{ab}	7.3^{a}	7.5^{b}	7.600^{a}
$v_2m_1s_1$	7.6^{abi}	6.6^{abcdeg}	6.9^{afg}	7.1^{abkl}	7.051^{abfgjk}
$v_1m_1s_2$	$7.2^{abcdefghi}$	5.8^{aci}	7.0^{afg}	5.2^{cdeghj}	6.300^{efghi}
$v_2m_1s_2$	$7.1^{abcdefghi}$	6.3^{abcdeg}	6.2^{bcdeg}	5.0^{cdeghj}	6.125^{deghi}
$v_1m_1s_3$	6.7^{fh}	6.2^{abcdg}	5.6^{bcdeg}	5.2^{cdeghj}	5.925^{deghi}
$v_2m_1s_3$	6.8^{fh}	3.7^{h}	5.3^{c}	3.7^{d}	4.876^{c}
$v_1m_1s_4$	$7.2^{abcdefghi}$	4.7^{hi}	5.8^{bcdeg}	4.6^{cdeg}	5.575^{cdei}
$v_2m_1s_4$	7.6^{abi}	6.4^{abcdg}	6.8^{abfg}	$6.2^{abfhijkl}$	6.751^{abfgjk}
$v_1m_2s_1$	7.4^{abi}	$7.0^{bcdefgj}$	6.9^{afg}	7.0^{abkl}	7.075^{abfgk}
$v_2m_2s_1$	6.7^{dfh}	6.5^{abcdeg}	7.2^{a}	$5.9^{efhijkl}$	6.550^{afghjk}
$v_1m_2s_2$	$7.1^{abcdefghi}$	6.3^{abcdeg}	6.2^{bcdeg}	5.0^{cdegj}	6.126^{deghi}
$v_2m_2s_2$	6.1^{cdefgh}	3.9^{h}	5.5^{bcde}	4.1^{cd}	4.900^{c}
$v_1m_2s_3$	6.7^{fh}	6.2^{abcdg}	5.6^{bcde}	5.2^{ceghj}	5.925^{deghi}
$v_2m_2s_3$	6.7^{fh}	4.5^{hi}	6.3^{bcdeg}	4.1^{cdg}	5.400^{cdehi}
$v_1m_2s_4$	7.6^{a}	6.0^{abci}	6.4^{bcdeg}	$5.8^{efghijk}$	6.525^{afghjk}
$v_2m_2s_4$	$7.0^{abcdefghi}$	4.8^{hi}	5.4^{bcde}	4.6^{cdeg}	5.450^{cde}
χ^2	47.213	121.536	58.691	97.013	98.782
p-value	0.017	0.001	0.021	0.002	0.001

Treatments combination with same letter are not significantly different

According to Zahra *et al.* (2014) [7] for the extraction of sesame milk soaking treatments were performed in order to enhance the flavour and better extraction of the milk and the best extraction was selected by sensory evaluation. From the table 05 it is evident that $v_1m_1s_1$ had the highest overall acceptability making it the best treatment in soaking media giving the highest sensory attributes among other treatments.

Table 6: Sensory attributes of the extracted jackfruit seed milk samples in different Heat treatment

Treatment	Color and appearance	Taste	Texture	Flavour	Overall acceptability
$v_1m_1h_1$	7.7^{abcde}	6.4^{abcdeg}	6.8^{abfg}	6.2^{abfh}	6.775^{abfg}
$v_2m_1h_1$	6.4^{fh}	7.2^{defg}	6.4^{abfg}	6.5^{abfh}	6.625^{afgh}
$v_1m_2h_1$	7.3^{abcdef}	6.7^{abc}	6.8^{adbfg}	6.6^{abfh}	6.900^{abfg}
$v_2m_2h_1$	7.5^{abcdef}	5.5^{ab}	6.6^{abfg}	5.5^{cefgh}	6.275^{efgh}
$v_1m_1h_2$	7.4^{abcdef}	7.1^{defg}	7.0^{a}	6.9^{a}	7.100^{a}
$v_2m_1h_2$	7.6^{abcegf}	6.6^{abcdeg}	6.9^{abdfg}	7.1^{ab}	7.050^{abfg}
$v_1m_2h_2$	6.7^{fh}	6.2^{abcdg}	5.6^{bcbeg}	5.5^{cegh}	5.925^{degh}
$v_2m_2h_2$	$7.2^{abcdefg}$	4.7^{h}	5.8^{bcde}	4.6^{cdeg}	5.575^{cde}
$\chi 2$	43.258	96.137	59.384	98.782	107.146
p-value	0.002	0	0	0	0

Treatments with same letters are not significantly different

A study by Christina *et al.* 2009 [2] by explained heat treatments on groundnut seeds was to influence consumer appeal for taste, aroma and overall acceptability. In this study the two heat treatments steaming and pressure cooking was done to find the overall acceptability of heat-treated seeds in preparing jackfruit seed milk. From the above table (06) it is evident that $v_1m_1h_2$ (7.100) had the highest value compared to other milk samples for sensory attributes under heat treatments.

Conclusions

The extraction of jackfruit seed milk provides a valuable and nutritious plant-based alternative to traditional dairy milk. Through a simple process of soaking the seeds, blending them with water, and straining the mixture, a creamy and flavourful milk can be obtained. Moreover, jackfruit seed milk aligns with various dietary preferences and restrictions, as it is cholesterol-free and lactose-free and is a very innovative way of utilizing underutilized parts of the jackfruit. The results show *varikka* fully ripe soaked in water has the highest yield ratio, sensory attributes and curd setting properties compared to *Koozha* variety seeds of different maturity indices by statistical analysis making it the most suitable treatment for the extraction of jack fruit seed milk. By incorporating jackfruit seed milk into our diets, we can enjoy a plant-based milk alternative that not only satisfies our taste buds but also contributes to a balanced and wholesome lifestyle.

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