International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(8): 779-782
www.biochemjournal.com
Received: 15-06-2024
Accepted: 19-07-2024

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Finger millet starch extraction: Comparative analysis of solvent efficiency, yield, and colour attributes

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DOI: https://doi.org/10.33545/26174693.2024.v8.i8j.1866

Abstract

Finger millet, known for its exceptional nutritional profile, remains underutilized due to challenges in processing and limited research focus. This study aimed to standardise the isolation process of finger millet starch based on yield and colour attributes, crucial for its industrial applications. Finger millet grains were cleaned, and processed using both dry and wet milling methods, with steeping solutions of distilled water, 0.25% NaOH, and 0.5% Na_2SO_4. The starch was isolated through centrifugation and subsequently dried. The yield and color (L*, a*, b* values) of the starch were evaluated to find the better isolation process. Results revealed that the wet milling method with 0.25% NaOH steeping solution produced the highest starch yield of 55.05 ± 1.32% and the highest L* value of 89.85, indicating superior lightness and purity. The alkali-assisted method facilitated effective dehulling and bleaching, contributing to better starch characteristics. In contrast, the distilled water steeping solution resulted in the lowest yield and colour values. The study involved a comparative analysis of finger millet starch obtained using different steeping solutions and isolation methods. The starch isolation using the wet milling method with NaOH steeping emerged as the most effective approach. This refined protocol offers a standardized method for obtaining high-quality finger millet starch, enhancing its potential for use in various food and industrial applications. The findings underscore the significance of the isolation process in determining the yield and quality of starch, providing valuable insights for future research and industrial practices.

Keywords: Finger millet starch, alkali-assisted extraction, starch yield

Introduction

Among millets and cereal grains, finger millet stands out for its exceptional nutritional profile, which includes high levels of minerals like calcium, phosphorus, potassium, iron, and manganese (Aljobair, 2022) [2]. Finger millet has many nutritional benefits, but it is underutilised due to several reasons these include challenges with threshing and milling, lack of improved varieties, barriers to technological adoption, susceptibility to diseases like blast, lodging problems, stress related to moisture, and a general lack of research focus (Shobana *et al*., 2013) [13]. Finger millet contains significant amount of carbohydrates, including starch, non-starchy polysaccharides and free sugars (Singh and Raghuvanshi, 2012) [18]. Finger millet contains between 72 and 79.5% total carbohydrates and between 5 and 69% starch. Anatomically, finger millet starch is mostly shaped like a polygon and is deeply entrenched in the protein matrix of the grains Jideani *et al*., 1996) [8]. Given the rising need, finger millet starch presents itself as a novel food ingredient in the ongoing search for new starch sources (Rathore *et al*., 2019) [12]. Starch is the most prevalent carbohydrate in finger millet grain, which provides the majority of its nutritious value (Chandra *et al*., 2016) [6]. Starch isolation is a three-step process that starts with anatomic fragmentation, moves on to cell breaking and ends with purifying the separated starch (El Halal, 2019) [7]. Diverse chemicals and milling techniques, such as the wet milling approach that uses water, alkaline, and acidic solvents to separate starch from millets, pseudocereals and cereals are used in diverse ways to isolate starch (Kumari *et al*., 2024; Sindhu & Khatkar, 2023, 2018; Rao *et al*., 2022) [9, 17, 16, 11]. Building on these foundational insights, the present study was designed to investigate how different isolation processes influence the yield and colour of finger millet starch. The goal was to refine an effective isolation protocol that maximizes starch yield while preserving or enhancing its colour attributes. By systematically evaluating various extraction methods, this research aims to establish a standardized protocol that could potentially improve the usability and appeal of finger millet starch in food and industrial applications.

Materials and Methods
Material
Eleusine coracana L., often known as finger millet, was obtained from ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan in Almora, Uttarakhand, specifically the cultivar VL-380. The grains were prepared for future use by cleaning, washing, and drying them for three hours at 50 °C in a tray drier. They were then placed in airtight glass containers.

Methods
Starch isolation
Finger millet starch was isolated using a slightly modified method of Beleia *et al.*, (1980) [5]. Dry milling and wet milling process were used, dry milling process involved grinding grain into flour and then subjecting it to steeping solutions. On the other hand, the wet milling process involved wet grinding of grain directly into the steeping solution. The steeping solutions used were distilled water, 0.25% NaOH solution, and 0.5% Na_2SO_4 solution. Soaked finger millet grains and flour were turned into a fine slurry and the slurry was centrifuged. The centrifugation process was repeated with the addition of distilled water until all of the visible brown protein layer was eliminated from the sediments. Starch was dried in hot air oven and stored for further analysis.

Yield
The weight of the isolated starch was carefully recorded and the following formula was used to determine the percent yield of starch

% Yield = (weight of starch/ weight of grains) X 100

Colour parameters
The Hunter lab calorimeter was used to determine the colour using L*, a* and b* values. The sample was uniformly placed in sample holder in the instrument and L*, a* and b* values were recorded. 'L*' value, which is 100 for completely white or 0 for completely black substances, indicates lightness. The 'a*' value indicates (redness/greenness) and 'b*' value indicates (yellowness/blueness).

Results
Yield
The variation in the yield of the starch was observed, using different steeping solutions and processing methods as depicted in from Figure 1. This indicates that the steeping solution and the method of isolation does affect the yield of the starch. It was also observed that in all three steeping solutions the wet milling method obtained higher yield. The results have been exhibited in the Table 1. The highest yield of 55.05% was obtained by wet milling method of 0.25% NaOH steeping solution. This was followed by 50.22% yield in the dry milling method of 0.25% NaOH steeping solution. Na_2SO_4 obtained a moderate yield while the lowest yield of 18.72% was obtained in the case of distilled water. The yield recorded in this study was higher than the yield obtained by Afolabi *et al.*, (2012) [1] which was around 37.67%. On the other hand Starch yield of finger millet starch was found to be 60.37% (dry basis) by Balasubramanian *et al.*, (2011) [4].

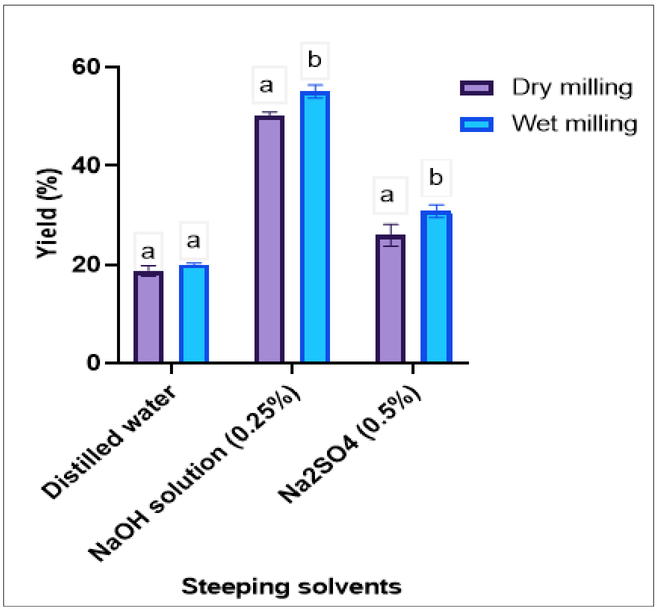

Fig 1: Yield of finger millet starch isolated using different steeping solutions. Superscript in capital letters represents a significant difference ($p<0.05$) within the treatment

Colour
The colour values of the starch were determined as it is a parameter of paramount importance for its acceptance in the industry. The data related to color parameters of finger millet starch has been presented in Figure 2 and Table 1.

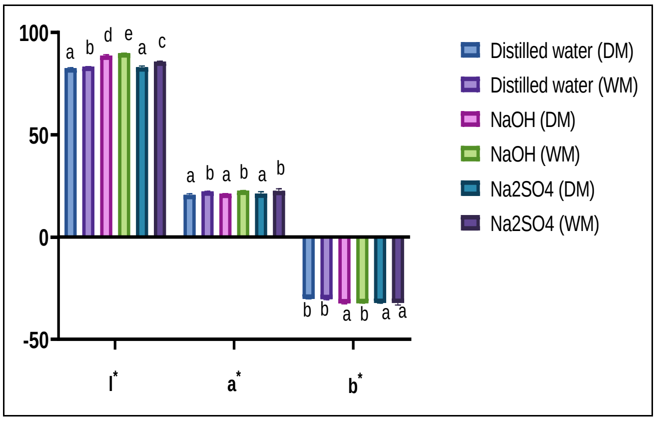

Fig 2: Colour parameters of finger millet starch isolated using different steeping solutions. Superscript in small letters represents significant difference ($p<0.05$) within the same attribute

All the values are Mean ± S.D (n=3), superscript in capital letters represents significant difference ($p<0.05$) within the treatment and superscript in small letters represents significant difference ($p<0.05$) within the same attribute

Significantly ($p<0.05$) higher L* value of 89.85 was recorded for the starch obtained using the wet milling and NaOH steeped solution which was followed by 88.70 for the starch obtained using the dry milling and NaOH steeping solution as mentioned in the Table 1. This could be due to the property of alkali that helps in dehulling of the finger millet grain and also due to the bleaching ability of NaOH. It can be concluded that despite the same origin the method of starch isolation affects

Table 1: Yield and colour values of the starch obtained by using different steeping solutions

S. No.	Method	Yield	Colour		
			l*	a*	b*
1	Distilled water				
(a)	Dry milling	18.72 ± 1.06^{A}	82.51 ± 0.27^{a}	20.56 ± 0.59^{a}	-30.15 ± 0.06^{b}
(b)	Wet milling	20.03 ± 0.27^{A}	83.26 ± 0.06^{b}	22.25 ± 0.12^{b}	-30.33 ± 0.26^{b}
2	NaOH solution (0.25%)				
(a)	Dry milling	50.22 ± 0.44^{A}	88.70 ± 0.47^{d}	21.16 ± 0.11^{a}	-32.42 ± 0.28^{a}
(b)	Wet milling	55.05 ± 1.32^{B}	89.85 ± 0.04^{e}	22.68 ± 0.04^{b}	-30.32 ± 0.22^{b}
3	Na_2SO_4 solution (0.5%)				
(a)	Dry milling	25.95 ± 2.15^{A}	82.92 ± 0.70^{a}	21.20 ± 0.95^{a}	-32.20 ± 0.06^{a}
(b)	Wet milling	30.83 ± 1.29^{B}	85.73 ± 0.27^{c}	22.57 ± 1.05^{b}	-32.22 ± 0.99^{a}

the starch characterisations. Comparable value of L* were reported for amaranth and buckwheat starches isolated by NaOH steeping method (Sindhu & Khatkar, 2016a, b) [14, 15] Balasubramanian *et al*. (2011) [4] reported L* value of 76.30 in the native finger millet starch which changed to 76.43, 76.60 and 77.66 upon heat moisture treatment, enzyme modification and acid modification, respectively. Balakumaran *et al*., (2023) [3] reported that the modification of finger millet starch had a significant change in the b* value which caused an increase in the chroma (ΔC) value.

Standardised process

The process of starch isolation was refined based on colour values and yield% of the finger millet starch obtained from different steeping solutions. As presented in Figure 3, the NaOH steeping solution and wet milling method were found to be better as they produced the highest L* value and yield% of starch. The steps this process included the cleaning of finger millet grains followed by steeping in 0.25% NaOH alkali solution at 4 °C overnight. Then the steeping solution was decanted and grains were wet milled followed by filtration of the slurry using a 400 mesh size sieve. The filtered slurry was then centrifuged at 4000 rpm for 12 min and 25 °C. The trailing brown part was removed from the surface upon centrifugation and the resultant product was subjected to repeated centrifugation till no more brown residue was observed. Thereafter resultant starch was washed with ethanol followed by water. The pH of the resultant starch was also maintained at 7 and it was dried at 45 °C for 12 hours.

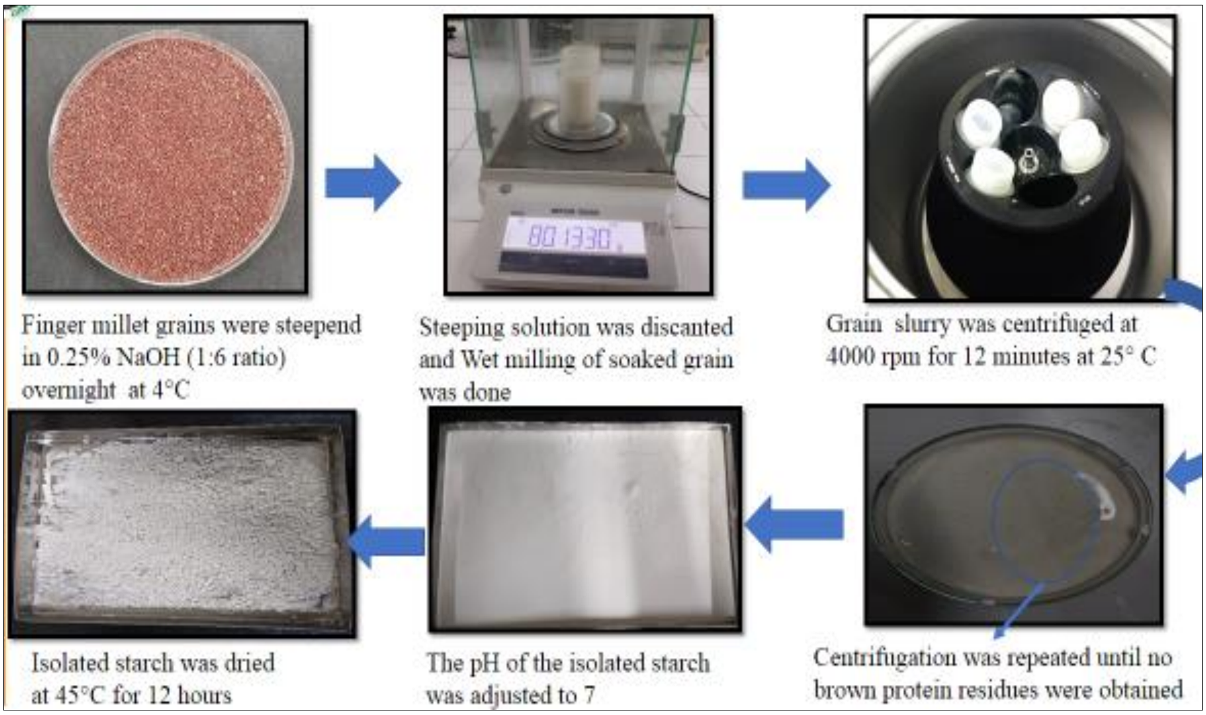

Fig 3: Process of starch isolation

Conclusion

The present investigation effectively refined the finger millet starch separation procedure, emphasising yield maximisation and colour attribute enhancement, two crucial aspects for its industrial use. The research showed that the wet milling process, when paired with a 0.25% NaOH steeping solution, produces the best colour quality and maximum starch recovery when compared to other steeping solutions and milling techniques. The lightness and purity of the finger millet starch were enhanced by the alkali-assisted process, which also made it easier to dehull and more appealing as an ingredient for a variety of culinary and industrial applications. Conversely, the lowest yield and colour values were obtained when distilled water was used as a steeping solution, underscoring the need to use the right solvents and extraction techniques for extracting starch. The procedure that has been refined in this study provides a standardized and efficient approach to isolating finger millet starch, addressing the challenges associated with its underutilization. The findings provide a foundation for further research and suggest that finger millet starch when properly extracted, can be a valuable resource in developing novel food products and industrial applications. This work contributes to the broader understanding of starch isolation and emphasizes the need for continued exploration of finger millet as a significant starch source.

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