Jurnal Kesehatan Lingkungan
Journal of Environmental Health
Journal Home Page:
https://e-journal.unair.ac.id/JKL
Vol. 16 No. 2
DOI: 10.20473/jkl.v16i2.2024.137-143
ISSN: 1829 - 7285 | E-ISSN: 2040 - 881X

ORIGINAL RESEARCH Open Access

ECO-FRIENDLY ALTERNATIVES TO CONVENTIONAL PLASTICS – FINGER MILLET-BASED SOLUBLE FOOD FOLDS

Vinodhini Jeyaveeraraghu[1]*, Chinnappan Ambrose Kalpana[2]

[1]Research Scholar, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore 641043, Tamil Nadu, India
[2]Deputy Dean, School of Home Science and Professor, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore 641043, Tamil Nadu, India

Corresponding Author:
*) vinu.samskruthi@gmail.com

Article Info
Submitted : 23 February 2024
In reviewed : 5 March 2024
Accepted : 19 April 2024
Available Online : 30 April 2024

Keywords : *Antioxidant potential, Finger millet, Phytochemicals, Soluble food folds*

Published by *Faculty of Public Health Universitas Airlangga*

Abstract

Introduction: *Plastics are rendered as a symbol of this disengagement – a psychological and physical barrier between us and what we consume. People have been involved in preparing and consuming food folds since the 1900s. From the method of making a particular traditional sweet from Atreyapuram, Andhra Pradesh, this study attempted to create folds from 'Ragi'. The main objective is to create soluble food folds that serve as a versatile bio-packaging unit that is 100% consumable and contributes to zero wastage, which the common womenfolk of community can prepare.* ***Methods:*** *Raw and germinated millets were processed to create edible folds. Subsequently, phytochemical and antioxidant analyses were conducted to evaluate the potential health benefits of the folds.* ***Results and Discussion:*** *Both the folds were relatively compatible to hold the dry contents inside. The highest percentage of scavenging activity is observed for aqueous extract of Germinated ragi fold (G), which scavenged 79.13 % radicals at a 100 µg/ml concentration. The low absorption percentage was expressed by an aqueous extract of Non- Germinated ragi fold (NG), which scavenged 5.22 % radicals at a concentration of 500 µg/ml. However, there is no significant difference between the phytochemical components between folds made from germinated ragi and non-germinated ragi.* ***Conclusion:*** *Edible food folds present a novel strategy for diminishing plastic waste and promoting eco-friendly food habits. Continued research could facilitate widespread acceptance, encouraging a greener approach to food packaging and consumption.*

INTRODUCTION

Owing to the pessimistic environmental impacts of synthetic plastics, the event of biodegradable plastics for both commercial and industrial applications is crucial today. Eating and biodegradable food wrappers are used to reduce the utilization of plastic packaging. Edible food packaging for premium products can be eaten or can biodegrade and it is eco-friendly (1).

Once thought to be the pauper's food, millets have taken a comeback in exclusive supermarkets in urban areas. The crop has forged a distinct segment within the healthy foods genre, and the commercial stores profess an exciting increase in the sales of millet. Although rice, wheat, and millet have similar amounts of carbohydrates, because of low fibre content, people consume more rice and wheat to feel content, as compared to millet. In India, ragi is one of the ancient millets and a predominant staple food for people (2).

Finger millet ragi is popular in India and Africa. It is rich in calcium, iron, and amino acids, making it highly nutritious (3). It has been disclosed that millet has many medical and nutritional functions (4). Finger millet has high radical-scavenging activity when compared to wheat, rice, and other types of millet and it is a promising source of antioxidants. Using the DPPH method, it was found that the red or brown variety of finger millet had higher activity (94%) than the white variety (4%), which had lower activity (5-6). The eco-friendly nature of the finger millet-based food folds extends beyond their material properties. The cultivation of finger millet itself

Cite this as :
Jeyaveeraraghu V, Kalpana CA. Eco-Friendly Alternatives to Conventional Plastics – Finger Millet Based Soluble Food Folds. *Jurnal Kesehatan Lingkungan*. 2024;16(2):137-143. https://doi.org/10.20473/jkl.v16i2.2024.137-143

is understood for its low environmental impact. This hardy, drought-resistant crop requires minimal water and flourishes in diverse agroecological zones. Thus, promoting finger millet cultivaion aligns with desirable agricultural practices, contributing to biodiversity and assisting resilient farming structures.

Finger millet-based totally soluble meal folds represent a sustainable and green opportunity for traditional plastics, addressing the pressing issues that can be related to plastic pollution, environmental degradation, and the need for biodegradable packaging answers. Apart from the dietary significance of finger millet, it presents particular properties that make it a perfect supply for eco-friendly packaging. The fibrous nature of the finger millet, blended with its capacity to undergo positive processing strategies, renders it appropriate for formulating environmentally possible options to conventional plastics. To illustrate the point, finger millet-based plastic can help reduce the carbon footprints that arise from conventional ones (7). Manufacturing of plastics is one of the major sources of greenhouse gas emissions, with petrochemicals being one of its major contributors.

Research on food-based soluble folds has several research gaps, such as poor comprehension of their makeup and structure, unproductive processing methods, lack of knowledge on their nutritive content and impact on health, unawareness of sensory characteristics and consumers' acceptance, as well as challenges to stability and shelf life. These barriers can be closed through dedicated scientific research to enable the production of novel food products that have the potential to provide enhanced nutrition, improve sensorial appeal, and gain market advantage for both consumers and food industry players. There are several research works done on bio-degradable, non-edible starch-based films from various plant sources, but not many on the edible soluble food-based folds. Soluble food folds are unique they combine traditional culinary practices with modern sciences around food, resulting in a new convenient way to eat, catering to different diets people prefer.

There are concerns about food competition. Among them, large companies have too much control over people, making it harder for smaller producers to succeed. This can restrict consumer choice and lead to unfair practices such as price manipulation or labour exploitation. It undermines local food traditions and makes it harder for small businesses to comply with safety regulations. To address these issues, we need fair regulations that support small producers, encourage healthy competition, and ensure good food for all.

So, homemade food folds, which are made up of millets, might be efficiently used as soluble food folds. The finger millet food folds will be subjected to antioxidant and phytochemical analyses as part of the study.

METHODS

Sample Selection and Processing

Finger millet, known as Ragi, commonly was sourced from Karur, Tamilnadu. The plant specimen authentication was done at the Botanical Survey of India, Tamil Nadu Agricultural University (TNAU), Coimbatore, India (BSI/SRC/5/23/2022/Tech/491). The plant specimen was identified as *Eleusine coracana* (L.) – *Poaceae*. Ragi samples were segregated into two parts for the sample preparation. The research was conducted at Avinashilingam Institute for Home Science & Higher Education for Women, Coimbatore, Tamil Nadu, India.

Soaking

Ragi samples were manually cleaned by discarding any visible sticks and stones, other crop seeds, weeds, debris, and foreign matter. The seeds were then subjected to viability tests by placing them in water. Those that floated on the top of the water were discarded as unviable. Soaking is the most desirable technique for reducing the anti-nutrient content in food. Ragi was taken in the 1:10 ratio and soaked in water at room temperature for 12 hours. Water used for soaking was then drained for further processing.

Germination

Ragi samples that floated on the top of the water were discarded as unviable. All the chapped, broken or discoloured seeds were discarded. Regular tap water was used to wash, rinse, and clean seeds. The seeds were cleaned and then soaked in drinking water for 12 hours at 28°C (room temp) without direct contact with sunlight. Later, the soaked seeds were drained of excess water and then tied in a muslin cloth for 48 hours with intermittent sprinkling of water and left to germinate (8). Samples were taken up for further processing.

Preparation of Folds

The unique method of preparation of the soluble food folds are unique to the traditional folds prepared by the people of Atreyapuram, Andhra Pradesh. The technique has been passed down from generation to generation, and folds are prepared purely by eye measurement. One part of Ragi was made into a wet batter with one and a half parts of water with a runny texture. The folds were made from the batter by smearing on a hot surface. It was neither steaming nor the frying method, as no water or oil was used to process folds. The folds were then collected and stored aside for further analysis.

Antioxidant Activity Using DPPH Free Radical Scavenging Assay

The free radical scavenging activity of the samples was tested using the DPPH RS assay (9). Samples were prepared using a concentration of 10mg of each sample in 1ml of water. Aqueous extracts were evaluated for antioxidant activity based on ascorbic acid as a standard. The absorbance of the blank and combination were measured at 517 nm at the ambient temperature. The scavenging effect of DPPH radical was depicted as a percentage inhibition against concentration in the sample (10). A standard curve of DPPH scavenging activity was plotted using various concentrations of standard ascorbic acid against the % inhibition. From the regression line of concentration versus % of inhibition, the IC_{50} value of standard Ascorbic acid was calculated.

Phytochemical Screening

The samples were subjected to qualitative phytochemical screening to check for the presence of metabolites like flavonoids, sterols, terpenoids, anthraquinones, alkaloids, proteins, carbohydrates, anthocyanins, phenolic compounds, quinones, tannins, saponins, cardiac glycosides, lignins, coumarins, and volatile oils.

RESULTS

Antioxidant Activity

Antioxidant activity of aqueous extracts of soluble food folds made from soaked, considered as non-germinated ragi (NG) and germinated ragi (G) were analysed by the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging activity assay with ascorbic acid as standard. The percentage scavenging activity of standard ascorbic acid and the sample extracts are depicted in Figures 1 and 2, and the values of free radical scavenging activity in Table 1.

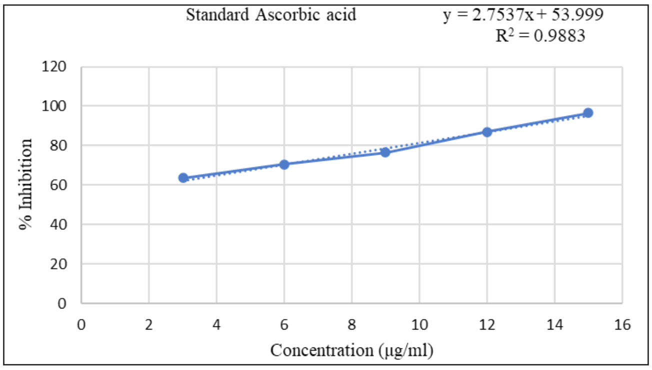

Figure 1. DPPH Radical Inhibition (%) Curve for Ascorbic Acid Standard

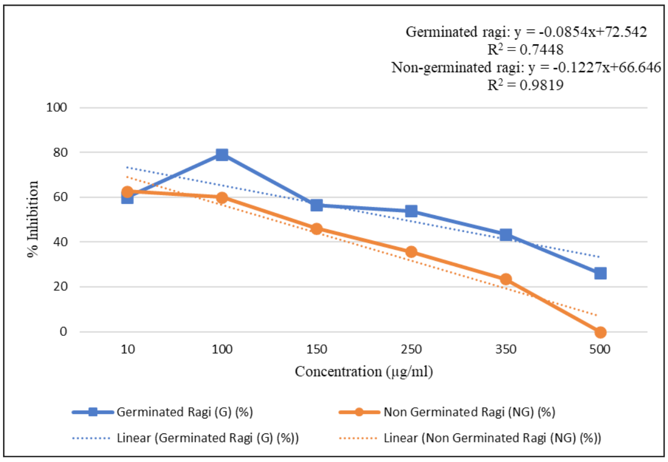

Figure 2. DPPH Radical Inhibition (%) Curve for Folds from Non-Germinated Ragi (NG) and Germinated Ragi (G)

Table 1. DPPH Free Radical Scavenging Activity (% Inhibition) of Folds from Non-Germinated Ragi (NG) and Germinated Ragi (G)

Serial no.	Concentration (µg/ml)	Germinated Ragi Fold (G) (%)	Non Germinated Ragi fold (NG) (%)
1	10	60	62.61
2	100	79.13	60
3	150	56.52	46.09
4	250	53.91	35.65
5	350	43.48	23.48
6	500	26.09	5.22

The DPPH radicals were scavenged by extracts of folds made from Germinated ragi fold (G) and Non germinated ragi fold (NG) in a dependent manner. Among these extracts, the highest percentage of scavenging activity is observed for the aqueous extract of Germinated ragi fold (G), which scavenged 79.13 % radicals at a 100 µg/ml concentration. The lowest percentage of absorption was expressed by an aqueous extract of Non germinated ragi fold (NG), which scavenged 5.22 % radicals at a concentration of 500 µg/ml.

Phytochemical Screening

Germinated and non-germinated ragi folds were screened for phytochemicals. The phytochemical screening results are given in Table 2.

Table 2. Phytochemical Screening of Folds from Non-Germinated Ragi (NG) and Germinated Ragi (G)

Phytochemicals	Test Conducted	Germinated Ragi Folds (G)	Non Germinated Ragi Folds (NG)
Alkaloids	Mayer's reagent	-	-
	Dragendorff's reagent	+	+
Flavonoids	Alkaline test	-	-
	H_2SO_4	-	-
	Lead acetate	-	-
	Shinoda test	-	-

Phytochemicals	Test Conducted	Germinated Ragi Folds (G)	Non Germinated Ragi Folds (NG)
Sterols	$CHCl_3$,+Acetic anhydride + Conc. H_2SO_4	-	-
Terpenoids	$CHCl_3$+Acetic anhydride + Conc. H_2SO_4	-	-
Anthraquinones	$FeCl_3$+Conc.HCl + Diethyl ether +Ammonia	+	+
Anthocyanins	HCl Test	-	-
Proteins	2% Ninhydrin	-	-
	2% $CuSO_4$ +95% ethanol+ KOH pellet	+	+
Phenolic compounds	5% neutral FeCl3	-	-
	Gelatin test	-	-
	Ellagic acid test	-	-
Quinones	Conc. HCl	-	-
	Alcoholic KOH	-	-
Carbohydrates	Molisch's test	+	+
	Fehling's test	+	+
Tannins	Braymer's test	-	-
	Gelatin test	-	-
	10% NaOH test	-	-
Saponins	Shaken with water	+	+
Cardiac glycosides	Baljet reagent	+	+
	Bromine water test	-	-
	Borntrager's test	-	-
	Aq. NaOH test	-	-
Lignins	Gallic acid	-	-
Coumarins	10% NaOH + $CHCl_3$	-	-
Volatile oils	Fluorescence test	-	-

Note: + indicates the presence of phytochemicals, and - indicates the absence of phytochemicals. The screening tests were carried out in triplicates.

The phytochemical screening exhibited the presence of cardiac glycosides, alkaloids, anthraquinone, proteins, carbohydrates, and saponins in both the germinated ragi fold sample (G) and the non-germinated ragi sample (NG). The rest of the phytochemicals showed no significant presence during the screening.

DISCUSSION

Soaking and Germination

The soaked ragi appeared to be slightly enlarged in appearance, however, it was not a significant change from the raw seeds. The increase in dimensional properties like length, width, and thickness of finger millet grains might have been due to the swelling of starch granules during soaking as water migrates to grains during soaking, which, leading to irreversible swelling (11). This stresses the soaking process's delicate impact on the seeds' microstructural composition. While the macroscopic changes may not be readily noticeable, they likely reflect underlying cellular and biochemical transformations induced by hydration. This subtle modification may indicate changes at the cellular level, potentially involving enzymatic activity and cellular expansion, contributing to the overall restructuring of the seed matrix.

Soaking improves the bioavailability, bioaccessibility, and nutritional quality of minerals in millets (12-13). As a pre-treatment, soaking is known to initiate processes such as enzyme activation and hydration. However, soaking commonly reduces the content of anti-nutrient phytochemicals like phytate, tannins, etc (14). These biochemical transformations contribute to the breakdown of complex compounds, facilitating the liberation of minerals from their bound forms, thereby rendering them more bio-accessible and available for absorption in the gastrointestinal tract (15).

Germination was of the desired rate after 48 hours when compared to germinated ragi of 12 hours, where the white elongated sprouts were visibly seen. The intentional selection of a 48-hour germination period signifies a strategic choice for optimizing the sprouting rate. The emergence of visibly elongated white sprouts is not just a visual indication of germination success but is indicative of an extended metabolic activity within the seed. Germination is a biochemical enrichment tool that involves transition of a seed from a dormant state to a vital active state (16). During germination, there is a swell in enzymatic activity, leading to the mobilization and synthesis of various bioactive compounds (17). This prolonged period may contribute to increased nutrient content, including the accumulation of essential amino acids, vitamins, and other phytochemicals.

Antioxidant Activity

Regression analysis on concentration versus percent inhibition ($y = 2.7537x + 53.999$, $R^2 = 0.9883$) allowed the calculation of the IC_{50} value of standard Ascorbic acid (18-19). The measure is essential because it represents the level at which any substance reaches a percentage inhibition of fifty in a particular chemical or biological process and is, therefore crucial in determining the antioxidant ability of compounds. In this study, The IC_{50} value for the standard compound (Ascorbic acid) was obtained by regression analysis as 267.331 µg/ml under the defined conditions set up by linear equation $y = 2.7537x + 53.999$ where $R^2=0.9883$. The value obtained through this method acted as a reference point to compare how well the germinated ragi sample worked as an excellent antioxidant against the non-germinated ragi sample. IC_{50} values for Germinated ragi (G) and Non-germinated ragi (NG), were found to be 417.134 µg/ml and 498.228 µg/ml, respectively. The datasets show that at which concentration these samples inhibit their respective activities by fifty percent. Antioxidant activity in food folds made from

Germinated ragi (G) and Non-germinated ragi (NG) differed significantly based on these IC_{50} values when compared.

For e.g., the IC_{50} values of Germinated ragi (G) and Non-germinated ragi (NG) were 417.134 and 498.228 µg/ml, respectively, indicating the higher scavenging activity of Germinated ragi (G) than Non-germinated ragi (NG). The term "fold" is used to quantify this difference in potency terms. To calculate the difference between the folds, it is necessary to divide IC_{50} value of Non-germinated ragi (NG) by that of Germinated ragi (G), which is approximately equal to 1.19. This means that for example under these experimental conditions, scavenging activity of Germinated ragi (G) was about 1.19 times as powerful as that of Non-germinated ragi (NG) (19). This indicated how germination process might affect the antioxidant properties of ragi thus providing a practical perspective on possible differences in bioactive compounds leading to such variations in the potentiality to scavenge for free radicals.

The thorough comparative analysis of IC_{50} values revealed different types or categories of antioxidants between germinated food folds and non-germinated food folds made from finger millet, presenting an overview of effects related to sprouting upon bioactivity of finger millet (20). Thus, these outcomes contribute significantly to understanding the biological implications of dietary components' anti-oxidant capacities during food processing techniques.

Phytochemical Screening

Phytochemicals are also known as phytonutrients, and they occur naturally in plants. These substances are of importance to human health and possess antioxidants as well. Phytochemicals could also be referred to as anti-inflammatory agents or an antioxidants. Pivotal information recently suggests that taking large quantities of phytochemicals can help protect the body against some diseases (21). In this study, a comparative analysis of the different types of phytochemical composition between germinated and non-germinated ragi food folds was done. There was a certain level of preservation or retention among specific phytochemical constituents recognized with antioxidant and anti-inflammatory activity during the germination. However, it is imperative to acknowledge that the process of fold-making may have led to considerable losses in certain phytochemicals, potentially attributed to the fundamental conditions and methodologies employed in this processing (21).

The cooking process also deactivates the heat-labile anti-nutrients in millets (22-23). The introduction of cooking as a component in the fold-making process appends an additional layer of complexity. Cooking, a thermal processing step, is recognized for its multifaceted effects on the nutritional composition of millets, including the deactivation of heat-labile anti-nutrients present in millets (24-25). This highlights the dynamic and context-dependent nature of food processing techniques and their demanding impact on the bioavailability of nutrients and bioactive compounds. The delicate interplay between preserving beneficial phytochemicals and potential losses during the cooking process will impact the bioactive components of the millet. As millets undergo processing, there is a risk of losing some of the beneficial phytochemicals.

CONCLUSION

Millets and cereals contribute to the significant amount of food consumed in countries like India, which is still developing. The processing of the grain is strenuous, giving poor sensory quality. Inefficient marketing strategies and exposure led to a decline in the production and consumption of the grain. The 'at home' processing method of soaking in advance and germination are the best techniques to enhance the level of nutrition content of food items. This would be a good tool for enrichment. There is a great transition of a dormant seed to the active state, which increases the bioavailability of minerals and leads to an improvised nutritive level of seeds. This was evident from the analysis where the Germinated ragi fold showed better scavenging activity than the Non-Germinated ragi fold sample. Though there may be a stipulated significant loss of antioxidants during the preparation of folds, ragi will still be a great substitute for food folds as they can diversify the delivery of nutrient-rich food products. Though there was no significant difference in phytochemicals between Germinated and Non - Germinated ragi fold samples, this study can be further diversified with folds prepared from the dried form of ragi to analyse the potential difference in phytochemical and antioxidant activity. Finger millet folds offer a promising and environmentally sustainable alternative to traditional plastics, providing a biodegradable, renewable, and eco-friendly solution for various packaging needs. This reduces the wastage to the environment as the folds are soluble and can be consumed with the designated food product. The preparation is so simple that it will be useful for smaller communities, enabling food security. Their innate qualities, such as biodegradability, low environmental impact, and versatility, make them a strong contender in the global effort to reduce plastic waste.

REFERENCES

1. Anitha R, Priya SN. Studies on Development and Analysis of Edible Millet Films. *In AIP Conference Proceedings.* 2022;2446(1):020007. https://doi.org/10.1063/5.0108292
2. Sawant PD, Tavhare SD. A Review on the Use and Scope of Finger Millet (Ragi) in Prevention and Management of Non-Communicable Diseases. *Journal of Drug Research in Ayurvedic Sciences*. 2023;8(Suppl 1):S55-S63. https://doi.org/10.4103/jdras.jdras_126_23
3. Maurya R, Boini T, Misro L, Radhakrishnan T, Sreedharan AP, Gaidhani D. Comprehensive Review on Millets: Nutritional Values, Effect of Food Processing and Dietary Aspects. *Journal of Drug Research in Ayurvedic Sciences*. 2023;8(Suppl 1):S82-S98. https://doi.org/10.4103/jdras.jdras_123_23
4. Kazi TS, Laware SL, Auti SG. Analysis of Nutritional Diversity and Antioxidant Activity of Finger Millet Landraces. *Indian Journal of Agricultural Research*. 2022;56(1):1-6. https://doi.org/10.18805/IJARe.A-5741
5. Sripriya G, Antony U, Chandra TS. Changes in Carbohydrate, Free Amino Acids, Organic Acids, Phytate and HCL Extractability of Minerals During Germination and Fermentation of Finger Millet (*Eleusine coracana*). *Food chemistry*. 1997;58(4):345-350. https://doi.org/10.1016/S0308-8146(96)00206-3
6. Thapliyal V, Singh K. Finger Millet: Potential Millet for Food Security and Power House of Nutrients. *International or Research in Agriculture and Forestry*. 2015;2(2):22-23. https://www.ijraf.org/v2-i2
7. Kumar R, Mishra JS, Mondal S, Meena RS, Sundaram PK, Bhatt BP, Pan RS, Lal R, Saurabh K, Chandra N, Samal SK. Designing an Ecofriendly and Carbon-Cum-Energy Efficient Production System for The Diverse Agroecosystem of South Asia. *Energy*. 2021;214(118860):1-16. https://doi.org/10.1016/j.energy.2020.118860
8. Geetha K, Banu KSP, Ramasamy DP. Evaluation of Functional and Sensory Characteristics of Probiotic Incorporated Millet Based Instant Health Mix. *The Pharma Innovation Journal.* 2021; 10(10):289-292. https://www.thepharmajournal.com/archives/2021/vol10issue10/PartE/10-9-3-407.pdf
9. Sivamma P, Rao PJ. Fuzzy Logic for Sensory Evaluation of Paper Sweet (Pootharekulu). *International Journal of Bio-resource and Stress Management*. 2023;14(1):1487-1494. https://doi.org/10.23910/1.2023.4867a
10. Pascoal GD, Cruz MA, de Abreu JP, Santos MC, Fanaro GB, Júnior MR, Silva OF, Moreira RF, Cameron LC, Ferreira MS, Teodoro AJ. Evaluation of the antioxidant capacity, volatile composition and phenolic content of hybrid Vitis vinifera L. varieties sweet sapphire and sweet surprise. *Food Chemistry*. 2022;366(130644):1-10. https://doi.org/10.1016/j.foodchem.2021.130644
11. Mishra K., Ojha H, Chaudhury NK. Estimation of Antiradical Properties of Antioxidants Using DPPH Assay: A Critical Review and Results. *Food Chemistry*. 2012;130(14):1036-1043. https://doi.org/10.1016/j.foodchem.2011.07.127
12. Kumar A, Kaur A, Kumar V, Gat Y. Effects of Soaking and Germination Time on the Engineering Properties of Finger Millet (*Eleusine coracana*). *Carpathian Journal of Food Science & Technology*. 2020;12(1):6. https://doi.org/10.34302/crpjfst/2020.12.1.6
13. Wilson A, Elumalai A, Moses JA, Anandharamakrishnan C. Effect of Processing on Functional Characteristics, Physiochemical Properties, and Nutritional Accessibility of Millets. InHandbook of Millets-Processing, Quality, and Nutrition Status 2022. Singapore: Springer Nature Singapore; 2022. https://doi.org/10.1007/978-981-16-7224-8_10
14. Jagati P, Mahapatra I, Dash D. Finger Millet (Ragi) as an Essential Dietary Supplement with Key Health Benefits: A Review. *International Journal of Home Science*. 2021;7(2):94-100. https://doi.org/10.22271/23957476.2021.v7.i2b.1152
15. Samtiya M, Aluko RE, Dhewa T. Plant Food Anti-Nutritional Factors And Their Reduction Strategies: An Overview. *Food Production, Processing and Nutrition*. 2020;2(6):1-14. https://doi.org/10.1186/s43014-020-0020-5
16. Gunathunga C, Senanayake S, Jayasinghe MA, Brennan CS, Truong T, Marapana U, Chandrapala J. Germination Effects on Nutritional Quality: A Comprehensive Review of Selected Cereal and Pulse Changes. *Journal of Food Composition and Analysis*. 2024; 128(106024):1-16. https://doi.org/10.1016/j.jfca.2024.106024
17. Chauhan ES. Effects of Processing (Germination and Popping) on the Nutritional and Anti-Nutritional Properties of Finger Millet (*Eleusine coracana*). *Current Research in Nutrition and Food Science Journal*. 2018;6(2):566-572. https://dx.doi.org/10.12944/CRNFSJ.6.2.30
18. Nkhata SG, Ayua E, Kamau EH, Shingiro JB. Fermentation and Germination Improve Nutritional Value of Cereals and Legumes Through Activation of Endogenous Enzymes. *Food Science & Nutrition*. 2018;6(8):2446-2458. https://doi.org/10.1002/fsn3.846
19. Akande T, Salawu SO, Akindahunsi AA, Mulinacci N. Antioxidants and Ameliorative Potentials of Stem Bark Extract of *Anogeissus leiocarpus* against Formalin-Induced Pain and Inflammation in Wistar Rats. *Academic Research Journal of Biotechnology*. 2021;9(1):1-10. https://doi.org/10.14662/arjb2021020
20. Kulla S, Hymavathi TV, Kumari BA, Reddy RG, Rani CV. Impact of germination on the nutritional, antioxidant and antinutrient characteristics of selected minor millet flours. *Annals of Phytomedicine*. 2021;10(1):178-184. https://dx.doi.org/10.21276/ap.2021.10.1.18

21. Dey S, Saxena A, Kumar Y, Maity T, Tarafdar A. Understanding the Antinutritional Factors and Bioactive Compounds of Kodo Millet (*Paspalum scrobiculatum*) and little millet (*Panicum sumatrense*). *Journal of Food Quality*. 2022;2022(1578448):1-19. https://doi.org/10.1155/2022/1578448
22. Hu Y, Lin Q, Zhao H, Li X, Sang S, McClements DJ, et al. Bioaccessibility and Bioavailability of Phytochemicals: Influencing Factors, Improvements, And Evaluations. *Food Hydrocolloids*. 2023;135(108165):1-10. https://doi.org/10.1016/j.foodhyd.2022.108165
23. Gowda NN, Siliveru K, Prasad PV, Bhatt Y, Netravati BP, Gurikar C. Modern Processing of Indian millets: A Perspective on Changes in Nutritional Properties. *Foods*. 2022;11(4):499. https://doi.org/10.3390/foods11040499
24. Rathore T, Singh R, Kamble DB, Upadhyay A, Thangalakshmi S. Review on Finger Millet: Processing and Value Addition. *The Pharma Innovation Journal*. 2019;8(4):283-291. www.thepharmajournal.com/archives/2019/vol8issue4/PartE/8-4-16-516.pdf
25. Yadav GP, Dalbhagat CG, Mishra HN. Effects of Extrusion Process Parameters on Cooking Characteristics and Physicochemical, Textural, Thermal, Pasting, Microstructure, and Nutritional Properties of Millet Based Extruded Products: A Review. *Journal of Food Process Engineering*. 2022;45(9):e14106. https://doi.org/10.1111/jfpe.14106