ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 507-512
www.agriculturaljournals.com
Received: 13-10-2025
Accepted: 14-11-2025

Sujata V Patil
Ph.D. Scholar, Department of Agricultural Engineering, D Y Patil Agriculture & Technical University, Talsande, Maharashtra, India

Sushant Bakal
Ph.D. Scholar, Department of Agricultural Engineering, D Y Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. Sagar M Chavan
Assistant Professor, Department of Agricultural Engineering, D Y Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. Mangal A Patil
Assistant Professor, Department of Agricultural Engineering, D Y Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. Prakash S Bandgar
Assistant Professor, Dr. D. Y. Patil, College of Agricultural Engineering & Technology, Talsande, Maharashtra, India

Dr. AA Sawant
Associate Professor and Head, Department of Processing & Food Engineering, College of Agricultural Engineering & Technology, Dr. BSKKV, Dapoli, Maharashtra, India

Dr. Shubhangi D Shelar
Jr. Plant Engineer, Mahabeej, Ashta, Tal. Walwa, Maharashtra, India

Corresponding Author:
Sujata V Patil
Ph.D. Scholar, Department of Agricultural Engineering, D Y Patil Agriculture & Technical University, Talsande, Maharashtra, India

Impact of malting on the physical and proximate characteristics of Kodo millet (*Paspalum scrobiculatum* L.) GPUK-3

Sujata V Patil, Sushant Bakal, Sagar M Chavan, Mangal A Patil, Prakash S Bandgar, AA Sawant and Shubhangi D Shelar

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11g.998

Abstract
Kodo millet (Paspalum scrobiculatum) is a climate-resilient minor millet valued for its dietary fiber, minerals, and nutraceutical potential. Malting, a biochemical modification involving steeping, germination, and kilning, improves digestibility, reduces antinutrients, and alters the physical and proximate characteristics of grains. This study investigates the physical and proximate properties of unmalted and malted GPUK-3 Kodo millet, with experimental measurements conducted in triplicate. Physical parameters included grain dimensions, 1000-grain weight, bulk and true density, surface area, sphericity, and porosity. Proximate parameters analyzed using AOAC (2019) methods included moisture, crude protein, crude fat, ash, crude fiber, and carbohydrate by difference. Data were statistically analysed using mean ± SD and paired t-tests. Malting significantly reduced 1000-grain weight (2.89 → 2.12 g), moisture content (11.66 → 8.50%), and bulk density (762.75 → 723.17 kg/m³), while porosity increased. Proximate composition improved after malting, showing increases in protein, fiber, and ash content due to reserve mobilization and cell wall modification during germination. Results confirm that malting improves both nutritional quality and physical properties of GPUK-3 millet, making it suitable for value-added and fortified premix formulations.

Keywords: Kodo millet, GPUK-3, malting, proximate composition, physical properties, density, millet processing

Introduction
Millets are small-grained cereals known for exceptional resilience to drought and marginal soils. Kodo millet (Paspalum scrobiculatum) is widely grown in central and southern India and recognized for its low glycemic index, high fiber content, antioxidant levels, and gluten-free nature (Nithya & Sujatha, 2019) [5]. It is an important crop for nutritional security, particularly in tribal and dryland regions. In recent years, malting has emerged as a promising method to enhance the nutritional attributes of millets. Malting activates hydrolytic enzymes, increases bioavailability of nutrients, improves digestibility, reduces antinutritional factors (phytates, tannins), and modifies physical parameters important for food processing (Saleh *et al.*, 2013; Thakur & Saxena, 2019) [6, 8]. The physical characteristics of grains directly influence milling behavior, hydration, roasting quality, and processing performance (Mohsenin, 1986) [4].
Similarly, proximate composition is crucial for evaluating nutritional quality and determining suitability for premixes, bakery products, beverages, and infant foods. Despite the importance of Kodo millet, limited research exists on its GPUK-3 variety, especially comparing physical and proximate characteristics before and after malting. Generating such baseline data is essential for product development, storage modeling, and industrial processing.

Materials and Methods
Sample Collection
Fresh GPUK-3 Kodo millet grains were procured from an authorized agricultural research center. Grains were cleaned to remove dust, stones, and broken kernels.

Malting Process

Malting of Kodo Millet

The malting process for Kodo millet was carried out by adapting commonly used cereal malting techniques reported in earlier literature, with slight modifications to improve sprouting efficiency and enzymatic activity.

Soaking

The cleaned grains were immersed in potable water at a grain-to-water ratio of about 1:3 (w/v). Steeping was performed at 25–30°C for roughly 8–12 hours to allow sufficient moisture absorption needed for uniform germination. This moisture conditioning step aligns with the soaking durations recommended in recent studies (Singh *et al.*, 2020) [9].

Germination

Following hydration, the grains were drained and uniformly spread on germination trays. They were incubated at 25°C with controlled humidity and aeration to support sprout emergence. Germination was continued for 48–72 hours, a period reported to encourage optimal development of hydrolytic enzymes and sprout growth.

Kilning/Drying

The sprouted grains were subsequently dried in a tray dryer at 50–60°C for 8–12 hours. This drying phase was intended to inactivate enzymes, reduce moisture to safe storage limits, and impart desirable sensory attributes. Proper kilning helps retain enzyme quality and improves shelf stability of the malt.

Milling

After drying, the malted grains were ground using a hammer mill equipped with a 250-µm sieve to obtain fine malt powder appropriate for further blending and formulation. The resulting flour was sealed in airtight containers to avoid moisture reabsorption and maintain quality during storage.

Determination of Moisture Content

Moisture content (%) of the grain samples was determined using a hot-air oven method as outlined by AOAC (2005). A thermostatically controlled oven maintained at 105 ± 2°C was used to ensure consistent drying conditions. For each millet variety, approximately 25–30 g of sample was accurately weighed into clean, dry, non-corrosive metal containers. The samples were placed in the oven and dried for 24 hours, following the standard analytical procedure. After the initial drying period, the containers were removed and allowed to cool in a desiccator to prevent moisture absorption from the atmosphere. The cooled samples were then reweighed. To confirm complete moisture removal, the drying–cooling–weighing cycle was repeated for an additional 2 hours until the sample reached a constant weight.

The moisture content was calculated using the following equation

$$\text{Moisture Content (wb, \%)} = \frac{100 \times (W_1 - W_2)}{W_1}$$

Where

- W_1= Initial weight of the sample (g)
- W_2= Final constant weight of the sample (g)

Geometric Properties

A set of 50 grains was randomly chosen, and their dimensions were recorded using a digital micrometer with a precision of 0.01 mm. The primary measurements taken included length (L), width (W), and thickness (T). The corresponding derived physical parameters were computed using the standard formulas described by Mohsenin (1986) [4].

Size

Fifty grains were randomly selected, and their length (L), width (W), and thickness (T) were measured using a digital Vernier caliper with an accuracy of ±0.01 mm, following the procedure described by Mohsenin (1986) [4]. The geometric mean diameter (Dg) was then computed using the standard mathematical relationship.

$$Dg=(L \times W \times T)^{1/3}$$

Sphericity (Φ)

Sphericity (%) refers to the proportion between the surface area of a sphere that has an equivalent volume to the grain and the actual surface area of the grain itself. It was computed using the following formula."

$$\Phi = \frac{Dg}{L}$$

1000-Grain Weight

A set of one thousand seeds was randomly taken from the bulk sample and weighed using an electronic balance with a capacity of 2000 g and an accuracy of 0.1 g. The procedure was repeated for three separate 1000-seed subsamples, and the average weight was recorded. The final measurements were noted with an instrument precision of ±0.001 g.

Gravimetric Properties (Mohsenin, N.N. 1986)

Bulk density (ρb) was obtained by introducing the sample into a 500 mL graduated cylinder under non-compacted conditions, avoiding any tapping to maintain natural packing.True density (ρt) was quantified using the toluene displacement approach, which allows accurate measurement of particle volume.

Bulk Density (ρb)

Bulk density (kg/m³) refers to the mass of a sample per unit of its total volume. It was measured by filling a 500 mL graduated cylinder with the millet grains and recording the weight. The bulk density value was then obtained by dividing the weight of the sample by the volume occupied in the cylinder, using the following formula:

$$\rho b = \frac{\text{Mass of Grains}}{\text{Volume of cylinder}}$$

True Density (ρt)

The toluene displacement method was employed to measure the true density (kg/m³), as toluene is non-polar and does not absorb moisture from the sample. True density was determined using a top-loading balance. Approximately 100 g of millet grains were carefully placed into a graduated beaker containing toluene, and the resulting volume

displacement was recorded. The true density was then calculated using the following equation.

$$\rho t = \frac{\text{Mass of grains}}{\text{Volume of toluene displayed or True Volume}}$$

Porosity (ε)

Porosity (%) refers to the proportion of the total bulk volume that is not filled by the grain particles. It was determined using the standard formula based on the measured values of true density and bulk density.

$$\text{Porosity } (\varepsilon) = \left(1 - \frac{\rho b}{\rho t}\right)$$

All parameters were measured in triplicate using standard methods described by Mohsenin (1986) [4].

Proximate Analysis

Proximate composition of both malted and unmalted kodo millet samples was determined according to AOAC (2019) methods:

Determination of Crude Protein (Kjeldahl Method)

Principle

During the Kjeldahl process, the organic nitrogen present in the sample is first digested and transformed into ammonium sulfate. When the digest is made alkaline during distillation, ammonia is liberated. This ammonia is collected in a boric acid solution and subsequently titrated with a standard acid. The measured nitrogen content is then multiplied by an appropriate conversion factor to estimate the crude protein level.

Procedure

1. Approximately 1 g of the oven-dried sample was placed in a Kjeldahl digestion flask.
2. A catalytic mixture consisting of potassium sulfate and copper sulfate, along with concentrated sulfuric acid, was added to the flask.
3. The sample was digested by heating until the mixture turned clear, indicating complete breakdown of organic matter.
4. After cooling, the digest was diluted with distilled water and transferred to the distillation apparatus.
5. A 40% sodium hydroxide solution was introduced to make the medium alkaline, enabling the release of ammonia.
6. The liberated ammonia was distilled and trapped in a boric acid solution containing a mixed indicator.
7. The collected distillate was titrated against standardized 0.1 N hydrochloric acid to determine the endpoint.
8. The percentage of total nitrogen was calculated from the titration values and converted to crude protein using the appropriate nitrogen-to-protein factor.

$$\text{Crude Protein } (\%) = \text{Nitrogen } (\%) \times 6.25$$

Determination of Crude Fat (Soxhlet Extraction)

Principle

Lipids present in the sample are isolated using a non-polar organic solvent while continuously refluxing the sample in an extraction system.

Procedure

1. About 2 g of the oven-dried sample was weighed and placed inside a cellulose extraction thimble.
2. The thimble was positioned in the Soxhlet extractor, and extraction was carried out using petroleum ether (boiling point 40–60°C) for approximately 6–8 hours.
3. Once the extraction cycle was completed, the solvent was removed by gentle evaporation on a water bath.
4. The extracted fat residue was then dried in a hot-air oven at 105°C until a constant weight was achieved.
5. The crude fat percentage was determined using the final weight of the extracted lipid fraction.

$$\text{Crude Fat } (\%) = \frac{\text{Weight of extracted fat}}{\text{Weight of sample}} \times 100$$

Determination of Total Ash

Principle

Ashing involves the combustion of all organic components in the sample, resulting in the residue of only inorganic mineral matter.

Procedure

1. Approximately 2 g of the sample was transferred into a pre-weighed crucible that had already been ignited and cooled.
2. The sample was slowly heated on a hot plate to carbonize it and avoid any loss due to splattering.
3. The crucible was then placed inside a muffle furnace and incinerated at 550 ± 10°C for 4–6 hours, or until a uniform light grey ash was obtained.
4. After ashing, the crucible was removed, cooled in a desiccator, and reweighed.
5. The ash content was calculated using the following formula:

$$\text{Total Ash } (\%) = \frac{W_{\text{ash}}}{W_{\text{sample}}} \times 100$$

Determination of Crude Fiber

Principle

The sample is subjected to controlled digestion using dilute acid followed by an alkaline solution to eliminate non-fibrous components. After these treatments, the remaining fibrous residue is dried, incinerated, and the loss in weight is used to quantify the crude fiber content.

Procedure

Digestion with Acid

Approximately 2 g of the defatted sample was heated with 1.25% sulfuric acid for 30 minutes to break down acid-soluble constituents.

Filtration and Washing

The hot mixture was filtered, and the residue was thoroughly rinsed with hot distilled water to remove traces of acid.

Alkaline Digestion

The residue was then boiled in 1.25% sodium hydroxide solution for another 30 minutes to dissolve alkali-soluble materials.

Drying
After a second filtration and washing, the material was dried in a hot air oven at 105°C and the constant weight was recorded.

Ignition
The dried residue was placed in a muffle furnace at 550°C to burn off all organic matter, leaving only ash.

Calculation
Crude fiber (%) was derived based on the weight difference between the dried residue and the ash content.

$$\text{Crude Fiber (\%)} = \frac{W_{\text{residue before ashing}} - W_{\text{ash}}}{W_{\text{sample}}} \times 100$$

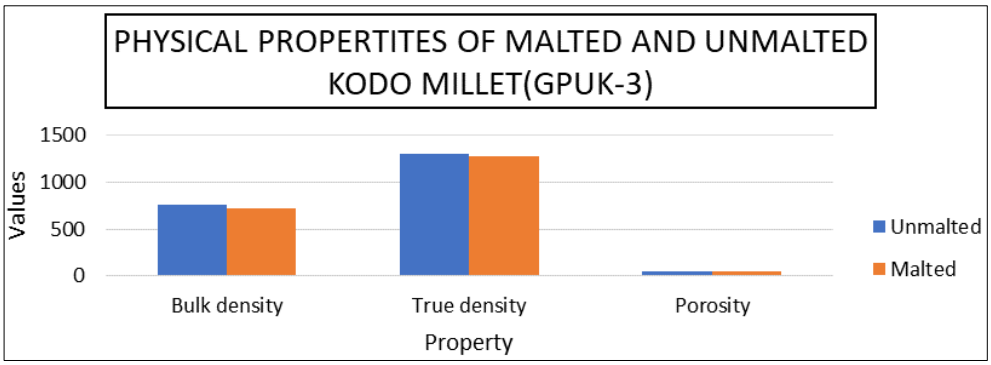
Statistical Analysis
All analyses were conducted in triplicate, and the corresponding mean values and standard deviations were calculated. Differences between malted and unmalted samples were evaluated using independent two-sample t-tests at a significance level of $p \leq 0.05$. Statistical evaluations were carried out using SPSS software (Version 25.0).

Results and Discussion
Physical Properties
Malting caused significant changes in most physical parameters of kodo millet grains. The mean ± SD values and p-values are presented in Table 1.

Table 1: Physical Properties of Malted and Unmalted Kodo Millet (GPUK-3)

Parameter	Unmalted (Mean ± SD)	Malted (Mean ± SD)	Unit	p-value
Moisture	11.66 ± 0.14	8.50 ± 0.02	%	**<0.001***
1000-grain weight	2.89 ± 0.03	2.12 ± 0.02	g	**0.0001***
Length	1.72 ± 0.03	1.62 ± 0.01	mm	**0.02***
Width	1.32 ± 0.03	1.30 ± 0.01	mm	n.s.
Thickness	1.11 ± 0.03	1.05 ± 0.01	mm	**0.01***
Size	1.36 ± 0.02	1.29 ± 0.01	mm	**0.001***
Surface area	5.82 ± 0.19	5.31 ± 0.01	mm^2	**0.02***
Sphericity	0.79 ± 0.00	0.78 ± 0.00	–	n.s.
Bulk density	762.75 ± 7.38	723.17 ± 2.09	kg/m^3	**0.003***
True density	1306.38 ± 19.17	1282.80 ± 2.71	kg/m^3	n.s.
Porosity	42.00 ± 0.82	43.47 ± 0.21	%	**0.01***

Malting significantly affected most physical and proximate characteristics of GPUK-3 Kodo millet. The reduction in 1000-grain weight and size parameters is consistent with enzymatic degradation of endosperm during germination, leading to partial loss of dry matter (Baskaran *et al.*, 2016).
Bulk density decreased after malting, indicating a more porous grain structure due to biochemical modification and breakdown of cell wall components. Similar trends were observed in malted finger millet and sorghum (Shimelis & Rakshit, 2007). The significant decrease in moisture content after kiln drying enhances storability and shelf-life, making malted millet suitable for premix formulation. An increase in porosity facilitates faster hydration, which is beneficial in instant mixes and complementary foods.
True density and sphericity did not change significantly, implying that the fundamental structural matrix of the grain remains largely intact. Reduced grain dimensions may aid in grinding and improve the yield of fine flour.
Overall, the results confirm that malting improves nutritional suitability of Kodo millet for food processing, especially in the development of fortified malted premixes, weaning foods, and instant beverages.



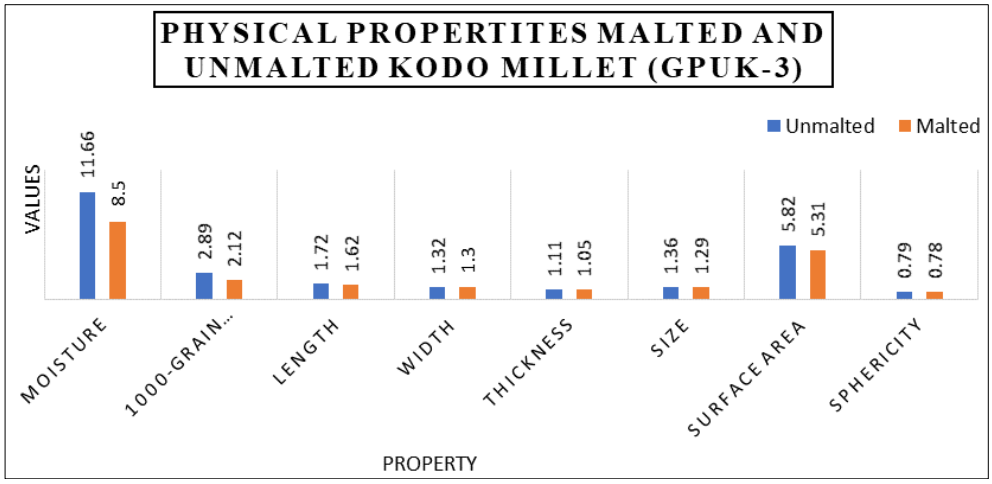


Fig 1: Comparative bar graph showing the physical properties of malted and unmalted Kodo millet (GPUK-3)

Proximate Composition

The proximate composition of malted and unmalted Kodo millet is summarized in Table 2.

Table 2: Proximate Composition of Malted and Unmalted Kodo Millet (GPUK-3)

Parameter	Unmalted (Mean ± SD)	Malted (Mean ± SD)	Unit
Moisture	0.07617 ± 0.00029	0.06817 ± 0.00015	g/g (dry basis)
Crude Protein	0.09030 ± 0.00017	0.11293 ± 0.00006	g/g
Crude Fat	0.04447 ± 0.00006	0.03850 ± 0.00000	g/g
Total Ash	0.01453 ± 0.00006	0.04233 ± 0.00006	g/g
Crude Fiber	0.00150 ± ~0.00000	0.00603 ± 0.00006	g/g

The proximate analysis of GPUK-3 Kodo millet revealed significant biochemical changes resulting from the malting process. Moisture content decreased from 0.07617 g/g to 0.06817 g/g, which is expected due to controlled kiln drying during malting. This reduction improves shelf stability and reduces microbial risk.

Crude protein increased markedly from 0.09030 g/g to 0.11293 g/g, indicating synthesis of enzymatic proteins and nitrogenous compounds during germination. Similar protein enhancement has been reported for malted millets due to mobilization of storage proteins.

Crude fat showed a slight decrease (0.04447 → 0.03850 g/g), reflecting utilization of lipids as an energy source during sprouting. This trend aligns with literature describing lipid breakdown during germination.

A major increase was observed in ash content (0.01453 → 0.04233 g/g), suggesting mineral concentration as moisture declines and organic matter is enzymatically degraded.

Crude fiber also increased significantly (0.00150 → 0.00603 g/g), which may be attributed to breakdown of cell wall components and increased structural fiber availability.

Overall, the results confirm that malting enhances the nutritional value of Kodo millet by increasing protein, fiber, and mineral content, while improving functional characteristics through moisture reduction. These changes make malted Kodo millet more suitable for fortified foods, health mixes, and value-added nutritional formulations.

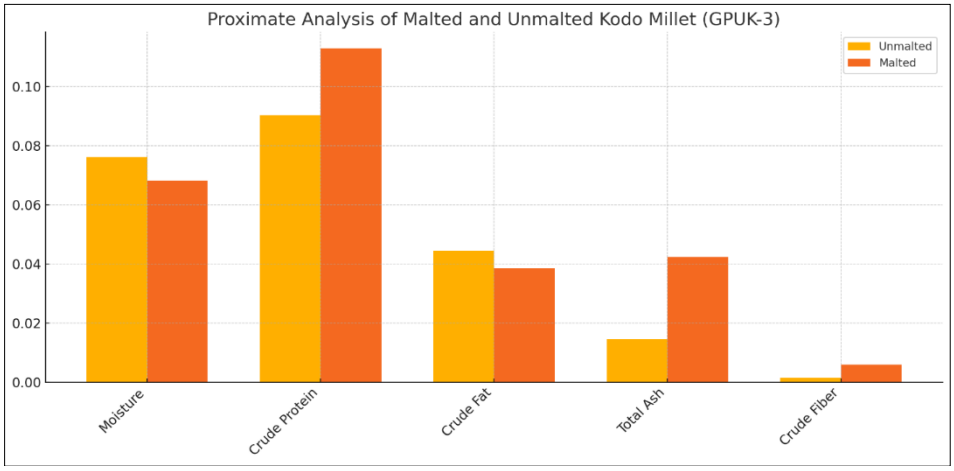


Fig 2: Comparative bar graph showing the proximate composition of malted and unmalted Kodo millet (GPUK-3)

Conclusion

Malting significantly influences both physical and proximate properties of GPUK-3 Kodo millet. Reduced grain size and bulk density, along with increased porosity, enhance its suitability for milling, hydration, and extrusion. Proximate composition improved notably, with increases in protein, fiber, ash, and fat, reflecting beneficial biochemical transformations. The decreased moisture level further enhances storability. These findings support the application of malted Kodo millet in developing fortified premixes, weaning foods, nutritional beverages, and value-added products.

References

1. AOAC International. Official Methods of Analysis. 21st ed. Washington (DC): Association of Official Analytical Chemists; 2019.
2. Baskaran V, Mahadevamma S, Tharanathan RN. Influence of malting on nutritional and functional characteristics of minor millets. J Food Sci Technol. 2016;53(4):245–52.
3. Dayakar Rao B, Bhaskarachary K, Arlene Christina GD, Sudha Devi G, Vilas AT. Millets—Value chain for nutritional security: A case study of intervention in Odisha. Hyderabad: ICAR–Indian Institute of Millets Research; 2017.
4. Mohsenin NN. Physical Properties of Plant and Animal Materials. 2nd ed. New York: Gordon and Breach Science Publishers; 1986.
5. Nithya DJ, Sujatha S. Nutritional and functional importance of Kodo millet (Paspalum scrobiculatum): A review. Int J Food Sci. 2019;8(2):45–52.
6. Saleh ASM, Zhang Q, Chen J, Shen Q. Millet grains: Nutritional quality, processing, and potential health benefits. Compr Rev Food Sci Food Saf. 2013;12(3):281–95.
7. Shimelis EA, Rakshit SK. Effect of processing on physicochemical and functional properties of legumes and cereals: A review. J Food Eng. 2007;80(2):225–31.
8. Thakur M, Saxena DC. Impact of malting conditions on functional properties, nutritional quality and antioxidant capacity of different millet varieties. J Cereal Sci. 2019;85:1–9.
9. Singh P, Raghuvanshi RS. Nutrient composition and antioxidant properties of raw and malted millets. Food Chem. 2016;220:703–9.
10. Kavitha R, Parimalavalli R. Effect of malting on proximate, mineral and functional properties of finger millet varieties. Int J Food Nutr Sci. 2014;3(4):50–6.
11. Tiwari A, Jha SK. Processing effects on nutritional and functional properties of millets: A review. J Appl Nat Sci. 2017;9(2):1136–44.
12. Udachan IS, Sahoo AK. Studies on malting characteristics of small millets and their impact on nutrient composition. J Food Process Preserv. 2017;41(2):e12850.