

Effect of drying methods on the drying behaviour and nutrient composition of tiger nut (*Cyperus esculentus*)

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Received 9th January 2026; Accepted 1st February 2026

ABSTRACT: This study compared parabolic solar drying and electric dehydrator drying of tiger nut (*Cyperus esculentus* L.) and evaluated their effects on moisture removal behaviour, proximate composition, selected minerals, phytochemical content, and rehydration ratio relative to a fresh control. One hundred grams of tiger nut tubers were cleaned, sorted, and decontaminated by washing with 1% NaCl solution. Samples were dried using a parabolic solar dryer (54–56°C, 48 h) and an electric dehydrator (60°C, 48 h). Proximate composition, mineral content, and phytochemical indices were determined for fresh and dried samples. Moisture, crude protein, crude fat, ash, crude fibre, and carbohydrate ranged from 9.75–54.00%, 2.64–5.17%, 8.01–10.00%, 0.50–2.00%, 9.01–11.09%, and 23.86–64.25%, respectively. Mineral concentrations (mg/100 g) ranged from 18.07–21.41 for magnesium, 3.56–8.18 for iron, and 1.51–3.34 for calcium. Total phenol, saponin, flavonoid, tannin, and alkaloid ranged from 4.20–7.19 mg/100 g, 6.47–9.30%, 4.29–13.25%, 9.29–12.57 mg/kg, and 3.50–5.55%, respectively. Based on percentage moisture reduction and final moisture values, the dehydrator achieved greater moisture removal than parabolic solar drying under the conditions tested, and dehydrator-dried samples showed higher rehydration ratios, indicating better water uptake during rehydration. In contrast, parabolic solar drying yielded higher values for several phytochemical indices (notably flavonoids and tannins). Overall, the results demonstrate trade-offs between moisture removal efficiency, phytochemical indices, and rehydration behaviour, suggesting that drying method selection should be guided by intended product use.

Keywords: Drying, rehydration ratio, tiger nut, parabolic solar dryer, electric dehydrator.

INTRODUCTION

Tiger nut (*Cyperus esculentus* L.) is a sweet, nut-like underground tuber from a perennial cyperaceous plant cultivated widely in tropical and subtropical regions, including Nigeria, Ghana, Togo, Côte d'Ivoire, Egypt, and Spain (Tasiu *et al.*, 2023). Tiger nut tubers contribute meaningful amounts of carbohydrate, lipids, dietary fibre, protein, minerals, and antioxidant-associated compounds such as ascorbic acid and tocopherols (Obinna-Echem *et al.*, 2024). Their nutritional composition varies with cultivar (black, brown, yellow), soil and growing conditions, agronomic practices, and postharvest handling (Yu *et al.*, 2022). Beyond macronutrients, tiger nut has been reported as a source of monounsaturated fatty acids, polyphenols, tocopherols, phytosterols, and other bioactive constituents

relevant to food quality and functionality (Rebezov *et al.*, 2023).

Fresh tiger nuts contain substantial moisture, which can limit storability and accelerate quality loss during handling and storage (Osae *et al.*, 2023). Moisture reduction through drying is therefore a common postharvest strategy to stabilise tubers by reducing available water and slowing degradative changes such as lipid rancidity and quality deterioration (Zhang *et al.*, 2022). Prior studies have examined the effects of convective hot-air drying conditions (e.g., temperature, humidity, air velocity) on tiger nut quality and have shown that both processing conditions and product geometry (whole, halved, pulverized) influence drying behaviour and quality outcomes (Li *et al.*,

2021; Abano *et al.*, 2021). More broadly, drying method and operating conditions can modify microstructure and physicochemical properties, particularly in products rich in unsaturated oils and bioactive compounds (Wang *et al.*, 2021).

Drying is a heat and mass transfer process that removes moisture and concentrates dry matter, and drying behaviour can be described using drying curves and related indices derived from weight loss over time (Cosme-De Vera *et al.*, 2021; Mabasso *et al.*, 2024). In practice, small- and medium-scale processors often choose between solar-based systems and electrically powered dehydrators depending on access to energy, operating stability, and desired product quality. Controlled solar dryers reduce direct exposure to dust and environmental contaminants compared with open sun drying and can improve product handling and quality consistency when appropriately engineered (Missana *et al.*, 2020). In Nigeria, the Nigerian Stored Products Research Institute (NSPRI) has developed a parabolic-shaped solar dryer (also described as a greenhouse-type solar dryer) designed to enhance drying efficiency through concentrated solar heating and protective coverings (Joel *et al.*, 2024). In contrast, electric food dehydrators provide more stable and controllable heat and airflow, which may promote faster moisture removal and produce different quality outcomes, including rehydration behaviour (Khairulnizam *et al.*, 2020).

Given the practical need to select drying methods that balance moisture removal efficiency with retention of nutritional and functional attributes, this study compared parabolic solar drying and electric dehydrator drying of tiger nut under defined time–temperature conditions. The work evaluated proximate composition, selected minerals, phytochemical indices, simple moisture reduction behaviour based on periodic weight measurements, and rehydration ratio relative to fresh tubers. The findings are intended to inform method selection based on targeted quality attributes, while recognizing that additional safety endpoints (water activity and microbiological measurements) are required to directly assess shelf-life and microbial stability.

MATERIALS AND METHODS

Tiger nut (*Cyperus esculentus* L.; yellow variety) tubers were purchased from Mile 1 Market, Port Harcourt, Rivers State, Nigeria. All chemicals and equipment used were obtained from the laboratories of the Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria.

Drying of tiger nut

Whole tiger nut tubers were dried using the method

described by Obinna-Echem *et al.* (2024) with modifications. One hundred grams (100 g) of tubers were cleaned, sorted, and washed with 1% (w/v) NaCl solution for decontamination, followed by rinsing with clean water and draining. The samples were dried using (i) a parabolic solar dryer at 54–56°C for 48 hours and (ii) an electric dehydrator at 60°C for 48 hours (Figure 1). After drying, samples were packaged in zip-lock bags and stored at ambient temperature until analysis.

Determination of proximate composition

Moisture, crude protein, crude fat, crude fibre, and ash contents were determined using AOAC methods (AOAC, 2023). Moisture content (AOAC 925.09) was determined gravimetrically by drying to constant weight at 70 °C in a hot-air oven (DHG 9140A). Crude fat was determined by Soxhlet extraction using diethyl ether as solvent. Crude protein (AOAC 991.20) was determined using the Kjeldahl method with a nitrogen-to-protein conversion factor of 6.25. Ash content (AOAC 942.05) was determined by incineration in a muffle furnace (Model SXL) at 550 °C for 2 h. Crude fibre (AOAC 978.10) was determined using an enzymatic–gravimetric method. Carbohydrate content was calculated by difference:

$$\text{Carbohydrate (\%)} = 100 - (\text{Protein} + \text{Fat} + \text{Fibre} + \text{Ash})$$

Determination of mineral composition

Mineral analysis was conducted using APHA 3030F nitric acid–hydrochloric acid digestion as described by (Amadi *et al.*, 2025). Briefly, 1.0 g of each sample was ashed and digested with 10 mL HNO₃. The digest was evaporated carefully to <5 mL, cooled, and 10 mL of 1:1 HCl was added. The mixture was heated to dissolve residues and filtered to remove insoluble material. The filtrate was transferred into a 100 mL volumetric flask and made up to volume with deionized water. Magnesium, calcium, and iron were determined using an atomic absorption spectrophotometer (Buck Scientific, Model 210). Mineral results were reported as mg/100 g sample.

Determination of phytochemical content

Phytochemical contents were determined using the method described by Nbaeyi-Nwaoha and Onwuka (2014). Total phenols and total tannins were determined using Folin–Ciocalteu-based colorimetric methods. Saponins were determined by double-solvent extraction (gravimetric). Alkaloids were determined by alkaline precipitation (gravimetric). Flavonoids were determined gravimetrically after solvent (80% methanol) extraction and evaporation of the extract to dryness.

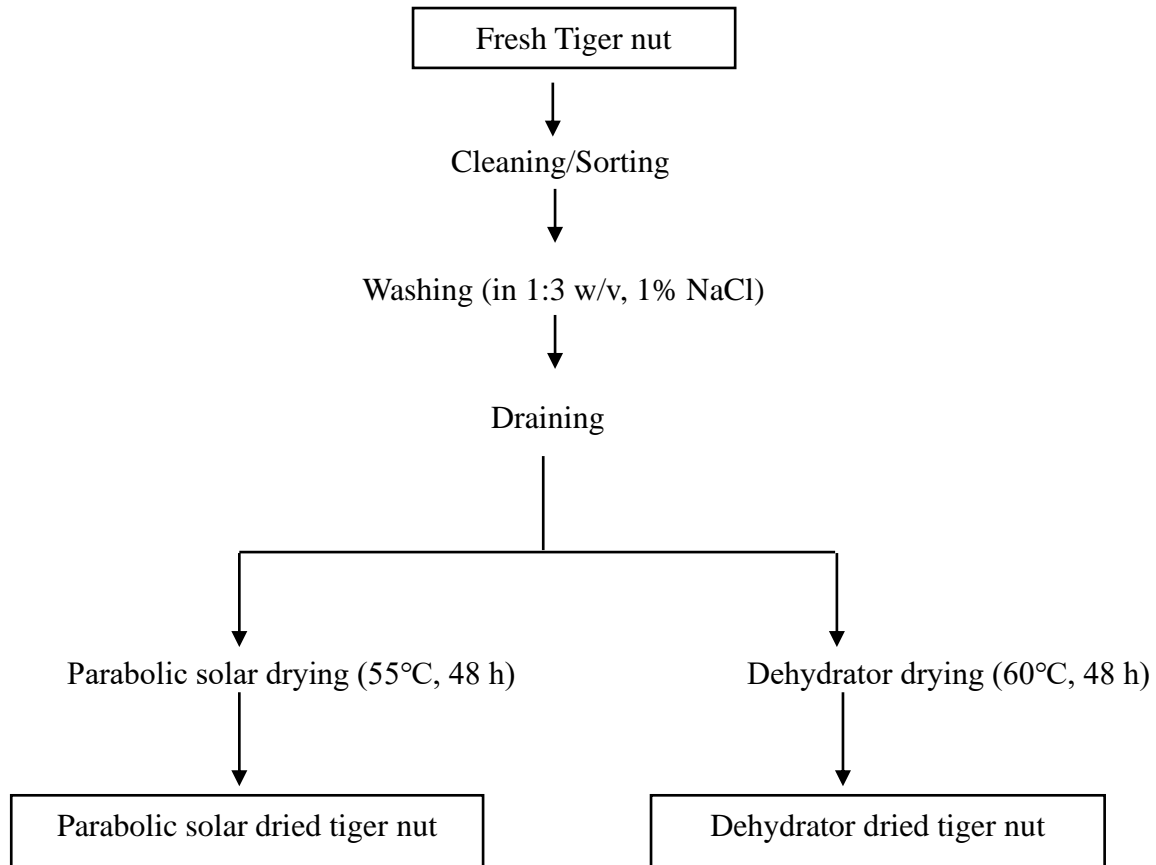


Figure 1. Drying of tiger nut using different methods (Source: Obinna-Echem *et al.*, 2024 with modifications).

Determination of drying behaviour (moisture reduction indices)

Drying behaviour was evaluated using periodic mass measurements. Samples were placed on perforated trays during drying, and mass was recorded at 24 h and 48 h using a digital weighing balance to monitor weight loss. Percentage moisture reduction (%MR) at time (t) was calculated as:

$$\%MR = \frac{M_0 - M_t}{M_0} \times 100$$

Where: M_0 = the initial moisture content (%), M_t = the moisture content (%) at time (t).

Because measurements were taken at 24-h intervals only, drying behaviour is presented as moisture reduction indices rather than thin-layer kinetic model parameters.

Determination of rehydration ratio

Rehydration ratio (RR) was determined as described by (Doymaz, 2013). Briefly, 2.0 g of dried tiger nut was placed in a 100 mL container, and 50 mL distilled water was

added. Samples were soaked in a constant-temperature water bath at 60°C for 5 h, removed, blotted with filter paper to remove surface water, and weighed. Rehydration ratio was calculated as:

$$RR = \frac{W_w}{W_d}$$

Where: W_w = the weight after rehydration and W_d = the weight before rehydration.

Statistical analysis

Data were analysed using IBM SPSS Statistics (version 26). Where applicable, analysis of variance (ANOVA) under a general linear model was performed, and means were separated using Tukey's test at 95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

Chemical composition of fresh and dried tiger nut

The proximate and mineral composition of fresh and dried

Table 1. Chemical composition (%) of fresh and dried tiger nut

Sample	Moisture	Crude Protein	Crude Fat	Ash	Crude Fibre	Carbohydrate	Magnesium (mg/100 g)	Iron (mg/100 g)	Calcium (mg/100 g)
FTN	54.00 ^a ±0.35	2.64 ^c ±0.01	10.00 ^a ±0.00	0.50 ^c ±0.00	9.01 ^c ±0.01	23.86 ^c ±0.33	18.07 ^c ±0.00	3.56 ^c ±0.00	1.51 ^c ±0.00
PSD	23.38 ^b ±0.53	4.31 ^b ±0.00	9.00 ^b ±0.00	2.00 ^a ±0.00	10.03 ^b ±0.01	51.29 ^b ±0.54	20.55 ^b ±0.28	8.18 ^a ±0.07	3.34 ^a ±0.07
DHD	9.75 ^c ±0.00	5.17 ^a ±0.04	8.01 ^c ±0.01	1.75 ^b ±0.00	11.09 ^a ±0.01	64.25 ^a ±0.02	21.41 ^a ±0.05	5.52 ^b ±0.05	2.14 ^b ±0.19

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscript are significantly different at $p < 0.05$. Keys: FTN = Fresh tiger nut, DHD = Dehydrator dried tiger nut, PSD = Parabolic solar dried tiger nut.

tiger nut samples is presented in Table 1. There was significant difference ($p < 0.05$) between samples in their proximate and mineral composition. Moisture content decreased markedly after drying, ranging from 54.00% in fresh tiger nut (FTN) to 23.38% in parabolic solar-dried tiger nut (PSD) and 9.75% in dehydrator-dried tiger nut (DHD). Lower moisture content reflects more effective moisture removal and is desirable for improving handling stability; however, this study did not measure water activity or microbiological quality, so direct conclusions about shelf-life or microbial safety are outside the scope of the present data. The lower final moisture observed for DHD indicates more efficient moisture removal under the conditions tested, consistent with reports that controlled mechanical drying can achieve greater moisture reduction than solar systems depending on operating conditions (Ibeoghu *et al.*, 2025).

Crude protein increased after drying, from 2.64% (FTN) to 4.84% (DHD) and 5.17% (PSD). This increase is expected because drying reduces water content and concentrates solids, resulting in higher measured nutrient proportions on a wet-weight basis. Similar increases in apparent protein concentration after drying of tiger nut have been reported in previous studies (Ibeoghu and Eze, 2022).

Crude fat decreased slightly across treatments,

from 10.00% (FTN) to 8.51% (DHD) and 8.01% (PSD). Changes in measured fat after drying may reflect oxidative degradation, thermal effects, or processing-related losses during drying and handling, particularly for products with appreciable unsaturated lipid content (Zhang *et al.*, 2022).

Ash content increased after drying, from 0.50% (FTN) to 1.75% (DHD) and 2.00% (PSD). Ash represents the inorganic residue after incineration and is commonly interpreted as an index of total mineral matter. The observed increase is consistent with concentration of inorganic constituents following moisture loss (Orisa *et al.*, 2023). Comparable increases in ash content after drying under solar and controlled drying conditions have been reported (Iordekighir *et al.*, 2025).

Crude fibre increased from 9.01% (FTN) to 9.33% (DHD) and 11.09% (PSD). Dietary fibre contributes to gastrointestinal function and metabolic health, and higher fibre values in dried samples may enhance their functional food potential. Increased fibre concentration after drying of tiger nut has also been reported by (Ibeoghu and Eze, 2022).

Carbohydrate increased substantially after drying, from 23.86% (FTN) to 56.57% (DHD) and 64.25% (PSD). As carbohydrates were calculated by difference, increases in measured carbohydrate reflect the combined concentration effects of moisture removal and shifts in the relative

proportions of other proximate components. It is also recognized that severe heat exposure can modify carbohydrate fractions through non-enzymatic browning reactions; however, this study did not quantify sugar profiles or browning indices (Zhang *et al.*, 2022).

Mineral concentrations (mg/100 g) generally increased after drying, consistent with concentration effects as water was removed. Magnesium ranged from 18.07 mg/100 g (FTN) to 19.88 mg/100 g (PSD) and 21.41 mg/100 g (DHD). The slightly higher magnesium level in DHD may reflect differences in final moisture content and processing conditions between the dryers (Ibeoghu and Eze, 2022).

Iron increased from 3.56 mg/100 g (FTN) to 6.18 mg/100 g (DHD) and 8.18 mg/100 g (PSD), while calcium increased from 1.51 mg/100 g (FTN) to 3.27 mg/100 g (DHD) and 3.34 mg/100 g (PSD). The increases in iron and calcium after drying are consistent with earlier findings that drying concentrates mineral constituents as moisture is reduced (Ibeoghu and Eze, 2022). Importantly, although PSD showed higher iron and calcium values than DHD, this cannot be attributed to lower residual moisture in PSD, because DHD had the lower final moisture content. Instead, the observed differences may reflect combined effects of method-specific conditions (e.g., temperature history, exposure environment) and analytical

Table 2. Phytochemical properties of fresh and dried tiger nut

Sample	Total phenol (mg/100 g DW)	Saponin (%)	Flavonoid (%)	Total Tannin (mg/kg)	Alkaloid (%)
FTN	7.19 ^a ±0.19	7.63 ^b ±0.18	4.29 ^b ±0.41	9.29 ^c ±0.23	3.50 ^c ±0.00
DHD	4.20 ^c ±0.14	6.47 ^c ±0.00	12.17 ^a ±0.24	10.26 ^b ±0.11	5.55 ^a ±0.07
PSD	6.12 ^b ±0.13	9.30 ^a ±0.42	13.25 ^a ±0.35	12.57 ^a ±0.08	4.10 ^b ±0.14

Values are means ± Standard Deviation of duplicate determinations. Means in the same column with different superscripts are significantly different at $p < 0.05$.

variability. From a nutritional perspective, higher iron content supports haemoglobin formation, while calcium supports bone health and neuromuscular function (Djikeng *et al.*, 2022). Overall, both drying methods increased measured mineral concentrations relative to the fresh sample, with method-dependent differences across specific minerals.

Phytochemical properties of fresh and dried tiger nut

The phytochemical indices of fresh and dried tiger nut samples are presented in Table 2. Total phenol content decreased after drying, ranging from 7.19 mg/100 g DW in fresh tiger nut (FTN) to lower values in the dried samples, with the lowest value observed in dehydrator-dried tiger nut (DHD; 4.20 mg/100 g DW). Differences in total phenols among treatments suggest that drying conditions can reduce measurable phenolic compounds, likely due to thermal and oxidative degradation during processing (Zhang *et al.*, 2022). In comparison, parabolic solar drying (PSD) retained higher phenolic levels than DHD, which may reflect differences in heat exposure profile and processing environment between the two methods (Djikeng *et al.*, 2022). There was significant difference between samples, in their total phenol content.

Saponin content ranged from 6.47% (DHD) to 9.30% (PSD). The higher saponin value in PSD may reflect concentration effects from moisture removal and/or increased extractability of saponins from the plant matrix following drying. Because saponins were determined by a gravimetric extraction approach, the measured differences are best interpreted as changes in the extractable fraction rather than de novo synthesis during drying. Similar increases in extractable saponins after drying have been reported previously (Kouame *et al.*, 2022; Djikeng *et al.*, 2022).

Flavonoid content showed no significant difference ($p < 0.05$) between the dried samples, and ranged from 4.29% (FTN) to 13.25% (PSD). Increased flavonoid values after drying may reflect a combination of concentration effects and enhanced extractability due to heat-induced disruption of cell structures and release of bound compounds (Rumicha *et al.*, 2025). The higher flavonoid content observed in PSD relative to DHD may indicate that the solar drying conditions used in this study better preserved flavonoid-related constituents or promoted their

extractability compared with dehydrator drying (Yu *et al.*, 2022). However, because the flavonoid method applied was gravimetric, results should be interpreted as “extractable flavonoid fraction” rather than a highly specific quantification of defined flavonoid standards.

Tannin levels ranged from 9.29 mg/kg (FTN) to 12.57 mg/kg (PSD), while alkaloid content ranged from 3.50% (FTN) to 5.55% (DHD). The observed increases in tannins and alkaloids after drying are consistent with concentration effects and changes in extractability following moisture loss. In addition, heating can alter polyphenolic profiles through oxidation and polymerisation pathways, which may affect the measured tannin fraction (Ibeogu and Eze, 2022). For alkaloids, higher values in dried samples may reflect both concentration and enhanced recovery during extraction following matrix disruption (Djikeng *et al.*, 2022). Overall, PSD tended to retain or yield higher values for several phytochemical indices, whereas DHD showed lower phenolic content but higher alkaloid content in this dataset.

Drying behaviour of tiger nut during drying (24 and 48 hours)

Percentage moisture reduction of tiger nut during drying at 24 and 48 hours is presented in Figure 2. At 24 hours, percentage moisture reduction was 41.37% for parabolic solar drying (PSD) and 66.31% for dehydrator drying (DHD). At 48 h, moisture reduction increased to 56.91% (PSD) and 82.03% (DHD). Consistent with these values, DHD exhibited a steeper moisture reduction trend and achieved a lower final moisture content (9.75%) than PSD (23.38%) over the same drying duration.

The greater moisture removal efficiency observed for DHD reflects the more stable heat supply and airflow conditions associated with electric dehydrator drying. Similar findings have been reported for tigernut and other tubers, where controlled convective drying resulted in faster moisture reduction and lower equilibrium moisture compared with solar-based systems under comparable drying times (Abano *et al.*, 2021; Iordekighir *et al.*, 2025).

Because mass measurements were obtained at 24-h intervals only, drying behaviour in this study is presented using percentage moisture reduction rather than instantaneous drying rate or thin-layer kinetic models. More frequent mass monitoring would be required to

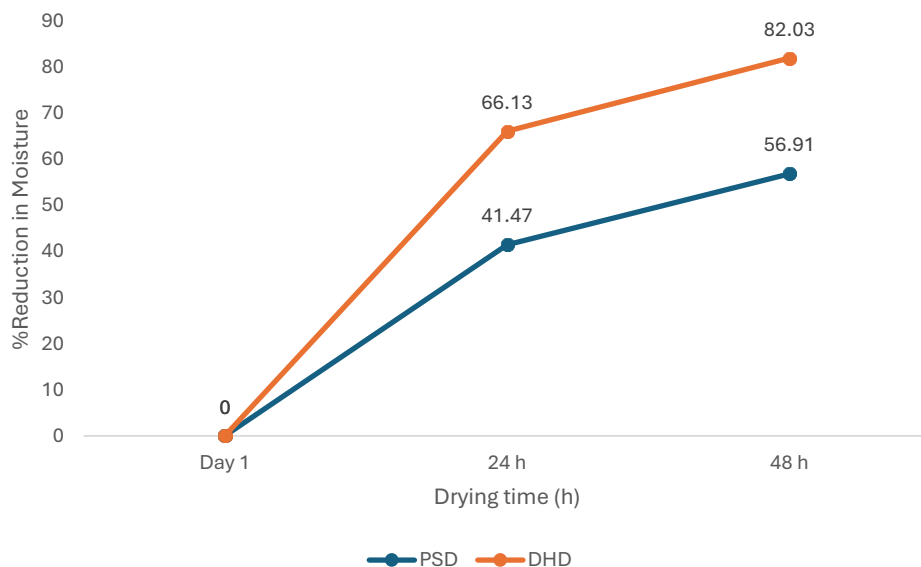


Figure 2. Percentage moisture reduction of tiger nut during drying at 24 h and 48 h under parabolic solar drying (PSD) and dehydrator drying (DHD). **Keys:** DHD = Dehydrator dried tiger nut, PSD = Parabolic solar dried tiger nut.

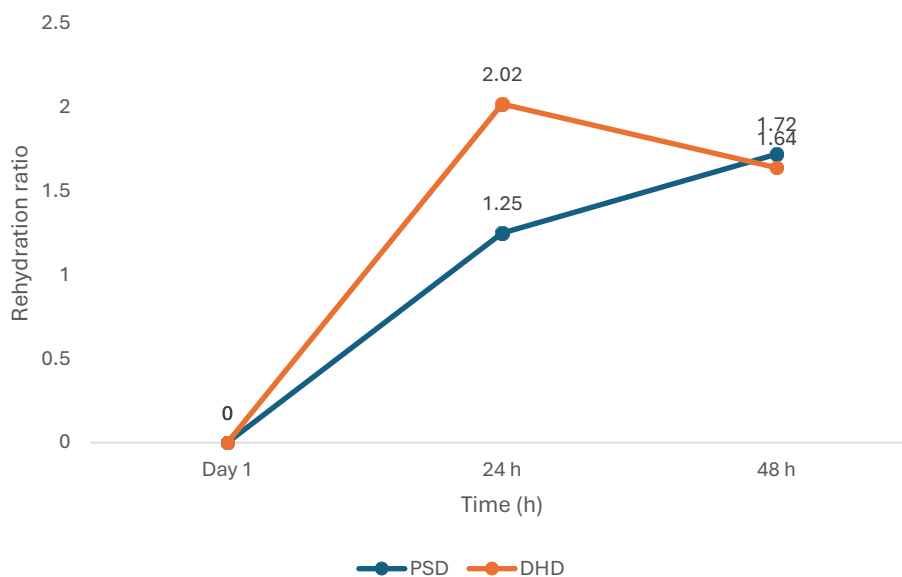


Figure 3. Rehydration ratio of tiger nut dehydrated using two different drying methods.

support model fitting and estimation of drying constants or effective moisture diffusivity in future studies.

Rehydration ratio of dried tiger nut (24 and 48 hours)

The rehydration ratio (RR) of dried tiger nut samples at 24 h and 48 hours is shown in Figure 3. At 24 hours, RR was 1.25 for parabolic solar-dried tiger nut (PSD) and 2.02 for dehydrator-dried tiger nut (DHD). At 48 h, RR increased to

1.64 (PSD) and 1.72 (DHD). Overall, DHD showed higher rehydration capacity than PSD, indicating that dehydrator drying produced samples with better water uptake upon rehydration under the conditions tested. Differences in RR between methods may reflect method-dependent structural changes during drying; however, microstructural measurements (e.g., microscopy or texture analysis) were not performed in this study, so mechanistic explanations such as “cell collapse” are presented as plausible interpretations rather than confirmed causes. Similar

relationships between drying conditions and reduced rehydration capacity due to structural alteration have been reported for dehydrated plant tissues (Osae *et al.*, 2023; Wang *et al.*, 2023).

Conclusion and Recommendation

This study showed that drying methods influenced the proximate composition, mineral content, phytochemical indices, moisture reduction behaviour, and rehydration capacity of tiger nut. Drying markedly reduces moisture content and concentrated measured nutrients and minerals relative to the fresh sample. Under the conditions tested, dehydrator drying (DHD) achieved greater moisture removal and a lower final moisture content than parabolic solar drying (PSD), and it produced samples with higher rehydration ratios, indicating better water uptake during rehydration. In contrast, PSD tended to retain higher values for several phytochemical indices (notably flavonoids and tannins) and yielded slightly higher calcium and iron values in this dataset, while the fresh sample showed the highest total phenol content.

Overall, the results demonstrate trade-offs between moisture removal efficiency, phytochemical retention, and rehydration behaviour. Therefore, selection of a drying method should be guided by the intended product application (e.g., products prioritising rehydration characteristics versus products prioritising phytochemical-related attributes). Because water activity and microbiological quality were not measured, the present findings should be interpreted primarily as a quality comparison rather than a direct assessment of shelf-life or microbial safety. Therefore, further study on the effect of the drying methods in the shelf-life of tiger nut is recommended.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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