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EFFECT OF SUN-DRYING ON THE PROXIMATE COMPOSITION AND PHYTOCHEMICAL PROFILE OF GINGER (*Zingiber officinale* Roscoe) RHIZOME FROM KACHIA, KADUNA STATE, NIGERIA

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ABSTRACT

Ginger (*Zingiber officinale*) is widely consumed as a spice and valued for its nutritional and bioactive constituents. This study evaluated the effect of sun-drying on the proximate and phytochemical composition of ginger collected from Kachia Local Government Area, Kaduna State, Nigeria. Proximate composition was determined using standard analytical procedures, while qualitative and quantitative phytochemical analyses were conducted on fresh and sun-dried samples using standard colour and precipitation reactions and spectrophotometric/gravimetric assays, respectively. All quantitative determinations were performed in triplicate and expressed as mean $\pm$ standard deviation (SD). Welch's independent-samples t-test showed significant differences ($p < 0.05$) between fresh and sun-dried ginger for all quantitative parameters evaluated. Sun-drying reduced moisture, ash, crude fibre, crude fat and crude protein, while calculated carbohydrate increased. Quantitative phytochemical contents of total phenolics, flavonoids, alkaloids, tannins and saponins also decreased significantly after drying. Qualitative screening detected alkaloids, flavonoids, tannins, phenols, saponins and terpenoids in both samples, whereas cardiac glycosides were detected only in fresh ginger. The findings demonstrate that sun-drying significantly altered the measured proximate and phytochemical profiles of ginger and highlight the need to optimize drying conditions for adequate moisture reduction while retaining valuable

nutrients and phytochemicals.

Keywords: Zingiber officinale; ginger; sun-drying; proximate composition; phytochemical screening

1. INTRODUCTION

Zingiber officinale (Ginger) is a widely used spice and medicinal plant known for its unique flavor and various health benefits. It is commonly used fresh or dried, with sun drying being a traditional method to preserve and enhance the shelf-life of ginger. Sun drying involves exposing ginger slices or rhizomes to direct sunlight, allowing for the removal of moisture content through evaporation. (Mascolo, *et al.*, 2019) The proximate composition of ginger, which includes parameters like moisture content, protein content, total carbohydrate content, ash content, lipid content, and fiber content, plays a crucial role in determining its nutritional value and functional properties. Understanding the effect of sun drying on the proximate composition of ginger is important for ensuring the quality, storage stability, and utilization of sun-dried ginger (Ugwoke, *et al.*, 2010).

Ginger has many medicinal uses; the fresh or dried rhizome is used in oral or topical preparations for treating a variety of ailments, while the essential oil is applied topically as an analgesic. Ginger is a kind of herbal plant that can strengthen the body and treat diseases. Scientists have found evidence to support a wide range of medicinal functions of Gingers. These functions include lowering cholesterol, relieving allergies, and asthma, arthritis, colds, and nausea, and protecting the digestive tract and liver against toxins and parasites (Imo, *et al.*, 2019) while the essential oil is used tropically as an analgesic. Ginger has been reported to have tenderization effect on meat. Tenderization is a quality of meat gauging, how easily it is chewed or cut. It can be increased by a number of processing techniques of Ginger such as sun-drying, oven- drying, impregnated feed; cooking etc. Meat tenderness is one of the most important eating quality parameters (Ghosh, *et al.*, 2011). Tenderness of meat is influenced by breed, age, feeding, suspension of carcass during slaughter, electrical stimulation, chilling rate and aging, mechanical, marination, freezing, thawing and cooking. Tenderness plays a very important role in deciding the quality of meat by consumers (Singletara, *et al.*, 2015) and is considered to be a critical component of processed meat. Since it ensured that meat reach an optimum level of tenderness before consumption.

Sun-drying is a common method used to preserve and store various food products including ginger. Sun-dried ginger is commonly used in various culinary applications such as seasoning, flavoring and herbal remedies.

Several studies have reported the effect of sun drying methods on the proximate composition of different food products. For example (Yu, *et al.*, 2014), investigated the effect of different drying method on the proximate composition of mush room they found that sun-drying resulted in a decrease in moisture content, and increase in protein content and no significant change in ash, lipid and fiber content respectively. Therefore, this study is aimed at determining the effect of sun drying on the proximate

composition and phytochemical profile of ginger rhizomes from Kachia Local Government Area, Kaduna State.

2.0 MATERIALS AND METHODS

2.1 Sample collection

Fresh ginger rhizomes were collected from Kachia Local Government Area, Kaduna State, Nigeria, placed in clean polyethylene bags and transported to the herbarium of the Department of Botany, Ahmadu Bello University, Zaria, for botanical identification and voucher-number documentation. The identified material was subsequently transported to the Biochemistry Laboratory of the Department of Science Laboratory Technology, Nigerian Institute of Leather and Science Technology (NILEST), Zaria, for processing and analysis.

2.2 Sample preparation and sun-drying

The rhizomes were washed to remove adhering soil and debris, peeled, inspected and sliced into relatively uniform pieces. The slices were spread in a single layer on clean drying trays and exposed to sunlight until the desired dryness was attained. Drying duration and prevailing environmental conditions should be recorded in the final experimental record because solar intensity, ambient temperature and relative humidity can influence drying kinetics and phytochemical retention. The dried material was milled to a uniform powder and stored in airtight containers protected from light and moisture until analysis.

2.3 Proximate composition

Moisture, ash, crude fat, crude protein, crude fibre and carbohydrate were determined using standard AOAC (2023) procedures.

Moisture was determined by oven drying to constant mass; ash by incineration in a muffle furnace; crude fat by Soxhlet extraction with an appropriate petroleum-ether fraction; crude protein by Kjeldahl digestion, distillation and titration; and crude fibre by sequential acid and alkali digestion. Carbohydrate was calculated by difference: $\% \text{ carbohydrate} = 100 - (\% \text{ moisture} + \% \text{ ash} + \% \text{ protein} + \% \text{ fat} + \% \text{ fibre})$.

2.4 Preparation of extracts

Fresh and sun-dried ginger samples were separately ground to a fine powder. Exactly 20g portion of each powdered sample was extracted with 200 ml 70% ethanol at room temperature with intermittent shaking. The extracts were filtered and concentrated at low temperature, and the concentrates were stored in clean, airtight amber containers until analysis.

2.5 Phytochemical Screening and Quantification

2.5.1 Qualitative phytochemical screening

Alkaloids (Wagner's test): A portion of each extract was acidified with dilute hydrochloric acid and filtered. Wagner's reagent was added dropwise. Formation of a brown or reddish-brown precipitate was recorded as a positive reaction (Ahmed *et al.*, 2022).

Flavonoids (alkaline reagent test): A portion of the extract was treated with dilute sodium hydroxide solution. Development of an intense yellow colour that disappeared or became markedly lighter following acidification was recorded as evidence of flavonoids (Ahmed *et al.*, 2022).

Tannins (ferric chloride test): The extract was diluted with distilled water and treated with a few drops of 5% ferric chloride solution. Development of a blue, blue-black or greenish-black colour was interpreted as a positive reaction for tannins (Ahmed *et al.*, 2022; Akullo *et al.*, 2023).

Saponins (froth test): The extract was diluted with distilled water and vigorously shaken in a stoppered test tube. Persistent froth/foam that remained after standing was recorded as evidence of saponins (Ahmed *et al.*, 2022).

Phenols (ferric chloride test): The aqueous/alcoholic extract was treated with ferric chloride reagent. Development of a characteristic dark green, blue or bluish-black colour was recorded as a positive reaction for phenolic compounds (Shalaby *et al.*, 2023).

Terpenoids (Salkowski reaction): The extract was dissolved in chloroform and carefully layered/treated with concentrated sulphuric acid. Development of a reddish-brown colour at the interface was recorded as evidence of terpenoids (Ahmed *et al.*, 2022).

Cardiac glycosides (Keller–Killiani reaction): The extract was treated with glacial acetic acid containing a trace of ferric chloride and carefully layered with concentrated sulphuric acid. Formation of a characteristic brown/reddish-brown ring at the interface, with an associated bluish-green coloration in the upper layer, was interpreted as a positive reaction for cardiac glycosides (Ahmed *et al.*, 2022).

2.5.2 Quantitative phytochemical determination

Total phenolic content: Total phenolics were determined by the Folin–Ciocalteu colorimetric method using gallic acid as the reference standard. An aliquot of extract was mixed with Folin–Ciocalteu reagent and sodium carbonate solution, allowed to develop colour under the specified reaction conditions, and absorbance was measured spectrophotometrically against a reagent blank. A gallic-acid calibration curve was prepared from standard solutions, and results were expressed as mg gallic acid equivalents per gram of extract (mg GAE/g extract) (Shalaby *et al.*, 2023; Akullo *et al.*, 2023).

Total flavonoid content: Total flavonoids were determined by an aluminium-based colour-development assay using quercetin as the reference standard. The extract was reacted with sodium nitrite, aluminium salt reagent and alkaline solution according to the assay sequence, and absorbance was measured against a reagent blank. A quercetin calibration curve was used for quantification, and results were expressed as mg quercetin equivalents per gram of extract (mg QE/g extract) (Shalaby *et al.*, 2023; Akullo *et al.*, 2023).

Total alkaloid content: Total alkaloids were estimated after extraction/fractionation of the alkaloid-

containing fraction. The recovered alkaloid fraction was dried to constant mass and expressed as a percentage of the dry extract. The same extraction and weighing procedure was applied to both fresh and sun-dried samples.

Total tannin content: Total tannins were quantified using a colourimetric ferric/Folin-type assay with an appropriate tannin standard. Absorbance of the developed colour was measured spectrophotometrically against a reagent blank and the concentration was obtained from the calibration curve. Results were expressed as percentage of dry extract (Akullo *et al.*, 2023).

Total saponin content: Total saponins were determined gravimetrically following solvent extraction and concentration of the saponin-containing fraction. The dried residue was weighed and expressed as a percentage of the dry extract.

2.6 Data presentation and statistical reporting

All quantitative determinations were carried out in triplicate ($n = 3$), and results were expressed as mean $\pm$ standard deviation (SD). Differences between fresh and sun-dried ginger samples were evaluated using an independent-samples Welch's t-test, which does not assume equal variances. Statistical significance was accepted at $p < 0.05$. Qualitative phytochemical results were treated as categorical presence/absence observations and were not assigned t-test p-values.

3.0 RESULTS

Table 1: Proximate composition of fresh and sun-dried ginger

Proximate component	Fresh ginger (% mean $\pm$ SD)	Sun-dried ginger (% mean $\pm$ SD)	p-value
Moisture	6.50 $\pm$ 0.21 ^a	5.00 $\pm$ 0.18 ^b	<0.001
Ash	7.50 $\pm$ 0.15 ^a	6.00 $\pm$ 0.17 ^b	<0.001
Crude fibre	43.00 $\pm$ 0.65 ^a	41.50 $\pm$ 0.58 ^b	0.0413
Crude fat	11.80 $\pm$ 0.31 ^a	10.26 $\pm$ 0.27 ^b	0.0031
Crude protein	21.56 $\pm$ 0.42 ^a	18.13 $\pm$ 0.39 ^b	<0.001
Carbohydrate	9.64 $\pm$ 0.52 ^a	19.11 $\pm$ 0.61 ^b	<0.001

Table 2: Qualitative phytochemical profile of fresh and sun-dried ginger

Phytochemical	Fresh ginger	Sun-dried ginger
Alkaloids	+	+
Flavonoids	+	+
Tannins	+	+
Saponins	+	+
Phenols	+	+
Terpenoids	+	+
Cardiac glycosides	+	–

Note: + = detected; – = not detected.

Table 3: Quantitative phytochemical profile of fresh and sun-dried ginger

Parameter	Unit	Fresh ginger (mean $\pm$ SD)	Sun-dried ginger (mean $\pm$ SD)	p-value
Total phenolic content	mg GAE/g extract	18.42 $\pm$ 0.64 ^a	15.27 $\pm$ 0.51 ^b	0.0031
Total flavonoid content	mg QE/g extract	7.36 $\pm$ 0.28 ^a	5.91 $\pm$ 0.24 ^b	0.0026
Total alkaloid content	% dry extract	2.84 $\pm$ 0.12 ^a	2.31 $\pm$ 0.10 ^b	0.0046
Total tannin content	% dry extract	1.92 $\pm$ 0.08 ^a	1.54 $\pm$ 0.07 ^b	0.0037
Total saponin content	% dry extract	3.18 $\pm$ 0.14 ^a	2.76 $\pm$ 0.11 ^b	0.0168

4.0 DISCUSSION

The present study demonstrates that sun-drying altered both the proximate composition and phytochemical profile of ginger (*Zingiber officinale*) collected from Kachia, Kaduna State. The reduction in moisture from $6.50 \pm 0.21\%$ in fresh ginger to $5.00 \pm 0.18\%$ in sun-dried ginger is consistent with the primary objective of drying, namely removal of water to improve storage stability. Similar reductions in moisture have been reported for dried ginger, although the magnitude depends strongly on drying method, temperature, slice thickness and environmental conditions (Odunukan *et al.*, 2022; Osae *et al.*, 2021). Osae *et al.* (2021) reported moisture contents as low as 5.45% in ginger subjected to relative-humidity convective drying. Recent work also confirms that drying temperature affects ginger drying kinetics and quality attributes (Shaukat *et al.*, 2024).

Ash decreased from $7.50 \pm 0.15\%$ in fresh ginger to $6.00 \pm 0.17\%$ after sun-drying. This agrees with the general observation that processing can alter the apparent proximate composition of ginger (Odunukan *et al.*, 2022). However, the decrease cannot automatically be interpreted as direct destruction of minerals,

because ash measures total inorganic residue and can be influenced by physical losses during washing, peeling, slicing and handling as well as changes in the analytical basis. Thus, the present result indicates an alteration in the measured mineral-residue fraction rather than proving loss of specific mineral elements.

Crude fat decreased from $11.80 \pm 0.31\%$ to $10.26 \pm 0.27\%$ after sun-drying. A similar reduction in proximate lipid values following ginger drying has been reported by Odunukan *et al.* (2022). The decrease may be associated with oxidation of susceptible lipids, volatilisation or physical loss during processing. Drying can also affect ginger volatile constituents and essential-oil composition. Osae *et al.* (2021) demonstrated substantial differences in essential-oil profiles among different drying techniques. This supports the interpretation that drying conditions can influence both measured fat and the broader volatile fraction.

Crude fibre decreased from $43.00 \pm 0.65\%$ to $41.50 \pm 0.58\%$ following sun-drying. The high fibre values in both samples indicate that ginger rhizome contains a substantial structural carbohydrate fraction. The observed reduction differs from some reports in which fibre was relatively stable or increased after drying, highlighting the influence of cultivar, maturity, drying conditions and analytical procedures.

Crude protein declined from $21.56 \pm 0.42\%$ in fresh ginger to $18.13 \pm 0.39\%$ in sun-dried ginger. The direction of change is comparable with observations that drying can modify the proximate protein fraction of ginger, although the magnitude varies among studies (Odunukan *et al.*, 2022). Prolonged exposure to heat, oxygen and sunlight may promote protein denaturation and other chemical changes, while physical losses and changes in the relative proportions of other constituents can also influence the calculated percentage. The result suggests that uncontrolled sun-drying may be less favourable than optimized drying when preservation of the measured protein fraction is a priority.

Carbohydrate increased from $9.64 \pm 0.52\%$ in fresh ginger to $19.11 \pm 0.61\%$ in sun-dried ginger. This finding differs from some earlier reports of ginger drying and the apparent increase therefore does not demonstrate carbohydrate synthesis during drying; it could result from changes in the relative proportions of moisture, protein, fat, fibre and ash. Differences in cultivar, maturity, drying conditions and analytical procedures may also explain disagreement with earlier reports (Odunukan *et al.*, 2022).

Qualitative phytochemical screening detected alkaloids, flavonoids, tannins, saponins, phenols and terpenoids in both fresh and sun-dried ginger, whereas cardiac glycosides were detected only in the fresh sample. The broad occurrence of these phytochemical classes is consistent with reports describing ginger as a chemically diverse rhizome containing phenolic compounds, flavonoids, terpenoid constituents and other secondary metabolites (Garza-Cadena *et al.*, 2023; Gao *et al.*, 2024). The disappearance of the cardiac-glycoside reaction after drying should be interpreted cautiously because qualitative phytochemical tests depend on extraction efficiency, reagent specificity and detection thresholds.

Quantitative phytochemical analysis showed that total phenolic content decreased from 18.42 ± 0.64 to

15.27 ± 0.51 mg GAE/g extract, while total flavonoid content decreased from 7.36 ± 0.28 to 5.91 ± 0.24 mg QE/g extract. These reductions are consistent with studies showing that drying method can significantly affect phenolic and flavonoid retention in ginger. Chen *et al.* (2023) reported lower polyphenol and flavonoid retention under hot-air and natural drying than under vacuum freeze-drying, while Ghafoor *et al.* (2020) demonstrated substantial differences in total phenolics among oven-, microwave-, freeze- and air-dried ginger. Osae *et al.* (2021) likewise found marked differences in total phenolic content among drying technologies. These findings support the interpretation that the reduction observed in the present study may be related to thermal, oxidative and light exposure during uncontrolled sun-drying.

Total alkaloid content decreased from $2.84 \pm 0.12\%$ to $2.31 \pm 0.10\%$, total tannin from $1.92 \pm 0.08\%$ to $1.54 \pm 0.07\%$, and total saponin from $3.18 \pm 0.14\%$ to $2.76 \pm 0.11\%$ after sun-drying. Although fewer recent studies quantify these groups in ginger than phenolics and flavonoids, the direction of change is compatible with evidence that drying can alter secondary metabolites through oxidation, thermal transformation and changes in extractability. Chen *et al.* (2023) similarly demonstrated that drying conditions affected the retention of functional components in ginger. The present findings therefore suggest that open sun-drying may reduce the extractable concentration of several phytochemical classes even when the compounds remain qualitatively detectable.

Overall, the findings agree with current literature showing that drying is a critical processing step that can improve moisture stability while altering nutritional and phytochemical quality. Recent studies demonstrate that drying technology affects gingerols, shogaols, phenolics, flavonoids, antioxidant activity and volatile compounds (Ghafoor *et al.*, 2020; Osae *et al.*, 2021; Chen *et al.*, 2023; Gao *et al.*, 2024). The reduction in phenolic and flavonoid contents observed in the Kachia sample therefore supports the use of controlled drying conditions where preservation of bioactive compounds is a major objective. Future investigations should compare sun-drying with standardized solar, shade, oven, vacuum and freeze-drying and quantify individual gingerols and shogaols using HPLC or LC–MS (Maghraby *et al.*, 2023; Gao *et al.*, 2024).

5.0 CONCLUSION

This study demonstrated that sun-drying significantly affected the proximate and phytochemical composition of ginger (*Zingiber officinale*). Statistical analysis of triplicate determinations showed significant differences ($p < 0.05$) between fresh and sun-dried ginger for all quantitative parameters evaluated. Sun-drying significantly reduced moisture, ash, crude fibre, crude fat and crude protein contents, while calculated carbohydrate content increased significantly. The reduction in moisture indicates effective water removal and may contribute to improved storage stability. However, the significant decreases in protein, fat, fibre and ash indicate that the drying process also altered the measured nutritional composition. Quantitative phytochemical analysis further showed significant reductions in total phenolics, flavonoids, alkaloids, tannins and saponins following sun-drying. Qualitative screening showed that alkaloids, flavonoids, tannins, saponins, phenols and terpenoids remained detectable after

drying, whereas cardiac glycosides were detected only in fresh ginger. Overall, the experimental findings establish that sun-drying significantly alters the measured nutritional and phytochemical profile of ginger. Drying conditions should therefore be optimized to achieve adequate moisture reduction while minimizing losses of valuable nutrients and phytochemicals.

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