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Investigation of Drying Methods, Storage Effects, and Quality Attributes of Dried Okra for Soup Production: A Comprehensive Nutrient Content Analysis

Dr. Fadimatu M. Maigari[1]; Bashiru Dahiru[2]; & Professor Caleb Filli Bulus[3]

[1]Department of Nutrition and Dietetics, Federal Polytechnic Mubi. [2]Department of Horticulture, Federal Polytechnic Mubi. [3]Department of Food Science and Technology, Modibbo Adama University Yola
Corresponding Author: matafadimatu@gmail.com
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Abstract

This study investigated the effects of different drying methods on the nutritional composition and microbiological quality of okra (*Abelmoschus esculentus*) intended for soup production. Fresh okra samples were processed using solar drying and oven drying at 50 °C and 60 °C, and the resulting products were evaluated for proximate composition, vitamin content, mineral composition, and microbial quality using standard analytical procedures. Drying significantly ($p < 0.05$) reduced moisture content compared with fresh okra, with values ranging from 9.56–16.10% for solar-dried samples and 12.41–17.34% for oven-dried samples at 50 °C, compared to 28.19–39.04% in fresh samples. Crude protein (19.80–21.71%) and crude fibre contents increased after drying, while ash content showed slight variation. Carbohydrate content increased markedly in dried samples (28.08–50.84%) due to moisture loss. Vitamin C and β-carotene contents decreased significantly following drying, with values ranging from 4.17–6.84 mg/100 g and 0.95–13.25 mg/100 g, respectively, reflecting the heat sensitivity of these vitamins. Mineral contents, including potassium (353.30–524.12 mg/100 g), iron (0.67–4.50 mg/100 g), zinc (0.60–3.86 mg/100 g), and calcium (82.71–802.00 mg/100 g), were higher in dried okra than in fresh samples, attributable to concentration effects following dehydration. Microbiological analysis showed total aerobic plate and fungal counts within acceptable limits for all samples, although solar-dried okra exhibited relatively higher microbial loads compared to oven-dried samples. Predominant microorganisms identified included *Lactobacillus*, *Bacillus*,

Pseudomonas, *Proteus*, *Enterobacter*, and *Escherichia coli*. Overall, oven drying at 50 °C emerged as the most effective method, offering superior retention of nutrients and better microbial quality, while solar drying provided acceptable preservation under controlled conditions. These findings demonstrate that appropriate drying techniques can enhance the shelf life, nutritional quality, and safety of dried okra, supporting its suitability for household and small-scale soup production.

Keywords: Drying methods, Nutritional composition, Vitamin retention, Mineral content, Microbial quality.

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Introduction

Okra (*Abelmoschus esculentus*) is an important vegetable crop widely cultivated in tropical and subtropical regions due to its nutritional, medicinal, and economic value. It is rich in dietary fiber, vitamins (A, C, and K), minerals, antioxidants, and bioactive compounds that contribute to human health and disease prevention. Fresh okra, however, is highly perishable because of its high moisture content and susceptibility to microbial spoilage, enzymatic degradation, and physical damage during storage and transportation. These characteristics result in significant postharvest losses, particularly in developing countries where cold-chain infrastructure is limited (Arapitsas, 2021).

Drying is one of the oldest and most widely used preservation methods for extending the shelf life of fruits and vegetables. By reducing water activity, drying inhibits microbial growth and slows enzymatic reactions responsible for deterioration. Traditional sun drying remains common in many rural areas because of its low cost and simplicity, but it is often associated with contamination, nutrient losses, poor color retention, and inconsistent product quality. Modern drying technologies—including oven drying, microwave-assisted drying, and solar drying—have been developed to improve efficiency, hygiene, and product characteristics (Deng et al., 2019; Tao et al., 2022).

The choice of drying method significantly influences the physicochemical properties, nutritional composition, and sensory quality of dried vegetables. Temperature, drying rate, air velocity, and pretreatment conditions affect moisture removal kinetics and structural changes within plant tissues. Excessive heat exposure can degrade heat-sensitive nutrients such as vitamin C and phenolic compounds, while inadequate drying may result in microbial instability during storage. Recent studies have demonstrated that optimized drying conditions can preserve color, texture, antioxidant capacity, and rehydration

properties, thereby enhancing consumer acceptability and market value (Nowacka et al., 2021).

In addition to drying conditions, storage duration and packaging also play critical roles in maintaining the quality of dried products. Exposure to oxygen, moisture, light, and fluctuating temperatures can lead to lipid oxidation, discoloration, loss of bioactive compounds, and microbial contamination. Proper storage strategies are therefore essential to ensure the long-term stability and safety of dried vegetables. Research indicates that moisture-proof packaging and controlled storage environments can significantly reduce quality deterioration and extend shelf life (Singh et al., 2020).

Despite the availability of various drying technologies, there remains a need to evaluate their comparative effectiveness for specific crops such as okra, particularly under local processing conditions. Understanding how different drying methods influence nutritional quality, physical properties, and storage stability is crucial for developing appropriate preservation strategies for small-scale farmers and food processors. Such information can contribute to reducing postharvest losses, improving food security, and promoting value addition in vegetable production systems.

Therefore, this study investigates the effects of different drying methods on the quality characteristics and storage stability of okra. By comparing the performance of selected techniques, the research aims to identify suitable processing options that balance efficiency, product quality, and practicality for local application.

Sample collection

Fresh, mature, and disease-free okra pods were obtained from a local Mubi main market shortly after harvest. The samples were carefully sorted, washed with clean water, and sliced uniformly to ensure even drying across all treatments and conveyed to the Department Nutrition and Dietetics Technology Federal Polytechnic Mubi in polythene bags for analyses.

Preparation of Samples

The okra sample was sorted from injured and deteriorated vegetable, washed under running tap water and weighed. The cleaned vegetable were cut into small slices (1cm in length) using sterilized stainless steel knives, and were placed into trays pending the drying process.

Drying Techniques

Two drying methods were investigated. These included sun (solar) drying and oven drying methods

For solar drying the okra ample were placed inside a solar dryer with perforated trays for better air movement around the samples. The reflection of the sun on the glass increases the drying temperature.

For oven drying, the method of Mbah *et al.*(2012) was engaged with little modification. Each vegetable were placed inside different trays and were dried using force air. The oven was preheated 50oC and 600C for the sample and was left for 12 hours to allow for complete

drying. The samples were allowed to cool before they were packed inside air tight container to avoid heat which could lead to caking before analysis.
For Freeze Drying, the slices sample was frozen at −40 °C and dried using a freeze dryer under vacuum conditions. This method will serve as a nutrient retention benchmark.
The drying characteristics, including moisture loss and drying time, were monitored throughout the process using standard gravimetric methods.
After drying, the samples were packaged in airtight containers and low-density polyethylene bags and stored at ambient temperature. Storage effects were evaluated over periods of zero, one, two, three, four and five months

Determination of the Proximate Composition and Mineral Contents
The proximate composition of the fresh and dried samples of okra for ash, moisture, crude fat, crude protein (N x 6.25), crude fiber and carbohydrate (by different) were determined in accordance with the methods as described by (Wójcik *et al*., 2021) .All proximate analyses of the samples were carried in duplicate and reported in percentage .All chemical were of Analar grade. The minerals potassium (K), calcium (Ca), zinc (Zn) and iron (Fe)] in the dried vegetables were analysed as described by A.O.A.C (2012) using atomic absorption spectrophotometer(perkin- Elmer Model 403,Norwalk CT).All the minerals determined were reported in mg/100g sample.

Determination of vitamin C and β-Carotenecontent (Pro-vitamin A)
The quantitative analysis of ascorbic acid content (vitamin C) of fresh, sun dried and oven dried vegetables was carried out using high-performance liquid chromatography-HPLC (Waters Alliance, Milford, Massachusetts, USA) as described by Maia *et al*.,
(2007). The quantification of ascorbic acid was done using a calibration curve of L-ascorbic acid standard. The β-Carotene content (Pro-vitamin A) of fresh, and oven dried vegetable samples was done using an autosampler Shimadzu Ultra-Fast Liquid Chromatography. Sample extraction and mobile phase preparation was done following the methods of (Abd El-Migeed,et al.,(2021) and (Kimura *et al*.,2007). Identification of the all-*trans*-β-carotene was calculated using retinol activity equivalents (RAE) conversion factor of 12 μg β-carotene to 1 μg retinol (Joint FAO/WHO 2003).

Preparation of media
All media used for the enumeration of bacteria cells and isolation of microorganisms from the vegetable samples were prepared according to the manufacturer's instruction.

Isolation and enumeration
Total bacterial count was determined using the method of Obasi *et al.* (2023). The stock solution was prepared by dissolving one millimeter (1ml) of the sample of the fresh and dried vegetable samples in nine millimeter (9ml) of sterile peptone water. Serial dilution (10 fold) was carried out (1:10, 1: 100, 1:1000…10,0000). 1.0ml of appropriate dilutions (10-2 and 10-

4) was placed on various agar plates using pour plate method and incubated at 370c for 18-24 hours for total aerobic bacteria and coliform count. For fungi 1.0ml amount of appropriate dilutions (10-2 and 10-4) was poured into the plates of potato dextrose agar and incubated at room temperature 28±10c for 3 to 5 days. All enumeration was expressed as colony forming unit (cfu/ml).

Identification and characterization of theisolates

Bacterial isolates were characterized using routine microbiological procedures as described by Ayeloja *et al.*, (2018) and Obasi *et al.* (2023) after which they were identified using Bergey's Manual of Determinative Bacteriology as described by John *et al* (1994).

Statistical Analysis

All analysis were carried out in duplicate and data obtained were subjected to one way analysis of variance (ANOVA) using statistical package for social science (SPSS) version 20:00. Separation of mean values were done using Duncan's New Multiple Range Test (DNMRT) at 5% significance level.

Nutritional Composition of the Fresh and Dried Vegetable Samples

Table 4 presents the proximate composition of fresh and dried okra samples processed using solar drying and oven drying at 50 °C and 60 °C. The parameters evaluated included moisture, crude protein, fat, crude fibre, ash, and carbohydrate contents.

Moisture Content

The moisture content of the okra samples differed significantly ($p < 0.05$), ranging from 9.56% to 28.59%. Fresh okra recorded the highest moisture content (28.19%), while solar-dried okra exhibited the lowest (9.56%). Oven-dried samples showed intermediate values, with moisture content decreasing as drying temperature increased. The reduction in moisture content following drying indicates effective water removal, which is critical for extending shelf life and reducing microbial growth. Similar moisture trends in dried vegetables have been reported in recent studies on dehydration processes (Nowacka et al., 2021; Tao et al., 2022). Low moisture levels enhance storability by limiting mould growth, enzymatic reactions, and microbial proliferation.

Crude Protein

Crude protein content of the dried okra samples ranged from 19.80% to 21.71%. Oven drying at 50 °C resulted in the highest protein retention, whereas oven drying at 60 °C showed a slight reduction. The observed variation may be attributed to thermal denaturation and degradation of proteins at higher temperatures. Similar observations have been documented in dried vegetable studies, where moderate drying temperatures preserve protein quality better than high-temperature treatments (Deng et al., 2019).

Fat Content

The fat content of the okra samples varied significantly ($p < 0.05$), ranging from 1.06% to 2.81%. Dried samples generally exhibited higher fat content than the fresh sample, with solar-dried okra recording the highest value. This increase is attributed to moisture loss, which concentrates lipid components in the dried product. Comparable findings have been reported for dehydrated vegetables, where fat appears proportionally higher after drying due to reduced water content (Nowacka et al., 2021). Although okra is not a major fat source, dietary lipids contribute to cellular structure and metabolic processes.

Crude Fibre

Crude fibre content showed significant differences ($p < 0.05$) among the samples. All dried okra samples recorded higher fibre content than the fresh sample, with oven-dried okra at 60 °C exhibiting the highest fibre level. The increase in fibre content following drying is attributed to the concentration effect resulting from moisture reduction. Vegetables are recognized as important sources of dietary fibre, and dehydration increases fibre density per unit weight (Arapitsas, 2021). Dietary fibre plays a crucial role in digestive health and the prevention of metabolic disorders such as obesity, diabetes, and cardiovascular diseases.

Ash Content

Ash content ranged from 7.16% to 11.02%, with oven-dried okra at 50 °C recording the highest value and oven-dried okra at 60 °C the lowest. Ash content reflects the total mineral content of food materials; thus, higher ash values indicate greater mineral availability. The observed variations suggest that moderate drying temperatures favor mineral retention. Similar findings have been reported in recent analyses of dried vegetables and plant foods (Singh et al., 2020).

Carbohydrate Content

Carbohydrate content varied significantly ($p < 0.05$), ranging from 28.08% to 50.84%. Solar-dried okra recorded the highest carbohydrate content, while oven-dried okra at 50 °C had the lowest. The increase in carbohydrate content after drying is mainly due to moisture loss, which increases the relative concentration of carbohydrates. Previous studies on dehydrated vegetables report similar concentration effects following water removal (Deng et al., 2019). Carbohydrates remain a major source of dietary energy, especially in plant-based foods.

Table 1 Proximate composition of the fresh and dried vegetable samples

Sample	Drying methods	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrate
Okra	solar	$9.56^{g}\pm0.23$	$20.21^{b}\pm0.21$	$2.81^{c}\pm0.02$	$9.42^{b}\pm0.46$	$7.18^{e}\pm0.03$	$50.84^{b}\pm0.38$
	oven50°C	$12.41^{e}\pm0.09$	$21.71^{a}\pm0.41$	$2.36^{a}\pm0.19$	$7.21^{c}\pm0.01$	$9.10^{b}\pm0.16$	$47.21^{a}\pm0.15$
	oven60°C	$11.34^{f}\pm0.14$	$19.80^{b}\pm 0.46$	$2.39^{cd}\pm0.28$	$9.56^{b}\pm0.39$	$7.16^{e}\pm0.00$	$49.77^{bc}\pm0.71$
	Fresh	$28.19^{b}\pm0.04$	$17.93^{c}\pm0.10$	$1.06^{e}\pm0.07$	$12.57^{a}\pm0.62$	$11.02^{a}\pm0.00$	$28.08^{e}\pm2.02$

Values are mean ± standard deviation of the duplicate scores. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test

Vitamin Content of Fresh and Dried Okra Samples

Table 1 presents the vitamin A and vitamin C contents of fresh and dried okra samples processed using different drying methods.

Vitamin C

The vitamin C content of the dried okra samples ranged from 4.17 to 6.84 mg/100 g. Fresh okra samples recorded significantly higher vitamin C levels than the dried samples, indicating considerable losses during drying. A significant difference ($p < 0.05$) was observed between the drying methods, with solar-dried okra retaining more vitamin C than oven-dried samples at 50 °C and 60 °C. This higher retention may be attributed to the relatively lower temperature associated with solar drying, as vitamin C is highly sensitive to heat, oxygen, and light. Recent studies confirm that ascorbic acid degradation increases with temperature and processing duration (Nowacka et al., 2021; Tao et al., 2022).

Despite these losses, dried okra still provides meaningful amounts of vitamin C, which plays a vital role in immune function, antioxidant defense, and collagen synthesis.

Vitamin A

Vitamin A content ranged from 0.95 to 13.25 mg/100 g across all samples. Fresh okra samples contained significantly higher levels than the dried samples, indicating losses during the drying process. A significant difference ($p < 0.05$) between drying methods suggests that processing conditions influenced vitamin A retention. Vitamin A degradation during drying is primarily due to oxidative reactions and thermal instability of carotenoids. Similar reductions in carotenoid content have been reported in dehydrated vegetables (Arapitsas, 2021). Nevertheless, dried okra still contributes to dietary vitamin A intake, which is essential for vision, immune function, and growth.

Table 2 Vitamin content of fresh and dried vegetable samples

Samples	Drying methods	Vitamin C	Vitamin A
Okra	solar	4.17^{g}±0.00	0.95^{g}±0.01
	oven-50ºC	6.84^{e}±0.01	3.00^{f}±0.01
	oven-60ºC	5.42^{f}±0.59	2.45^{f}±0.01
	Fresh	15.42^{b}±0.5	13.25^{e}±0.35

Values are mean ± standard deviation of the duplicate values. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test.

Mineral Content of Fresh and Dried Okra Samples

Table 2 presents the mineral composition of fresh and dried okra samples, specifically potassium (K), iron (Fe), zinc (Zn), and calcium (Ca).

Potassium

The potassium content of fresh and dried okra samples varied considerably. Fresh samples recorded values ranging from 299.06 to 385.73 mg/100 g, while dried samples ranged from 353.30 to 524.12 mg/100 g. Fresh okra exhibited the lowest potassium content, whereas oven-dried okra at 50 °C recorded the highest value. The increase in potassium concentration following drying is attributed to moisture loss and nutrient concentration. Vegetables are well-recognized sources of potassium, and dehydration increases mineral density per unit mass (Singh et al., 2020).

Iron

The iron (Fe) content of the okra samples ranged from 0.67 to 4.50 mg/100 g. Fresh samples had the lowest iron content, while oven-dried okra at 50 °C exhibited the highest value. The increase in iron concentration after drying is primarily due to water removal, which concentrates minerals. Iron is an essential micronutrient involved in hemoglobin formation, oxygen transport, and enzymatic processes. Similar trends have been observed in dried vegetable products (Nowacka et al., 2021).

Zinc

Zinc (Zn) content ranged from 0.60 to 3.86 mg/100 g across all samples. Fresh okra samples recorded the lowest zinc levels, while oven-dried okra at 50 °C showed the highest concentration. As with other minerals, the increase in zinc content after drying results from moisture reduction. Zinc plays key roles in immune function, protein synthesis, DNA formation, wound healing, and growth, particularly in children (Deng et al., 2019).

Calcium

Calcium content of fresh and dried okra samples ranged from 82.71 to 802.00 mg/100 g. Calcium is essential for bone formation, muscle function, nerve transmission, and metabolic processes. The results indicate that dried okra can serve as a valuable dietary source of calcium and other minerals due to nutrient concentration during dehydration. Adequate intake is particularly important for children, pregnant women, and lactating mothers.

Table 3 Mineral composition of fresh and dried vegetable samples

Samples	Drying methods	Potassium(k)	Iron(fe)	Zinc(zn)	Calcium(ca)
Okra	solar	$385.73^{c}\pm52.34$	$2.99^{de}\pm0.40$	$3.50^{a}\pm0.28$	$780.11^{ab}\pm65.83$
	oven-50ºC	$360.36^{c}\pm0.17$	$4.50^{b}\pm0.10$	$3.86^{a}\pm1.22$	$802.50^{a}\pm1.84$
	oven-60ºC	$357.62^{c}\pm1.51$	$3.48^{cd}\pm0.06$	$2.08^{b}\pm0.01$	$748.12^{b}\pm12.73$
	Fresh	$299.06^{d}\pm0.08$	$0.67^{f}\pm0.06$	$0.60^{c}\pm0.03$	$82.71^{e}\pm0.41$

Values are mean ± standard deviation of the duplicate values. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test.

Microbial Load of Fresh and Dried Okra Samples

Figure 1 illustrates the total aerobic bacterial counts and fungal counts of fresh and dried okra samples. The total aerobic plate counts ranged from 5×10^3 to 7.1×10^4 CFU/ml, while fungal counts varied from 1×10^3 to 2.80×10^4 CFU/ml across all samples.

Based on the Food and Agriculture Organization (FAO, 2012) guidelines, acceptable microbial limits for foods range from less than 10 CFU/ml to 10^5 CFU/ml. When compared with these standards, the microbial loads observed in all fresh and dried okra samples were within acceptable limits, indicating that the drying methods employed did not compromise microbial safety.

Among the treatments, okra samples oven-dried at 50 °C recorded the highest microbial load (4×10^4 CFU/ml), whereas the fresh samples exhibited the lowest count (2×10^3 CFU/ml). The relatively higher microbial counts observed in some dried samples may be attributed to secondary contamination during post-drying operations, particularly from milling or blending equipment used in sample preparation.

The results of this study are in agreement with the findings of Samuel and Orji (2015), although slight variations were observed when compared with earlier reports that recorded coliform counts ranging from 7.4×10^4 to 8.0×10^4 CFU/ml and fungal counts between 2.4×10^4 and 3.5×10^4 CFU/ml. These variations may be influenced by differences in processing conditions, hygiene practices, and environmental factors.

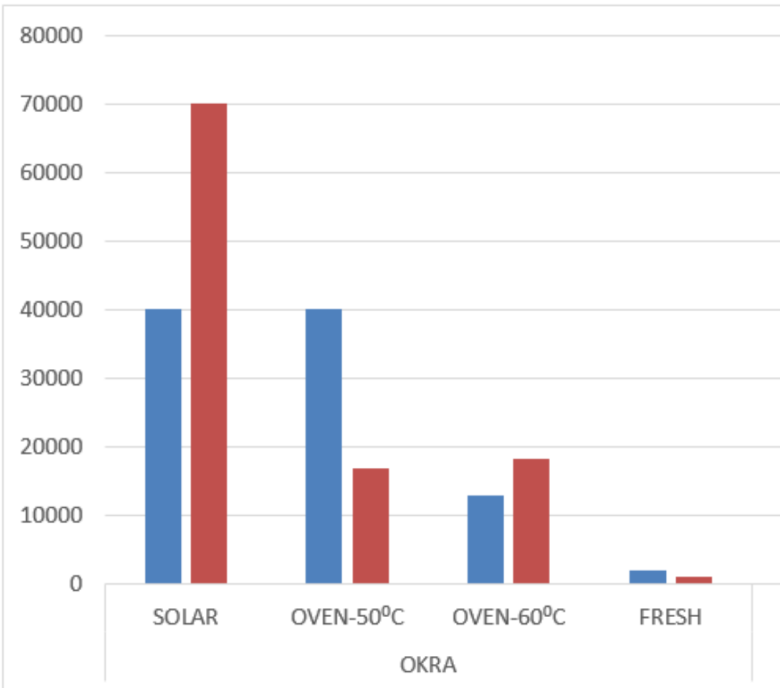


Figure 1 Total aerobic plate count for bacteria cells and fungi count for fresh and dried vegetable samples (okra).

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Table 4 Morphological characterization of bacteria from fresh and dried vegetable samples

Sample	Drying Methods	Cell structure	Cell appearance	Pigment	Cell size	Gram Reaction	Suspected organisms
Okra	solar	round	Chain	Yellow	Large	+cocci	*Staphylococcus, Neisseria spp, and Sarcina*
	oven-50ºC	triangular	Single	Yellow	Large	-rod	*pseudomonas spp.,salmonella , proteus spp, citrobacter species*
	oven-60ºC	oval	Cluster	Yellow	Medium	+cocci	*staphylococcus, streptococci*
	Fresh	triangular	Single	Yellow	Small	+rod	*Bacilli, Pseudomonas spp.,Staphylococcus, E. coli*

CONCLUSION AND RECOMMENDATIONS

This study provides a comprehensive evaluation of the effects of different drying methods on the nutritional quality and microbial safety of okra intended for soup production. The results demonstrated that drying significantly reduced moisture content, thereby enhancing shelf stability, while concurrently influencing the retention of proximate components, vitamins, minerals, and microbial load.

Among the drying methods investigated, oven drying at 50 °C proved to be the most effective. This method consistently achieved superior retention of essential minerals (potassium, calcium, iron, and zinc), vitamins (A and C), and proximate constituents, while maintaining microbial loads within acceptable safety limits. Although solar drying achieved lower

moisture content and moderate nutrient retention, it was less effective in preserving heat-sensitive vitamins and controlling microbial proliferation compared to oven drying at 50 °C. The findings further revealed that drying increased the concentration of carbohydrates, fibre, fat, and minerals due to moisture loss, while fresh okra samples exhibited higher moisture and vitamin contents. Microbial analysis confirmed that all dried samples were microbiologically safe according to FAO standards, indicating that the drying processes employed were suitable for producing safe dried okra products.

Based on these outcomes, oven drying at 50 °C is recommended as the most suitable processing method for producing dried okra with optimal nutritional quality and acceptable microbial safety for soup preparation. Future studies should focus on evaluating the long-term storage stability of dried okra, investigating the effects of different packaging materials and storage conditions, and assessing consumer acceptability and functional properties of dried okra in soup formulations.

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