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COMPARATIVE EVALUATION OF SENSORY ATTRIBUTES AND MICROBIAL SAFETY OF TIGER NUTS (*CYPERUS ESCULENTUS* L.) PROCESSED BY DIFFERENT DRYING METHODS

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Abstract: *This study investigates the sensory and microbial contents of fresh tiger nuts processed with three drying methods: sun drying, oven drying, and the Nigerian Stored Products Research Institute Parabolic Shaped Solar Dryer (NSPRI PSSD), while dried tiger nuts from the market serve as a control, to evaluate their sensory performance and effectiveness in minimizing microbial loads. Before sensory, thirty trained panelists evaluated five sensory attributes (appearance, aroma, taste, color, texture) using a 9-point hedonic scale. One-way ANOVA with Tukey's post-hoc test at a 95% confidence level revealed significant differences ($p < 0.05$) among all samples. Microbial analysis through serial dilution using the pour plate method. NSPRI PSSD had the highest overall acceptability (8.67, CI:8.43–8.91), showing a 16% improvement over Sample C (7.45) and a 102% improvement over Sample D (4.30). NSPRI PSSD (8.65) and market dried (4.25, 3.50) revealed the widest variation in taste and aroma. Various drying techniques significantly lowered microbial loads, with NSPRI PSSD proving to be the most effective. Critical pathogens such as Escherichia coli and Salmonella spp. were identified and isolated. These results underline the importance of implementing controlled drying methods to improve the safety and sensory quality of dried tiger nuts, providing essential evidence-based guidelines for food processing and consumption.*

Keywords: *contamination, consumers, food safety, postharvest, technology, tiger nuts*

1. Introduction

Cyperus esculentus L, commonly referred to as tiger nut, rush nuts, earth almond, nutsedge, and chufas, is a grass belonging to the *Cyperaceae* family in the genus *Cyperus* [1,2]. Tiger nuts (*Cyperus esculentus*) are nutrient-rich tubers widely consumed in Africa and Asia. However, their high moisture content postharvest makes them highly susceptible to microbial growth, posing significant food safety concerns [3,4]. Studies have reported that raw tiger nuts can harbor microbial loads exceeding 10^9 CFU/g, which far surpasses the acceptable threshold of 10^6–10^7 CFU/g [3]. The sensory attributes of appearance, aroma, taste, texture, and color fundamentally influence initial consumer impressions and overall eating satisfaction [5]. Optimizing these sensory parameters is essential for enhancing product appeal and maintaining a competitive advantage in increasingly sophisticated food markets. Microbial contamination in tiger nuts is often associated with pathogenic bacteria, including *Escherichia coli, Bacillus* spp., and *Salmonella* spp., which can persist in inadequately processed products [4,6]. Research on street-vended tiger nut drinks in Owerri, Nigeria, revealed that fecal coliform counts reached up to 10^4 CFU/mL, highlighting the risks associated with improper processing methods [6]. Drying is an essential preservation technique that

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reduces water activity and inhibits microbial growth. However, the effectiveness of drying depends on specific variables such as temperature, exposure duration, and hygiene practices [7]. The sun-drying method is a traditional practice and a cost-effective approach; however, its reliance on ambient environmental conditions often leads to incomplete microbial inactivation and potential product recontamination [7].

In contrast, controlled drying methods, such as oven-drying, provide consistent heat application, ensuring better microbial control and consumer acceptability. NSPRI Parabolic Shaped Solar Dryer is a solar-powered drying technology designed to reduce postharvest losses and improve the quality and shelf life of agricultural produce. It was designed for proper hygiene and food safety.

This is ensured by its enclosed drying chamber, UV-screened cover, raised trays with nets, an efficient airflow system, and solar-powered ventilation, which together protect agricultural produce from contamination while allowing efficient moisture removal. The NSPRI PSSD operates by admitting solar radiation into the dryer, generating heat within the chamber, warm air removing moisture from the produce, and moist air exiting through vents while fresh air continuously enters, resulting in efficient, hygienic, and fuel-free drying. It has also been explored for its potential to optimize energy efficiency while maintaining food safety standards and consumer acceptability.

However, despite these advancements, systematic comparisons of different drying methods in terms of sensory quality and microbial safety remain scanty.

This gap highlights the need for evidence-based food processing guidelines to enhance the safety and quality of tiger nuts and their derived products.

2. Materials and methods

2.1. Materials

2.1.1. Samples collection

Dried and wet tiger nuts (*Cyperus esculentus*) used for this study were obtained from the market in Ilorin (N 8° 28 31.1628" E 4° 30 21.2184"), Kwara State, Nigeria. Specimens were transported to the laboratory in sterile containers. Upon arrival, samples were carefully sorted to eliminate debris, stones, and other impurities.

2.1.2. Sample preparation

After sorting, the wet tiger nuts were divided into three equal portions, each weighing 250 g. These portions were designated for different drying methods: Sun drying, Oven drying, and Nigerian Stored Products Research Institute Parabolic Shaped Solar Dryer (NSPRI PSSD). A portion (250 g) of dried tiger nut was retained in its state for sensory evaluation, initial microbial load, and comparative analysis (control). After drying, 25 g of the sun-dried, oven-dried, and NSPRI PSSD dried were weighed for analysis.

2.2. Methods

2.2.1. Sensory evaluation protocol

Sensory analysis was conducted using a structured 9-point hedonic scale methodology, ranging from 1 (dislike extremely) to 9 (like extremely), with modifications as described by [8]. A panel of thirty trained evaluators, selected based on their sensory acuity and previous experience in food evaluation, assessed five critical sensory attributes: appearance, aroma, taste, color, texture, and overall acceptability. The evaluation was conducted in a controlled sensory laboratory environment with individual booths, appropriate lighting, and temperature control. Samples were presented in randomized order using three-digit codes to eliminate bias. Panelists were

provided with distilled water and unsalted crackers for palate cleansing between samples.

2.2.2. Microbial analysis

The microbial analysis of the samples was done using the method described by [9] and [10]. The serial dilution and pour plate method was used for the microbiological examination. After drying, 25 g of the sun-dried, oven-dried, and NSPRI PSSD dried tiger nuts were weighed and serially diluted into 225 mL of sterile water for 1 hour, followed by a fivefold serial dilution.

From the dilution, one milliliter (1 mL) of the 10^{-3} and 10^{-5} dilutions was aseptically transferred for each sample and plated using the pour-plate technique. The specific media were prepared following manufacturers' instructions, and the pour plate technique was adopted for the culture and enumeration of Total Viable Count (Nutrient Agar incubated at 30 ºC for 24 h), *E. coli* (Eosin Methylene blue Agar incubated at 37 ºC for 24 h), *Staphylococcus* count (Mannitol Salt Agar incubated at 37 ºC for 24 h), *Salmonella* and *Shigella* spp. (Salmonella Shigella Agar incubated at 37 °C for 24 h), yeast and mold count (Potato Dextrose Agar incubated at 37 °C for 2 days) in the tiger nut samples.

Following incubation, the average number of colony-forming units per milliliter of the tested sample was reported based on counting the number of microbial colonies in both plates. The plates were incubated under controlled conditions: bacterial colonies were allowed to grow for 24 hours, while fungal colonies were incubated for 48 hours.

This incubation period facilitated accurate colony counting and analysis of microbial presence in the samples.

2.3. Statistical analysis

All sensory data were subjected to statistical analysis using one-way Analysis of Variance (ANOVA) to determine significant differences among samples. Mean values were reported with standard errors and 95% confidence intervals (CI) to provide a comprehensive statistical interpretation. Duncan Multiple Range Test was employed for mean separation when significant differences were detected. Statistical significance was set at $p < 0.05$.

Confidence intervals were calculated using the formula:

CI = mean ± (t-value × standard error)

where t-value corresponds to 95% confidence level with appropriate degrees of freedom.

All analyses were performed using SPSS version 25.0 software.

3. Results and discussions

3.1. Sensory evaluation

The results of the sensory evaluation of the four tiger nut samples (NSPRI PSSD, Sun dried, Oven dried, and market dried) prepared using different drying methods are presented in Table 1 and Figure 1. NSPRI PSSD Sample showed the highest overall acceptability score across all sensory attributes (8.67±0.12) (Table 1). This implies that the NSPRI Sample showed superior performance, which can be attributed to the controlled processing environment, safety standardized application, and optimized Parabolic Shaped Solar Dryer technology that ensures uniform energy distribution and moisture control. This corroborates the study of [11]. Market dried and sun-dried samples have the lowest overall acceptability (4.30 ± 0.11 and 6.09 ± 0.15), particularly in terms of appearance, texture, and aroma (Table 1). This indicates poor drying method, uncontrolled temperature, unhygienic conditions, and prolonged drying, factors commonly associated with sensory rejection. Osae [12] reported that sun-drying is the poorest drying technique in tiger nuts because of the uncontrolled temperature. Oven-dried samples demonstrated moderate overall

acceptability, suggesting that although their processing methods preserved some sensory qualities, they were not as effective as the NSPRI PSSD. The differences in confidence intervals (CI) of all the samples without overlapping (Table 1) emphasized the importance of optimized processing in maintaining food quality attributes desirable for consumer acceptability.

Table 1.

Sensory evaluation scores for dried tiger nuts with 95% confidence intervals

Sample	Appearance	Aroma	Taste	Color	Texture	Overall Acceptability
NSPRI PSSD	8.40±0.17^{d} (CI:8.06-8.74)	8.45±0.14^{d} (CI:8.17-8.73)	8.65±0.13^{d} (CI:8.39-8.91)	8.65±0.11^{d} (CI:8.43-8.87)	8.65±0.11^{d} (CI:8.43-8.87)	8.67±0.12^{d} (CI:8.43-8.91)
Oven Dried	6.70±0.22^{c} (CI:6.26-7.14)	6.95±0.15^{c} (CI:6.65-7.25)	7.45±0.15^{c} (CI:7.15-7.75)	7.15±0.15^{c} (CI:6.85-7.45)	7.40±0.15^{c} (CI:7.10-7.70)	7.45±0.17^{c} (CI:7.11-7.79)
Sun Dried	4.60±0.29^{b} (CI:4.02-5.18)	5.05±0.21^{b} (CI:4.63-5.47)	6.05±0.17^{b} (CI:5.71-6.39)	5.70±0.13^{b} (CI:5.44-5.96)	5.10±0.16^{b} (CI:5.38-6.02)	6.09±0.15^{b} (CI:5.79-6.39)
Market Dried	3.30±0.26^{a} (CI:2.78-3.82)	3.45±0.20^{a} (CI:3.05-3.85)	4.25±0.19^{a} (CI:3.87-4.63)	3.50±0.21^{a} (CI:3.08-3.92)	3.50±0.25^{a} (CI:3.00-4.00)	4.30±0.11^{a} (CI:4.08-4.52)

**Means with different superscripts within columns are significantly different ($p < 0.05$)*
 CI = 95% Confidence Interval

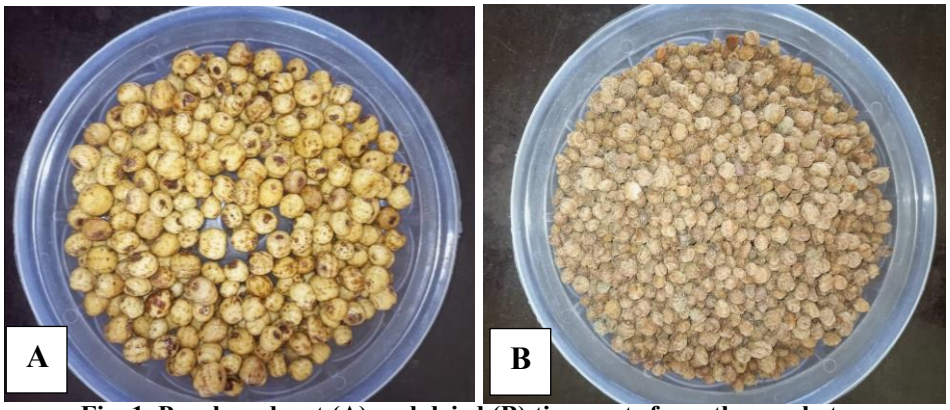

Fig. 1. Purchased wet (A) and dried (B) tiger nuts from the market

3.1.1. Statistical significance and practical implications

The 95% confidence intervals provide robust evidence for the statistical and practical significance of observed differences. NSPRI PSSD lower confidence limit (8.43) exceeds oven-dried sample supper confidence limit (7.79), confirming non-overlapping confidence intervals and definitive superiority (Table 1). Similarly, non-overlapping confidence intervals between consecutive ranking samples (oven vs. sun, vs. market dried) confirm distinct performance categories. The magnitude of differences is practically significant: NSPRI PSSD achieved 16.4% higher overall acceptability than oven dried (8.67 vs. 7.45), 42.4% higher than sun dried (8.67 vs. 6.09), and 101.6% higher than market dried (8.67 vs. 4.30).

These substantial differences translate to meaningful consumer preference variations with direct commercial implications.

3.2. Microbial analysis

The mean total viable counts of the microbial load observed in the initial wet and dried tiger nut and processed wet tiger nuts using different drying methods are

represented in Table 2, Figure 2. All the drying methods used for this study reduced the microbial load count (Table 2). NSPRI PSSD sample showed the lowest microbial load count in (Heterotrophic bacterial Count 1.4×10^4 CFU/g, no Escherichia Count, Salmonella-Shigella Count 1.8×10^4 CFU/g, Staphylococcus Count 2.3×10^4 CFU/g, and Fungal Count 1.0×10^4 CFU/g) compared to the purchased tiger nut from the market while the highest was observed in sun drying (Heterotrophic bacterial count 4.2×10^5 CFU/g, *Escherichia* Count 1.2×10^4 CFU/g, *Salmonella-Shigella* count 2.4×10^4 CFU/g, *Staphylococcus* count 5.4×10^5 CFU/g, and Fungal count 3.0×10^5 CFU/g). Oven drying demonstrated minimal counts in the Heterotrophic bacterial 2.0×10^4 CFU/g, *Escherichia* 2.6×10^4 CFU/g, *Salmonella-Shigella* 1.0×10^5 CFU/g, Staphylococcus 3.6×10^4 CFU/g, Fungal 2.1×10^4 CFU/g, all of which fall within the permissible limit of (5.30 log10 CFU/mL). This implies that the Nigerian Stored Products Research Institute Parabolic Shaped Solar Dryer (NSPRI PSSD) efficiently dries agricultural produce faster with better quality control, and protection from contamination. Ayandele [13] reported improper drying process and packaging in unhygienic conditions, deterioration, or low quality of tiger nuts. Wang [14] concluded that the drying method has a significant effect on the microstructure and quality of dehydrated products.

Table 2.

Mean total viable counts of the dried tiger nut samples

Plates **Samples**	**Heterotrophic bacterial count (CFU/g)**	***Escherichia* count (CFU/g)**	***Salmonella-Shigella* count (CFU/g)**	***Staphylococcus* count (CFU/g)**	**Fungal count (CFU/g)**
NSPRI (PSSD)	1.4×10^4	-	1.8×10^4	2.3×10^4	1.4×10^4
Sun Dried (SD)	4.2×10^5	1.2×10^4	2.4×10^4	5.4×10^5	3.0×10^5
Oven Dried (OVD)	2.0×10^4	2.6×10^4	1.0×10^5	3.6×10^4	2.1×10^4
Market Dried (MD)	1.2×10^5	6.0×10^6	1.5×10^5	1.4×10^5	2.2×10^6
Initial Market Wet (IMW)	9.0×10^4	2.0×10^4	3.1×10^4	3.6×10^4	9.3×10^4

Fig. 2. Laboratory setup of microbial load of Tiger nut (*Cyperus esculentus* L.)

4. Conclusion

The adoption of controlled drying technologies like the NSPRI PSSD emerges as a practical and sustainable strategy for enhancing the quality, safety, and market potential of tiger nuts. These results are particularly relevant for postharvest management, processing on small to

medium scales, and food safety regulations in regions where tiger nuts are commonly consumed. Future research should aim to investigate the scalability, cost-effectiveness, and applicability of this technology to other agricultural products, further contributing to the reduction of postharvest losses and the enhancement of food security.

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