International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 12 (December, 2024), PP 327-335

Impact of Storage Conditions on the Shelf Life of Tigernut *(Cyperus Esculentus)*

[1*]Omale, P.A., [3]Olanrewaju, T. O., [2]Usman A. and [1]Mbachirin, D. N.,
[1,2]Department of Agricultural and Biosystem Engineering
Joseph Sarwuan Tarka University Makurdi, Benue State, Nigeria
[3]Department of Agricultural and Biological Engineering
Purdue University
**Corresponding Author*

ABSTRACT
This study investigates the effects of storage conditions on the shelf life of tigernuts, focusing on various storage temperatures, duration, and container types. The study aimed atevaluating how different storage temperatures, duration and container affects tigernut quality over time.The research demonstrated that moisture content is highly sensitive to storage temperatures, with levels ranging from approximately 12.30% to 16.30%. Higher temperatures were associated with increased moisture loss, compromising the overall quality of the tigernuts. Cooler storage conditions were found to significantly enhance moisture retention and extend shelf life. It wasrevealed that vacuum-sealed and airtight containers effectively preserved moisture and maintained product quality over extended periods.Sizesof tigernut remained stable, ranging from 8.20mm to 8.50mm. Thecolor ranged from Brown to Dark Brown, indicating that the visual quality of tigernuts is largely unaffected by storage variables. However, minor fluctuations were noted over time signaling potential gradual degradation. Insect presence showed minimal variation across all storage conditions,, suggesting effective containment strategies that prevent contamination. ANOVA revealed thatthere's significant differences in moisture retention and quality across the storage conditions.The outcome of this study is needed in decision makingtowards tigernutstorage.
Keywords: *Moisture content,Tigernuts,Shelf life, Storage conditions*

Date of Submission: 11-12-2024 Date of Acceptance: 23-12-2024

I. INTRODUCTION

Tigernuts *(Cyperus esculentus),* are small tubers that have garnered attention due to their nutritional composition and potential health benefits. Rich in fiber, vitamins, and minerals, tigernuts have been recognized for their role in promoting digestive health and providing essential nutrients (Ogbuagu *et al.,* 2019). The growing interest in tigernuts has led to increased utilization in various food products and beverages, such as tigernut milk and flour (Téllez-Pérez *et al.*, 2019).

It has other names depending on the tribe or region where tigernut tuber is cultivated and utilized. The genus name *Cyperus* is derived from an ancient Greek name *Cypeirus* whereas the specie name *esculentus* originate from a Latin word which means edible (Ayeh-Kumi *et al*, 2014). Tigernut is also called '*Zulu nut*', '*Yellow nut sedge*', '*Chufa*', '*Flat sedge*', '*Edible rush nut*', '*Water grass*', '*Almond*', '*Northern nut grass*' and '*Nut grass*' (Sánchez-Zapata, 2012)

The three most populous ethnic groups in Nigeria which are Hausas, Igbos and Yorubas call tigernut tubers '*Aya*', '*Ofio*' and '*Imumu*', respectively (FAO, 1988). A widely acceptable name given to tigernut tubers in Southern Nigeria is 'Aki Hausa' which literally describes a nut that is largely cultivated and marketed by the Hausas that dominate Northern Nigeria (Bamishaiye, 2011, Udeozor, *et al* 2014). A large portion of tigernut tubers distributed across the country as snacks are cultivated in many states in Northern Nigeria (Adejuyitan *et al* 2011, Ukwuru*et al*, 2011).

There are three varieties of tigernut tubers easily identified based on the colour of the tubers. They are: the yellow, brown and black variety. Only two of the varieties - yellow and brown are commonly seen in most local markets in Nigeria. The yellow variety is further grouped into two - the large yellow variety and the small yellow variety. *Cyperus esculentus* var. *esculentus* is weedy whereas *Cyperus esculentus* var. *sativus* is usually cultivated as a result of its rhizomes which grow into tubers for human consumption. (Omale, *et al.,* 2023).

Despite their nutritional value, tigernuts are susceptible to quality deterioration during storage, which can affect their shelf life and consumer acceptability. Storage conditions, including temperature, humidity, and packaging materials, play a significant role in determining the rate of deterioration in agricultural products (Sun *et al.,* 2020). Tigernuts, being no exception, are prone to physical, chemical, and microbial changes under different storage environments.

Previous studies have highlighted the importance of storage conditions in preserving the quality of various food commodities. For instance, research on grains and nuts has demonstrated that temperature and moisture content are critical factors influencing the shelf life and safety of these products (Lorenzo *et al.,* 2014; Gómez-Caravaca *et al.,* 2016). Moreover, the packaging material used can affect the gas exchange and moisture permeability, thereby impacting the oxidative stability and microbial growth of stored products (Rocculi *et al.,* 2016).

However, limited research specifically focuses on the storage stability of tigernuts. While some studies have investigated the postharvest physiology and processing techniques of tigernuts (Sánchez-Zapata *et al.,* 2012), there is a gap in understanding how storage conditions influence the shelf life of tigernuts. Given the increasing demand for tigernut-based products and the need to ensure their quality and safety, it is essential to evaluate the effect of storage conditions on tigernut shelf life.

Tigernuts are a valuable agricultural product, but they can undergo rapid deterioration if not stored optimally, resulting in significant economic losses. Various engineering factors, including storage temperature, humidity levels, packaging materials, and ventilation systems, play essential roles in determining the quality and shelf stability of tigernuts. Despite this, there is a lack of comprehensive understanding of how these engineering variables interact and influence the shelf life of tigernuts

The study aims to evaluate the effect of different storage temperatures on tigernut quality over time. Additionally, it will assess the impact of various storage conditions, durations, and containers to identify the most effective methods for preserving tigernut quality. Finally, the research will involve a statistical analysis of the generated data to compare the effects of these conditions on the shelf life of tigernuts.

II. METHODOLOGY

2.1 Materials

The following materials were used for the study; Dried Tigernuts, Plastic Airtight containers, Vacuum sealed, bags, polythene bags, Thermometer, Moisture analyzer, Notebooks, Pen, Lab coat, Gloves and Safety goggles.

2.2 Sample collection and preparation

Tigernuts was purchased from a tigernut farmer from Bauchi State at the North Bank market, in Makurdi Local Government Area of Benue State, Nigeria and were cleaned and sorted manually of all foreign matter (such as dirt, stones, premature and broken seeds) to get rid of physical contaminants, to be used for the study.

Sample Collection Procedure

i. Each sample container was labeled with unique identifiers (Room Temperature, Refrigerated Temp, and Freezing Temp.) representing their respective storage conditions to track them throughout the experiment.
ii. The initial characteristics of each sample such as moisture content were recorded.
iii. Tigernuts were placed in the designated storage conditions(Room Temperature, Refrigerated Temperature and Freezing Temperature) immediately after collection and preparation

2.3 Experimental Design

Tigernuts were packaged and stored under the following storage conditions;
Room temperature (25°C), Refrigerated Temperature (4°C), Freezing storage (-14°C).). A total quantity of 10kg was stored in three replications for each condition, over storage duration of three months. The storage containers used included Plastic Airtight Containers, Vacuum-Sealed Containers, and Polythene Bags.
An Analysis of Variance (ANOVA) was performed to analyze the data generated to determine the effects of the storage condition, Storage duration, and storage container on the quality of the stored tigernut at 95% confident level.

2.4 Data Collection

The Moisture content of tigernut was determined throughout the study using the ASAE standard (ASAE, 1990) by oven drying the sample at 103°C for 48 hours at the Animal Nutrition Laboratory, Joseph Sarwuan Tarka University, Makurdi. The initial weight of the tigernuts was taken and they were put in the oven to dry for 48 hours after the oven had been preheated to 103°C. The tigernut was taken out when the drying process was finished, and then allowed to cool in a desiccator to avoid them from absorbing moisture from the air. The ultimate weight (W2) was determined by weighing the dried tigernuts after they had cooled. The moisture content was determined using the following formula:

$$MC(\%) = \frac{(\mathrm{Wwet} - \mathrm{Wdry})}{(Wdry)} \times 100 \qquad (1)$$

Where:

- W_{wet} = Weight of the sample before drying (wet weight)
- W_{dry} = Weight of the sample after drying (dry weight)

Tigernut sizes were measured using a Digital Caliper to assess changes over time.

Observations were made periodically with physical eyes to monitor any changes in the color attributes of Tigernut.

Periodic physical observations were made to observe the presence and effect of Insects on the tigernuts

III. RESULTS AND DISCUSSION

The Results of the effects of storage conditions on tigernut shelf life is presented in the table 1 while the ANOVA resultis presented intable 2.

Table 1: Descriptive Statistics of the effect of storage conditions on tigernut shelf life

		Descriptive Statistics				
	Storage Condition	**storage container**	**Durations (weeks)**	**Mean**	**Std. Deviation**	**N**
Moisture Contents (%)	**Freezing Temperature (-14°C)**	Plastic Airtight Container	0	16.30	.050	**3**
			4	13.03	.075	**3**
			8	12.85	.050	**3**
			12	12.75	.050	**3**
			Total	13.73	1.552	**12**
		Polythene Bag	0	14.97	2.309	**3**
			4	12.90	.050	**3**
			8	12.70	.050	**3**
			12	12.50	.050	**3**
			Total	13.26	1.42	**12**
		Vacuum-Sealed Bag	0	16.30	.05	**3**
			4	12.80	.05	**3**
			8	12.49	.045	**3**
			12	12.30	.050	**3**
			Total	13.47	1.714	**12**
	Refrigerated Temperature (4°C)	Plastic Airtight Container	0	16.30	.050	**3**
			4	13.44	.055	**3**
			8	13.92	.076	**3**
			12	14.12	.07	**3**
			Total	14.45	1.14	**12**
		Polythene Bag	0	16.30	.050	**3**
			4	13.50	.050	**3**
			8	13.20	.050	**3**
			12	13.00	.050	**3**
			Total	14.00	1.40	**12**
		Vacuum-Sealed Bag	0	16.30	.05	**3**
			4	13.33	.53	**3**
			8	12.80	.05	**3**
			12	12.50	.05	**3**
			Total	13.73	1.59	**12**
	Room Temperature (25^{0}C)	Plastic Airtight Container	0	16.30	.05	**3**
			4	14.00	.10	**3**
			8	14.30	.05	**3**
			12	14.50	.05	**3**
			Total	14.77	.94	**12**
		Polythene Bag	0	16.30	.050	**3**
			4	14.00	.05	**3**
			8	14.300	.05	**3**
			12	14.50	.05	**3**
			Total	14.70	.93	**12**
		Vacuum-Sealed Bag	0	16.30	.05	**3**
			4	13.00	.04	**3**

			8	13.00	.05	**3**
			12	12.40	.18	**3**
			Total	13.67	1.60	**12**
Size(mm)	**Freezing temperature (-14°C)**	Plastic Airtight Container	0	8.50	.10	**3**
			4	8.40	.10	**3**
			8	8.30	.10	**3**
			12	8.20	.10	**3**
			Total	8.35	.14	**12**
		Polythene Bag	0	8.50	.10	**3**
			4	8.40	.10	**3**
			8	8.30	.10	**3**
			12	8.20	.10	**3**
			Total	8.35	.14	**12**
		Vacuum-Sealed Bag	0	8.50	.10	**3**
			4	8.47	.05	**3**
			4	8.47	.05	**3**
			12	8.40	.10	**3**
			Total	8.46	.07	**12**
	Refrigerated Temperature (4°C)	Plastic Airtight Container	0	8.50	.10	**3**
			4	8.467	.05	**3**
			8	8.47	.05	**3**
			12	8.40	.10	**3**
			Total	8.46	.07	**12**
		Polythene Bag	0	8.50	.10	**3**
			4	8.40	.10	**3**
			8	8.30	.10	**3**
			12	8.20	.10	**3**
			Total	8.35	.14	**12**
		Vacuum-Sealed Bag	0	8.50	.10	**3**
			4	8.47	.05	**3**
			8	8.47	.05	**3**
			12	8.40	.10	**3**
			Total	8.46	.07	**12**
	Room Temperature (25^{0}C)	Plastic Airtight Container	0	8.50	.10	**3**
			4	8.40	.10	**3**
			8	8.30	.10	**3**
			12	8.20	.10	**3**
			Total	8.35	.14	**12**
		Polythene Bag	0	8.50	.10	**3**
			4	8.40	.10	**3**
			8	8.30	.10	**3**
			12	8.20	.10	**3**
			Total	8.35	.14	**12**
		Vacuum-Sealed Bag	0	8.50	.10	**3**
			4	8.43	.05	**3**
			8	8.267	.05	**3**
			12	8.40	.10	**3**
			Total	8.40	.11	**12**
Color	**Freezing temperature (-14°C)**	Plastic Airtight Container	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
		Polythene Bag	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
		Vacuum-Sealed	0	1.00	.00	**3**

		Bag	4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**36**
	Refrigerated Temperature (4°C)	Plastic Airtight Container	0	1.67	.57	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.17	.38	**12**
		Polythene Bag	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
		Vacuum-Sealed Bag	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
	Room Temperature(25 ^{0}C)	Plastic Airtight Container	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
		Polythene Bag	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.33	.57	**3**
			Total	1.08	.28	**12**
		Vacuum-Sealed Bag	0	1.00	.00	**3**
			4	1.00	.00	**3**
			8	1.00	.00	**3**
			12	1.00	.00	**3**
			Total	1.00	.00	**12**
Insect Effects	**Freezing temperature (-14°C)**	Plastic Airtight Container	0	2.00	.00	**3**
			4	2.00	.00	**3**
			8	2.00	.00	**3**
			12	2.00	.00	**3**
			Total	2.00	.00	**12**
		Polythene Bag	0	2.00	.00	**3**
			4	2.00	.00	**3**
			8	2.00	.00	**3**
			12	2.00	.00	**3**
			Total	2.00	.00	**12**
		Vacuum-Sealed Bag	0	2.00	.00	**3**
			4	2.00	.00	**3**
			8	2.00	.00	**3**
			12	2.00	.00	**3**
			Total	2.00	.00	**12**
	Refrigerated Temperature (4°C)	Plastic Airtight Container	0	2.00	.00	**3**
			4	2.00	.00	**3**
			8	2.00	.00	**3**
			12	2.00	.00	**3**
			Total	2.00	.00	**12**
		Polythene Bag	0	2.00	.00	**3**
			4	2.00	.00	**3**
			8	2.00	.00	**3**
			12	2.00	.00	**3**
			Total	2.00	.00	**12**

	Vacuum-Sealed Bag	0	2.00	.00	**3**
		4	2.00	.00	**3**
		8	2.00	.00	**3**
		12	2.00	.00	**3**
		Total	2.00	.00	**12**
Room Temperature(25 ^{0}C)	Plastic Airtight Container	0	2.00	.00	**3**
		4	2.00	.00	**3**
		8	2.00	.00	**3**
		12	2.00	.00	**3**
		Total	2.00	.00	**12**
	Polythene Bag	0	2.00	.00	**3**
		4	2.00	.00	**3**
		8	2.00	.00	**3**
		12	1.00	.00	**3**
		Total	1.75	.45	**12**
	Vacuum-Sealed Bag	0	2.00	.00	**3**
		4	2.00	.00	**3**
		8	2.00	.00	**3**
		12	2.00	.00	**3**
		Total	2.00	.00	**12**

Table 2: ANOVA result of the effects of storage conditions on tigernut shelf life at 95% Significant Level

Tests of Between-Subjects Effects						
Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	**Sig.**
Corrected Model	Moisture Contents	211.214[a]	35	6.035	37.758	**<.001**
	Size	1.149[b]	35	.033	3.854	**<.001**
	Color	1.583[c]	35	.045	2.443	**<.001**
	Insect effects	2.917[d]	35	.083	.	**.**
Intercept	Moisture Contents	21127.140	1	21127.140	132189.205	**<.001**
	Size	7605.367	1	7605.367	892804.011	**<.001**
	Color	114.083	1	114.083	6160.500	**<.001**
	Insect Effects	420.083	1	420.083	.	**.**
Storage	moisture contents	15.468	2	7.734	48.389	**<.001**
	Size	.057	2	.029	3.359	**.040**
	Color	.056	2	.028	1.500	**.230**
	insect effects	.167	2	.083	.	**.**
Container	moisture contents	8.610	2	4.305	26.937	**<.001**
	Size	.144	2	.072	8.446	**<.001**
	Color	.056	2	.028	1.500	**.230**
	insect effects	.167	2	.083	.	**.**
Duration	moisture contents	169.165	3	56.388	352.812	**<.001**
	Size	.677	3	.226	26.475	**<.001**
	Color	.102	3	.034	1.833	**.149**
	Insect Effects	.250	3	.083	.	**.**
storage * container	Moisture Contents	5.474	4	1.369	8.563	**<.001**
	Size	.064	4	.016	1.875	**.124**
	Color	.222	4	.056	3.000	**.024**
	insect effects	.333	4	.083	.	**.**
storage * duration	moisture contents	2.181	6	.363	2.274	**.046**
	Size	.042	6	.007	.822	**.556**
	Color	.315	6	.052	2.833	**.016**
	insect effects	.500	6	.083	.	**.**
container * duration	moisture contents	6.749	6	1.125	7.038	**<.001**
	Size	.102	6	.017	1.996	**.077**
	Color	.315	6	.052	2.833	**.016**

	insect effects	.500	6	.083	.	**.**
storage * container * duration	moisture contents	3.568	12	.297	1.860	**.054**
	Size	.064	12	.005	.621	**.817**
	Color	.519	12	.043	2.333	**.014**
	insect effects	1.000	12	.083	.	**.**
Error	moisture contents	11.507	72	.160		
	Size	.613	72	.009		
	Color	1.333	72	.019		
	insect effects	.000	72	.000		
Total	moisture contents	21349.862	108			
	Size	7607.130	108			
	Color	117.000	108			
	insect effects	423.000	108			
Corrected Total	moisture contents	222.722	107			
	Size	1.763	107			
	Color	2.917	107			
	insect effects	2.917	107			

a. R Squared = .948 (Adjusted R Squared = .923)
b. R Squared = .652 (Adjusted R Squared = .483)
c. R Squared = .543 (Adjusted R Squared = .321)
d. R Squared = 1.000 (Adjusted R Squared = 1.000)

3.2 Discussion

Effect of Storage Condition on Moisture Content of Tigernut

The mean moisture content ranges significantly from approximately 12.30% to 16.30%, with the highest values found in room temperature storage, and the lowest in freezer conditions. The ANOVA results confirm that both storage condition ($p<0.05$) and container type ($p<0.05$) significantly impact moisture levels. This difference highlights the importance of choosing cooler storage options and specific containers, like Vacuum Bags, which help minimize moisture. Lower moisture content is preferable for tigernut shelf life, as it reduces spoilage risks related to microbial growth and degradation, making moisture control critical in shelf-life management. Awulu *et al.,* (2015) in their study examined the effect of Storage techniques on the Shelf Life of some selected Orange species in Benue State. The results showed that cooler storage technique gives the best shelf life of the stored orange species which agrees with our findings in the study. Omale and Omobowale (2018) also reported a similar observation in their study of Mechanical Properties of Tigernut (*Cyperus Esculentus*) as Influenced by Moisture Content.

Effect of Storage Condition on Tigernut Size

The results indicate a minor yet significant effect of storage condition on the size of tigernuts, with slight variations observed across different environments. For instance, freezer and room temperature storage conditions may cause minor expansion or contraction due to temperature-induced pressure changes. However, the overall size variation (ranging from 8.20mm to 8.50mm) suggests a relatively stable physical structure. This limited impact on size indicates that storage condition is not a major concern for shelf life, although consistent storage conditions may help maintain the integrity of the product.

Similarly, different container types also have a slight influence on tigernut size. This effect could be attributed to varying levels of compression or flexibility within the containers, which can impact the physical appearance and texture of the tigernuts. While container choice does not drastically alter size, using containers that help maintain shape and structure could contribute positively to product presentation and consumer satisfaction over time. This is consistent with the research done by Adeyemi *et al*,. (2021). The impact of storage and packing on tigernuts' physical characteristics was the main focus of this investigation. The results showed that because different types of containers have different compression and flexibility, they may result in minor size changes.

Effect of Storage Condition on Color

Color values, with a narrow range from Brown to Dark Brown, are stable across storage conditions and container types, showing resilience to environmental changes. The ANOVA results reveal no significant effect of storage condition on color ($p = .149$), though an interaction between container type and duration shows a minor effect ($p = .016$). This stability in color is advantageous for maintaining visual quality, ensuring that tigernuts retain their appearance over time. Consequently, color stability supports long shelf life by preserving the product's appearance, making it less susceptible to environmental impacts.

Ogunwolu *et al.*, (2020): This study focused on the preservation of sensory attributes in stored food products, including tigernuts. The results indicated that color stability is maintained across various storage methods, with no significant deterioration noted. The authors emphasized that consistent color retention enhances the shelf life of tigernuts by ensuring they remain visually appealing to consumers

Effect of Storage Condition on Insect Effect

Insect presence, with values ranging from 1 to 2, (1 representing No Insect Effect while 2 representing visible Insect Effect) shows minimal variation across storage conditions, indicating that all tested environments effectively prevent insect contamination. This stability suggests that proper handling and sealing methods are employed, maintaining protection against insects regardless of storage environment. Effective insect control is crucial for shelf life, as infestations can lead to product degradation and pose health risks.

Similarly, container type does not significantly impact insect presence, with all options (Plastic Airtight, Polythene Bag, and Vacuum Bag) acting as effective barriers against insects. This consistency in insect protection across containers highlights that tigernuts are well-shielded from external contamination. Using containers that prevent insect entry is essential for long-term storage, ensuring product safety and extending shelf life by reducing risks of spoilage and contamination. Overall, the ANOVA results confirm no significant effect of either storage condition or container type on insect presence, demonstrating effective insect control across all tested conditions, which is beneficial for maintaining product quality and shelf stability.

IV. CONCLUSION

The study revealed that moisture content is highly sensitive to storage temperatures, with observed levels ranging from approximately 12.30% to 16.30%. Higher temperatures were associated with increased moisture loss, which can compromise the overall quality and shelf life of tigernuts. Consequently, maintaining optimal storage conditions is essential to prevent spoilage and extend the product's usability.

The findings also highlighted the significant role of packaging materials in moisture retention. Vacuum-sealed and airtight containers were particularly effective in maintaining moisture levels over extended periods, reinforcing the notion that appropriate packaging can mitigate the adverse effects of environmental factors. The stability of size measurements, ranging from 8.20mm to 8.50mm, indicated that while minor variations occurred due to container type, the physical dimensions of the tigernuts remained largely unchanged under optimal conditions. This stability in size suggests that storage conditions are not a major concern for shelf life, although consistent practices are recommended to maintain product integrity.

Color values showed remarkable stability, ranging from Brown to Dark Brown across various storage conditions, with ANOVA results confirming no significant effect of storage conditions on color ($p = .149$). This stability is advantageous for maintaining the visual quality of tigernuts, ensuring that they retain their appealing appearance over time. However, minor fluctuations were noted with prolonged storage, indicating the potential for gradual degradation.

Insect presence was consistently low, with values ranging from 1 to 2 (1 representing No Insect Effect while 2 representing visible Insect Effect) across all tested environments, suggesting effective containment strategies that prevent contamination. The consistency in insect control across different container types—Plastic Airtight, Polythene Bag, and Vacuum Bag—highlights the importance of using effective barriers to protect tigernuts during storage. Overall, the study underscores the critical need for proper storage practices to enhance the quality and shelf life of tigernuts, ultimately contributing to consumer satisfaction and safety.

REFERENCES

[1]. Adejuyitan JA.(2011).Tigernut processing: Its food uses and health benefits. Am. J. Food Tech. 2011;6(3):197-201.

[2]. American Society of Agric. Engineers (1990), ASAE S352.2 Standards, 45th Ed, DEC. 97. *Moisture Measurement. Unground grain and seeds*. 551. St. Joseph, Mich: ASAE.

[3]. Awulu, J. O., Ijabo, O. J., Omale, P. A. (2015). Effect of storage techniques on the shelf life of some selected orange species in Benue State. In *International Journal of Scientific & Engineering Research* (Vol. 6, Issue 7, p. 575). http://www.ijser.org

[4]. Ayeh-Kumi PF, Tetteh-Quarcoo PB, Duedu KO, Obeng AS, Addo-Osafo K, Mortu S, Asmah RH. A survey of pathogens associated with *Cyperus esculentus* L. (tigernuts) tubers sold in a Ghanian city. BioMed. Centra. Res. Notes. 2014;7(343): 1-9.

[5]. Bamishaiye, E.I and Bamishaiye, O.M (2011), Tiger Nut: as a plant, its derivatives and benefits.AJFAND African Journal of Food, Agriculture, Nutrition and Development, Vol. 11 No.5 September 2011. ISSN: 16845374. Published by African Scholarly Science Communication Trust.

[6]. FAO. Fermented fruits and vegetables: A global perspective. Battcock M, Azam-Ali S, Eds. FAO. Agric. Serv. Bul. No. 134 Rome; 1988.

[7]. FAO. Traditional food plants. Food Nutri. Paper 42 Rome. 1988;239-242.

[8]. Gómez-Caravaca, A. M., Verardo, V., Segura-Carretero, A., & Fernández-Gutiérrez, A. (2016). Cabernet Sauvignon red wine quality: Effect of storage temperature and packaging material. Food Control, 59, 65-73.

[9]. Lorenzo, J. M., Munekata, P. E. S., Gómez, B., & Barba, F. J. (2014). Moringa oleifera leaves: benefits and uses for food products. In A. B. de Oliveira (Ed.), Moringa oleifera: cultivation, nutritional properties and uses (pp. 35-54). Nova Science Publishers.

[10]. Ogbuagu, E., Azubuike-Osu, S., & Eme, U. (2019). Nutritional composition of tigernut (Cyperus esculentus) tubers Food Science & Nutrition, 7(8), 2706-2714

[11]. Omale, P. A., Aremu, A. K., & Omobowale, M. O. (2023). Modeling of Physical and Compressive Test Properties of Tigernut Using Response Surface Approach. *Journal of Engineering Research and Reports*, *24*(2), 1-14.

[12]. Omale, P. A, and Omobowale, M. O. (2018). Mechanical Properties of Tigernut (Cyperus esculentus) as Influenced by Moisture Content. VI Technical Symposium, CIGR, Oct 2018, Ibadan, Nigeria, Nigeria. hal-03956733

[13]. Rocculi, P., Castro, D., Dalla Rosa, M., & Siroli, L. (2016). Edible films and coatings for food packaging: Migrating from concepts to industrial application. In M. G. R. Vale (Ed.), Food Packaging: Advanced Materials, Technologies, and Innovations (pp. 529-549). Springer.

[14]. Sánchez-Zapata E, Fernández-Lopez J, Pérez-Alvarez JA. Tigernut (*Cyperusesculentus)* commercialization: Health aspects, composition, properties and food applications. Compre. Reviews Food Sci. Food Safety. 2012;11:366-377.

[15]. Sun, W., Xiao, H., Zhang, H., & Sun, Q. (2020). Effect of temperature and humidity on the storage quality of rice. Food Science & Nutrition, 8(7), 3471-3481.

[16]. Téllez-Pérez, C., Soto-Cruz, N. O., Estrada-Martínez, L. E., & Olivas, G. I. (2019). Tiger nut (Cyperus esculentus L.): A review on its composition and properties. Journal of Food Research, 8(3), 1-13.

[17]. Udeozor LO, Awonorin SO. Comparative microbial analysis and storage of tigernut soy milk extract. Austin J. Nutri. Food Sci. 2014;2(5):1-6.

[18]. Ukwuru MU, Ibeneme CL, Agbo GI. New product development from tigernut (*Cyperus esculentus*) and their sensory, proximate and microbiological evaluation. Pak. J. Nutri. 2011;10(2):101-105.