Original Research Article

Moisture sorption isotherm and quality characteristics of sun dried kilishiin Nigeria stored at 45 ^{0}C

ABSTRACT

The study investigated the relationship between moisture sorption isotherm and the quality of sun-dried kilishi in storage using various methods of analysis and experimentation. The results of sorption indicate indicated sundried kilishi is a stable product while proximate composition of sundried kilishi before and after storage at 45 ^{0}C showed that the protein content of this product after 35 days of storage was significantly higher ($p<0.05$) than before storage. This might be due to loss of moisture in storage which accounted for the concentration of some nutrients such as ash and carbohydrate content as revealed in this study. The study also revealed a decrease in fat content in storage, lipid peroxidation due to temperature change which may be responsible for the decrease as malondialdehyde increases from 0.223 to 0.341. Sensory characteristics were affected in storage. Aroma, flavour, juiciness and overall acceptability significantly decrease ($p<0.05$) after storage at 45 ^{0}C for 35 days as compared to the sensory status of this product before storage. In conclusion, moisture sorption and environmental conditions need proper control to keep sun dried kilishi stable on shelf.

Keywords: Adsorption, Packaging, Product, Shelf-life and Storage, KLISHI

INTRODUCTION

Kilishi is a popular Nigerian dried meat snack that is rich in flavor and has a unique texture. The term "kilishi" is derived from the Hausa language, where "kilishi" means a thin sheet of dried meat that is seasoned with a mixture of spices and peppers [1]. Typically, kilishi is made from lean cuts of beef or goat meat that are marinated in a blend of spices such as ginger, garlic, cayenne pepper, and salt before being air-dried or sun-dried to preserve the meat [2]. The result is a savory and spicy snack that is high in protein and low in fat, making it a popular choice for those looking for a healthy and flavorful snack option.add reference

Moisture sorption plays a critical role in the preservation of food products by influencing their shelf life [3], texture, and overall quality. When food is exposed to ambient moisture levels, it can lead to microbial growth [4], enzymatic reactions [5] and chemical degradation, all of which can compromise the safety and sensory attributes of the product. By controlling the moisture content through sorption processes, such as drying or good packaging, the growth of microorganisms can be inhibited, enzymatic activities can be slowed down, and chemical reactions can be minimized [6]. This can result in extended shelf life, improved texture, and enhanced flavor retention of the food product. Therefore, understanding the importance of moisture sorption in food preservation is crucial for maintaining the quality and safety of food products, particularly in the case of sun-dried kilishi.

The study of sorption isotherm in food products holds significant importance in understanding the behavior of moisture content over a range of relative humidity levels. This understanding is crucial for determining the equilibrium moisture content, which directly impacts the shelf life and overall quality of food products. By studying the sorption isotherm of sun-dried kilishi during storage, we can gain insights into the moisture adsorption and desorption characteristics of this traditional Nigerian meat product, aiding in optimal storage conditions and preservation methods [7]. Additionally, the sorption isotherm data can provide valuable information on the proximate composition changes in kilishi over time, helping to assess nutritional quality and safety aspects [8]. Therefore, delving into the sorption isotherm of food products like kilishi is essential for enhancing storage practices and ensuring product quality and safety in the food industry.

Previous studies on moisture sorption in food products have highlighted the importance of understanding how moisture interacts with different food matrices. For instance, research by Sá et al. [9] investigated the effect of varying levels of humidity on the moisture sorption behavior of peanut seeds. Their findings suggested that the sorption isotherms of peanut seeds were greatly influenced by the relative humidity of the surrounding environment. Similarly, a study by Roos [10] examined the moisture sorption properties of dairy products and concluded that the water activity influences the stability of food products by determining the availability of water for degradation reactions and microbial growth, with lower aw generally indicating greater stability. The shelf life of foods is influenced by intrinsic factors like water activity, which, along with extrinsic factors such as storage conditions and packaging, determines the rate of quality changes [11]. These studies underscore the significance of moisture sorption phenomena in food products. This part must be in discussion section

The importance of proximate composition analysis in food storage cannot be overstated. Understanding the chemical and physical properties of a food product is crucial for determining its shelf life, quality, and safety over time [12]. Proximate composition analysis provides valuable information about the moisture, fat, protein, ash, and carbohydrate content of a food item, which directly impacts its stability and susceptibility to spoilage. By conducting proximate composition analysis on sun-dried kilishi during storage, we can track changes in nutrient content and moisture levels, allowing us to make informed decisions about the best storage conditions to maintain its quality and extend its shelf life [13]. This analysis serves as a vital tool in the food industry to ensure that products remain safe for consumption while preserving their nutritional value and flavor profile. Ultimately, proximate composition analysis plays a critical role in optimizing food storage practices to enhance food quality and safety [14].

Sorption isotherm and lipid oxidation is crucial in understanding the behavior of sun-dried kilishi during storage. Lipid oxidation, on the other hand, refers to the degradation of fats in the presence of oxygen, leading to off-flavors and rancidity. In the context of sun-dried kilishi, an understanding of sorption isotherm can help predict potential moisture uptake during storage, while knowledge of lipid oxidation can guide strategies to prevent lipid deterioration and maintain product quality. By investigating these aspects, we can develop effective storage protocols to enhance the shelf life of sun-dried kilishi without compromising its sensory attributes. Lipid oxidation in food products, such as sun-dried kilishi, is a critical concern as it can lead to the development of rancidity, undesirable flavors, sensory degradation, consumer rejection, and the formation of toxic substances, highlighting the importance of controlling oxidative processes in the meat industry [15.]

This oxidation process is primarily influenced by factors like temperature, oxygen exposure, and the presence of pro-oxidants [16, 17, 18]. Lipid oxidation in foods can result in the formation of free radicals, which not only deteriorate the lipids themselves but also affect proteins, causing oxidation and aggregation that can alter their physicochemical characteristics and biological functions, thereby reducing food quality [19]. Also, the evaluation of the sensory characteristics of kilishi stored under various conditions will provide insights into its sensory changes during storage.

However, there is a noticeable gap in the research pertaining to the sorption isotherm behavior of sundried kilishi and nutritional stability of this product stored above the temperature experimented to determine its water activity. This gap in knowledge is significant as it hinders the optimization of storage conditions and shelf life of kilishi products. Therefore, this research aims to fill this gap by investigating the sorption isotherm characteristics of sundried kilishi using analytical techniques and mathematical models. Understanding the sorption behavior of kilishi will contribute to the development of efficient storage and packaging strategies in the food industry.

Introduction is too lenth

2. MATERIALS AND METHODS

2.1 Preparation procedures of sun-dried kilishi

2000g of boneless beef was procured from a reputable beef seller in Ado Ekiti, Nigeria. You've use just one sample? All excess fats and adhering connective tissues were trimmed off from the beef and sliced into flat sheets of 3mm by thickness to facilitate absorption of slurry and drying process. All dried non-meat ingredients were mixed and oil was added to constitute a homogenous mixture. Flat thin sheets of semitendinosus muscle of beef were sun dried for at least 6 hours thereafter soaked it in the kilishi ingredient slurry for 1 hr 30 minutes. The soaked muscles were spread out on the oven rack for proper draining. Oven trays were slightly lined with oil, baking sheets were spread on the oiled tray, the drained raw kilishi were separately placed side by side on the flat trays and cooked in already preheated oven at 63°for 40 minutes. Mixture of tsire (suya spice), pepper and olive oil (slurry) were used to coat the already oven-dried muscles. These were returned to the oven for 10 minutes for final drying. Processed kilishi product was cooled to room temperature prior to further analysis.

From whitch part of meat?

Table1. Ingredients composition of kilishi

Ingredients	Quantity (gms)
1000g semitendinosus muscle of beef cattle	
Garlic paste	2.5
Ginger paste	2.5
Cameroun pepper	5.0
Chili pepper	5.0
Black pepper	5.0
Tsire (suya spice)	50.0
olive oil	10.0
Salt	2.5.
Thyme	2.5
Curry	2.5
Paprika	5.0
Turmeric powder	7.5
Total	100

2.2 Procedure of Adsorption

Using the static gravimetric method [20], the equilibrium moisture content of sun dried kilishi was determined at 30 °C. Five (5g) grams of sun dried kilishi were placed in a mesh bag, which was dropped above the saturated salt solutions contained in a glass jar. The jar was tightly closed with the aid of petroleum jelly and placed in a temperature-controlled cabinet (±0.2 °C). The samples were equilibrated with set humidity conditions until a stable weight was achieved. The sample was weighed daily with digital mettler balance until the mass difference was less than 0.001g. The determination of the equilibrium moisture content was carried out by oven dry method, the sample was dried at 105 °C for 24 h. All the experiments were carried out in triplicate. Ten saturated salt solutions prepared ranged between 0.030 to 0.970. The water activities and the salt solutions used were as reported [21] and this is as given in Table 1.

Table 2: Names of saturated salt solution used for sorption experiment

Salt	Aw (30^{0}C)
Cesium Flouride	0.030
Lithium Chloride	0.113
Potassium Acetate	0.216
Magnesium Chloride	0.324
Potassium Carbonate	0.432
Sodium Bromide	0.560
Potassium Iodide	0.679
Sodium Chloride	0.751
Potassium Chloride	0.836
Potassium Sulfate	0.970

2.3 Determination of equilibrium moisture content

This was done as stated below:

$\mathrm{EMC} = \frac{We}{Wi}(\mathrm{Mi} + 1) - 1$ (Tantala et al., 2019) [22] ………………………………………Equation 1

where We is the equilibrium weight of the sample (g), Wi is the initial weight of the sample (g), and Mi is the initial moisture content of the sample (g)

The suitability of GAB equation for a_w of 0 - 0.95 [23], was employed to analyze the water activity and monolayer moisture value of sun dried kilishi.

GAB Equation = $= \frac{M}{Mm} = \frac{ABaw}{(1-Baw)(1-Baw+ABaw)}$[24] ………………………………………Equation 2

add a reference of this method

2.4 Stability test

Ten gramme (10g) of sun dried kilishi was stored in polyethylene bag of 20 micron thickness for 35 days at 45 ^{0}C, a temperature above the temperature (30 ^{0}C) experimented to determine its water activity of 0.39. Nutritional composition such as protein, fat, ash, moisture content and carbohydrate were evaluated and compared with its nutritional composition before storageadd a reference of this method

2.5 Sensory evaluation sun-dried kilishi

The sensory evaluation was conducted by the methods of Kumari et al. [25]. Semi-trained taste panelist comprising ten members of both sexes participated in the assessment of sensory properties of the samples. Individual unit cell housed the assessors and each person was given unsalted biscuits and table water to cleanse palate after each taste of the sample. Samples were labelled and independently evaluated using a 9- point hedonic scale ranked as follows; like extremely to very much (8–9 scores), like moderately to like slightly (5–7 scores), neither like nor dislike to dislike slightly or dislike moderately (2–4 scores) and dislike extremely to dislike very much (0–1 score) for aroma, flavor, tenderness, texture and over all- acceptability.Give scores in the results section

2.6 Proximate composition determination of sun-dried kilishi

Sun-dried kilishi samples were analyzed for proximate composition according to the methods outlined by the Association of Official Analytical Chemists (AOAC). In order to ensure correctness and reliability of the results, all analyses were conducted in triplicate [26].

2.7 Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) assay was used to measure malondialdehyde (MDA) levels as a marker of lipid oxidation [27]. Doyou make fatty acid analysis, whitch method and whitch fatty acids you've analysed?

2.8 Statistical analysis

Statistical analysis was carried out using IBM SPSS Statistics 20, One-way ANOVA Post Hoc Multiple Comparisons of Ryan-Einot-Gabriel-Welsch F' test at 0.05 significance level [28]. whitch parameters you've done by statistical analysis

3. RESULTS

Equilibrium moisture content ranged from 5.78 to 29.22 while water activity of sorption was between 0.0052 and 0.0332, over the range of relative humidities experimented. The curve of sorption isotherm of kilishi revealed a good fitness of curve at 0.8125. The calculated water activity and monolayer moisture of this product were 0.39 and 15.82 (g H_2O / g Solid) respectively. Table 2 showed the result of proximate composition of sundried kilishi before and after storage at 45 ^{0}C. Protein content of this product after 35 days of storage was significantly higher ($p<0.05$) than before storage. This might be due to loss of moisture in storage which accounted for the concentration of some nutrients such as ash and carbohydrate content as revealed in this study. The study also revealed a decrease in fat content in storage, lipid peroxidation due to temperature change may be responsible for the decrease as malondialdehyde increases from 0.223 to 0.341 (Table 3). Sensory characteristics were affected in storage. Aroma, flavour, juiciness and overall acceptability significantly decrease ($p<0.05$) after storage at 45 ^{0}C for 35 days as compared to the sensory status of this product before storage. Texture and tenderness were not significantly ($p>0.05$) affected. Redendency, all parameters must be in the table

Results and interpretation of sorption isotherm behavior of sun-dried kilishi revealed interesting insights into the moisture sorption characteristics of this popular Nigerian food product. The sorption isotherm data indicated a typical type 4 shape, suggesting kilishi's ability to exhibit a steep rise in adsorption at low pressures. The interpretation of this behavior highlights the importance of understanding kilishi's water activity levels to maintain its shelf stability during storage. These findings contribute significantly to the knowledge base on the moisture sorption properties of sun-dried kilishi, aiding in the development of appropriate storage and packaging strategies to ensure product quality and safety over time. Overall, the results underscore the need for precise control of environmental conditions to prevent moisture-induced deterioration in kilishi quality.

Nutritional composition analysis of kilishi in storage revealed that the moisture content of the product significantly decreased in storage, leading to changes in its overall composition. Specifically, the protein content was found to decrease, it’s not really important findingwhile the fat content increased, resulting in alterations to the product's texture and flavor profile

Experimental results on sorption isotherm and lipid oxidation of sun-dried kilishi in storage indicate a crucial relationship between moisture content and lipid oxidation. As moisture levels increases, lipid oxidation showed a corresponding upward trend, indicating a direct correlation between water activity and oxidative processes. These findings emphasize the importance of controlling moisture content during storage to prevent lipid oxidation in kilishi. Understanding these outcomes is vital for enhancing the quality and shelf life of kilishi and similar products in the food industry. Add a references

The results analysis of the sorption isotherm and sensory characteristics of sun-dried kilishi in storage revealed important insights into the behavior of the product over time. The data obtained from the sorption isotherm analysis illustrated the moisture sorption properties of kilishi, indicating its ability to absorb moisture from the surrounding environment. This information is crucial for determining the product's stability and shelf life. On the other hand, the sensory characteristics analysis provided valuable information on the changes in aroma, flavour and texture of kilishi during storage, offering a comprehensive understanding of its overall quality. By combining these results, we can make informed decisions about the packaging, storage conditions, and shelf-life recommendations for sun-dried Kilishi. Overall, the results analysis sheds light on the intricate relationship between storage conditions, moisture sorption, and sensory attributes of this traditional dried meat product, providing a solid foundation for further research in this area.

Table 3. Sorption Isotherm of Sun Dried Kilishi

aw (30^0C)	EMC	aw/M
0.030	5.78	0.0052
0.113	6.10	0.0185
0.216	10.45	0.0207
0.324	11.20	0.0289
0.432	16.13	0.0267
0.560	22.52	0.0249
0.679	24.25	0.0279

0.751	25.15	0.0299
0.836	27.31	0.0306
0.970	29.22	0.0332

EMC = M = Equilibrium Moisture Content

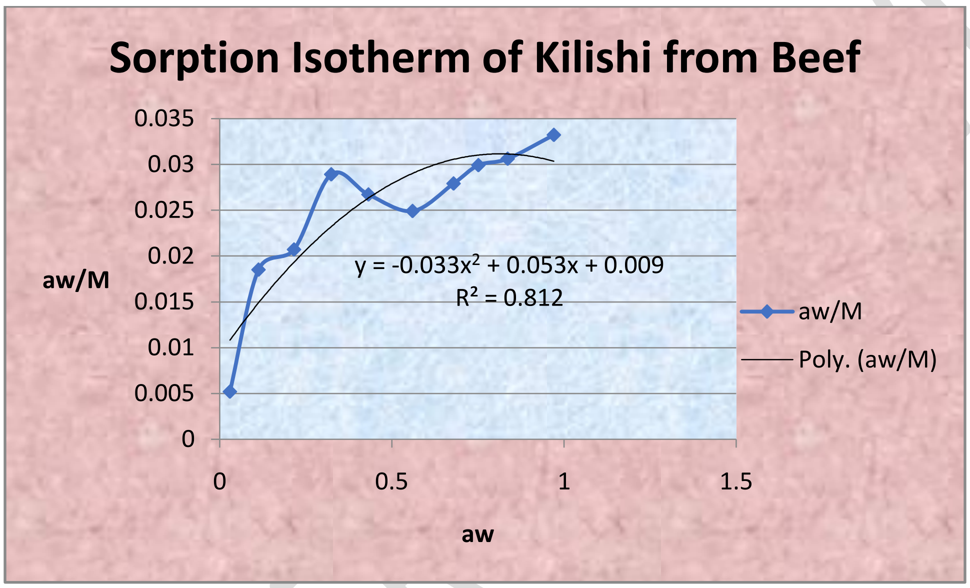

Figure 1. Adsorption Isotherm Curve of Sun Dried Kilishii

Table 4. Analysis of sorption data of Kilishii according to GAB Model

Product sample	Water activity (a_w)	Monolayer value (Mo) (g H_20/g Solid)	R^2
Kilishi	0.39	15.82	0.812


KILISHI
TECNO
SPARK

Figure 2. Product sample of Sun Dried Kilishii

Table 5. Proximate composition of sun dried kilishi before and after storage for 35 days at 45 ^{0}C

Components	Composition (%)	
	Mean ±SD before storage	Mean ±SD after storage at 45 ^{0}C
Crude protein	69.22±0.110^{a}	72.30±0.050^{b}
Moisture content	7.16±0.010^{b}	10.13±0.010^{a}
Ash	4.30±0.030^{a}	3.33±0.040^{b}
Fat	11.64±0.020^{a}	6.36±0.010^{b}
Carbohydrate	7.50±0.040^{a}	7.81±0.010^{b}

Table 6. Lipid oxidative stability of kilishi before and after storage for 35 days at 45 ^{0}C

Component	Composition	
	Mean ±SD before storage	Mean ±SD after storage at 45 ^{0}C
TBARS (MDA/Kg meat)	0.223±0.000^{a}	0.341±0.333^{b}

TBARS- Thiobarbituric AcidYou've to make table 5and6 together, in one table

-Reactive Substance, SEM- standard error of mean

Table 7. Sensory properties of Kilishi before and after storage for 35 days at 45 ^{0}C

Component	Composition	
Sensorial properties	Mean ±SD before storage	Mean ±SD after storage at 45 ^{0}C
Aroma	7.17±0.010^{b}	5.33±0.293^{a}
Flavour	7.33±0.030^{b}	6.00±0.010^{a}
Juiciness	7.17±0.030^{b}	5.5±0.050^{a}
Texture	6.67±0.026^{a}	7.00±1.000^{a}
Tenderness	4.17±0.010^{a}	4.00±0.100^{a}
Overall acceptability	8.18±0.010^{b}	7.10±0.100^{a}

SEM- standard error of mean

And table7 together

4. DISCUSSION

The effects of storage conditions on the proximate composition of kilishi are crucial considerations in maintaining the nutritional quality of this popular dried meat product [29]. As kilishi is prone to changes in moisture content, lipid oxidation, and protein degradation during storage, variations in storage conditions such as temperature, humidity, and packaging can significantly impact its proximate composition. For instance, exposure to high temperatures may lead to lipid rancidity and protein denaturation, affecting the overall nutritional value of kilishi. Lipid oxidation under high temperatures can generate free radicals, which in turn can lead to protein oxidation and aggregation, affecting the physicochemical characteristics and biological functions of proteins [19]. Conversely, proper storage conditions that control moisture levels and prevent oxidation can help preserve the protein, fat, and carbohydrate content of kilishi over an extended period. Understanding these effects is essential for ensuring the quality and safety of kilishi throughout its storage life cycle. A comparison of proximate composition pre and post-storage reveals essential insights into the changes that occur during the storage of sun-dried kilishi. The proximate composition, which includes moisture content, protein, fat, ash, and carbohydrate levels, can undergo alterations due to various storage conditions such as temperature, humidity, and packaging materials. Studies have shown that the moisture content of kilishi tends to decrease or increase post-storage, leading to potential changes in protein, fat, and carbohydrate concentrations [30]. These changes can impact the overall quality and shelf-life of the product, making it crucial to monitor proximate composition changes over time. By comparing pre and post-storage composition, researchers can better understand the effects of storage conditions on kilishi and make informed recommendations for optimal storage practices to preserve its quality.

To maintain the proximate composition stability of sun-dried kilishi during storage, several strategies can be implemented. Packaging plays a crucial role in preserving the quality of the product. Using airtight packaging materials can prevent moisture absorption and lipid oxidation, thus maintaining the proximate composition. Secondly, storing the kilishi in a cool, dry place away from direct sunlight can help prevent microbial growth and enzymatic reactions that could alter its composition. Additionally, regular monitoring of storage conditions such as temperature and humidity levels is essential to ensure the product's stability over time. By combining proper packaging, suitable storage conditions, and diligent monitoring, the proximate composition of sun-dried kilishi can be effectively preserved during storage periods, leading to a longer shelf life and better product quality.You've to discuss your results with other studies and to give more references

The particle size of spices used in marination could affect the proximate composition, with finer particles leading to lower microbial growth and oxidative rancidity, indicating the importance of spice particle size in meat storage [31]. Factors affecting lipid oxidation in sun-dried kilishi play a crucial role in determining the product's shelf life and overall quality during storage. Specifically, the presence of unsaturated fatty acids,this part don't reliezed in this tudy, so, you should not speak about moisture content, and the level of oxidative enzymes are essential variables to consider. Unsaturated fatty acids are more susceptible to oxidation compared to saturated ones, leading to rancidity and off-flavors in the product [32]. The moisture content in kilishi if not properly controlled may influence lipid oxidation by providing a favorable environment for enzymatic and non-enzymatic reactions. Additionally, the activity of oxidative enzymes such as lipoxygenase can accelerate lipid oxidation processes in the product. Understanding these factors is fundamental to developing effective strategies to control lipid oxidation and enhance the storage stability of sun-dried kilishi. The changes in sensory parameters of kilishi in storage might have been caused by decrease in fat during storage at relatively high temperature. Exposure to light and heat should be minimized to prevent flavor alterations and rancidity.

5. CONCLUSION

The sorption isotherm analysis revealed that the moisture content of kilishi increased gradually over time, indicating the need for proper packaging and storage conditions to prevent moisture absorption and maintain product quality. Additionally, the lipid oxidation, proximate composition and sensory characteristics results demonstrated that the level of changes in nutritional status highlight the importance of maintaining storage below its water activity and good packaging materials maintain product quality and consumer satisfaction. Hence, kilishi should ideally be stored in a cool, dark, and dry environment to maintain its sensory characteristics and extend its shelf life.

Conclusion is too short

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