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SORPTION ISOTHERM, PROXIMATE COMPOSITION AND SENSORY EVALUATIONS OF OVEN DRIED AND FRIED CHEESE PRODUCTS FROM LOCAL SOFT CHEESE

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ABSTRACT

In this study, the sorption isotherm, proximate composition and sensory characteristics of oven dried and fried cheese were investigated. The understanding of the moisture sorption properties, nutrient composition and sensory properties of the oven dried and fried cheese can help quality, shelf-life prediction and overall acceptance. The experimental methodology for this study followed a standard procedure to determine the sorption isotherm of oven-dried and fried cheese samples. First, the raw milk samples were obtained from white Fulani cows at the Teaching and Research Farm, Ekiti State, University, Ado-Ekiti, Nigeria and processed into cheese. The cheese was divided into two portions: one group was oven-dried at 50 ^{0}C for 16 hours, while the other group was fried in pre-heated edible canola to internal temperature of 68^{o}C. Sorption parameters, proximate and sensory characteristics were carried out according to standard methods. This study revealed that the monolayer moisture was higher in fried cheese than oven dried cheese. Oven-dried cheese had 0.299 water activity and 21.26 monolayer moisture while fried cheese had higher water activity of 0.32 and monolayer moisture of 29.67. Fitness of curve (R^2) of 0.731 0.903 were computed for oven-dried and fried cheese. The results of proximate composition and sensory characteristics showed that processing methods influenced the sensorial properties and nutritional composition of oven-dried and fried cheese. In conclusion, oven-dried cheese can be predicted to be more stable than fried cheese.

KEYWORDS: *Adsorption, Equilibrium, GAB Equation, Monolayer, Salts.*

1. INTRODUCTION

Cheese has been an important part of human history and culture for centuries, and its importance to man such as infant mortality reduction and enhancement of demographic shifts in farming communities [1] and food security [2] cannot be overstated. This is due to a number of reasons, including its nutritional value; as a rich source of protein, calcium, biologically active conjugated linoleic acid (CLA) and milk fat globule membrane (MFGM) biologically active conjugated linoleic acid (CLA) and milk fat globule membrane (MFGM) [3]. Cheeses are considered 'functional' foods due to their unique composition, which includes bioactive peptides, lipids, prebiotics, and probiotic bacteria, as well as calcium for bone health [4]. Also, cheese is used in a wide variety of dishes, making it an essential ingredient in many cuisines around the world [5]. The taste, texture and other attributes of cheese have made many to incorporate it into their diets as a regular indulgence [6]. Cheese has played an integral role in shaping human society through its nutritional benefits, versatility in cooking methods, economic impact, and cultural traditions. However, proximate composition which refers to the chemical components of a food item, including its moisture content, protein, fat, and carbohydrate levels and sensory properties can vary with processing methods and temperature [7].

Cheese being a popular and versatile food that has been enjoyed by humans for centuries is a perishable food item, which gets spoil if not properly stored or preserved [8]. The process of cheese spoilage involves the growth of microorganisms such as bacteria, mold and yeast which can alter its sensory properties such as taste, texture, and appearance [9]. There are several factors that contribute to cheese spoilage which include humidity and temperature fluctuations during storage, exposure to air and moisture [10], bad handling and animal hygiene [11], and improper packaging. These factors create a favourable environment for microorganisms to grow and cause deterioration of the cheese. Cheese stability has been a subject of concern due to its poor storability. Various techniques such as modified atmosphere, addition of preservatives, active and edible coatings had been adopted to extend its shelf-life [12].

To prevent cheese spoilage and extend its shelf life, various preservation methods have been developed over time. Some common techniques include refrigeration at low temperatures (around 4°C), vacuum sealing to remove oxygen from the packaging which inhibits bacterial growth [13], addition of preservatives such as salt or vinegar to provide unsuitable environment for microbes. As consumer demand for high-quality cheeses continues to rise globally, the importance of understanding how best to preserve them becomes crucial. Traditional method and factory system of fresh cheese making and storage, especially the cold storage has helped greatly in meeting the demand for fresh cheese [14]. To ensure cheese quality, several production and storage techniques such as pasteurization of milk, cold storage, use of commercial starters are been employed [15]. Product developments from fresh cheese such as boiled and fried cheese are the delicacies of many Nigerians. However, these products get spoiled within few days due to lack of proper knowledge of the storage conditions. Sorption isotherm which refers to the relationship between water activity and moisture content of a food product at a specific temperature may offer a more promising storage alternative. The interrelationship of moisture and water activity of products is crucial to it shelf life [16]. Water activity is also useful for predicting the final moisture content [17]. The moisture content and sensory properties of food are interrelated [18]. An understanding of the chemical and sensory properties of cheese can help manufacturers create desirable products [19]. The main objective of drying is to decrease the water activity to a safe value in order to increase shelf life by inhibiting the growth of microbes and enhance storage at ambient temperature [17].

A number of empirical models have been derived for the correlation of water sorption and water activity in food substances. Among these, is the Guggenheim-Anderson-de Boer (GAB) model [20] employed in this study because Guggenheim, Anderson and De Boer (GAB) model has been proven to be the best fit for the desorption and adsorption of foods over a large range of water activities [21] Determination of the sorption isotherm proximate composition and sensory characteristics of oven dried cheese and fried cheese will enhance their storage life quality assessment, hence this study.

2. MATERIALS AND METHODS

2.1 Procedure for collection of raw milk and production of soft cheese

The raw milk was obtained from white Fulani cows at the Teaching and Research Farm, Ekiti State, University, Ado-Ekiti, Nigeria. The raw milk was placed in 250ml beaker, pasteurized at 65^{0}C for 30minutes, cooled to 32^{0}C prior production of soft cheese. Fresh leaves of *Calotropis procera* were harvested from the surrounding villages in Ado-Ekiti, Nigeria, sorted, cleaned with distilled water, drained, dried, weighed and chopped into tiny sizes to aid the process of pulverization. 2500g of chopped fresh *Calotropis procera* were blender using USHA mixer grinder (MG 2053N, 500 watts). The mixture of the blended leaves of *Calotropis procera* was sieved and supernatant collected as the extract. 50ml of fresh supernatant of *Calotropis procera* extracts were added as source of calotropin enzyme, a milk coagulant into 500ml of pasteurized milk at a holding temperature of 32^{o}C in a stainless pot on heater, mixture was continually stirred until curds were produced. The curd was collected, sieved using cheese cloth and left 20 min to drain out the whey. The curds were pressed into v-shaped using perforated moulds, and allowed for 10 minutes for proper draining and shaping.

2.2 Cooking of Soft Cheese (Wara)

Two methods were adopted in the processing of the soft cheese, viz-a-viz deep frying and oven drying.

2.3 Fried Cheese

50g by wet weights of soft cheese were fried-cooked in pre-heated edible omega-3 fatty acid oil (canola oil) placed in deep frying pots with strainer, to internal temperature of 68^{o}C, drained and dried with kitchen disposable sheets.

2.4 Oven-Dried Cheese

50g (wet weights) each of soft cheese was set in a slight oiled oven tray, placed in a pre-heated oven at 50 ^{0}C for 16 hours. Each side was flipped at interval of 5 minutes until the cheese were totally dried. Dried cheese samples were cooled to room temperature and stored prior to analysis

2.5 *Procedure for Adsorption Isotherm*

The equilibrium moisture content of fried and oven dried cheese were determined at 25 °C using the static gravimetric method [22]. The product samples were dried over phosphorus pentoxide (P_2O_5) prior to sorption experiment, for a period of about 7 days to ensure they were at the same initial moisture content and dry enough for adsorption isotherm to take place [23]. Ten grams of fried and oven dried cheese were placed in a plastic mesh bag, which was dropped above the saturated salt solution contained in a glass jar. The jar was tightly closed and placed in a temperature controlled cabinet (±0.2 °C). The sample was weighted daily until the mass difference was less than 0.001g. To determine the equilibrium moisture content, the sample was dried in the oven at 105 °C for 24. The samples were cooled over silica gel before the final weights were taken. All the experiments were carried out in triplicate. Ten saturated salt solutions were prepared with a range of 0.043 to 0.973. The salt solutions used and their matching water activities were as reported [23] and this is as given in Table 1.

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Table 1 Salts and water activities

Salts	(25^0C)
Cesium Flouride	0.043
Lithium Chloride	0.113
Potassium Acetate	0.225
Magnesium Chloride	0.328
Potassium Carbonate	0.432
Sodium Bromide	0.576
Potassium Iodide	0.689
Sodium Chloride	0.753
Potassium Chloride	0.843
Potassium Sulfate	0.973

The formula for the determination of equilibrium moisture content is as stated below:

EMC $= \frac{wf-wi}{wi}$ x 100 (AOAC, 2010)

………………………… Equation 1

The GAB equation which is mostly suitable for a_w of 0 - 0.95 [Mustafa, 2018], was used to determine the water activity and monolayer moisture value of the product.

GAB Equation = $= \frac{M}{Mm} = \frac{ABaw}{(1-Baw)(1-Baw+ABaw)}$ (Van Den Berg, 1985)

………………………… Equation 2

GAB was rearranged into second degree polynomial for the determination of water activity and monolayer moisture value.

Mo – Monolayer value = $1/\sqrt{b^2} - 4ac$ ………………………… Equation 3

$a_w = a_w/M$ = Equation of line=y ………………………… Equation 4

Y= a_w/M (M= Monolayer value) Monolayer value indicates the amount of water that is strongly adsorbed in specific sites, and it is considered to be the value at which a food product is the most stable.

2.6 *Sensory Evaluation*

The sensory evaluation was conducted by the methods of Apata et al. [24]. A Ten member of semi-trained taste panelist of both sexes participated in the assessment of sensory properties of the samples. The assessors were placed in an individual unit cell without seeing each other; each person was given unsalted biscuits and fresh orange juice to cleanse palate after each taste of the sample. Samples were coded 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, saltiness, hotness and over all-acceptability.

2.7 Proximate Composition

Proximate composition was analyzed according to the official method of analysis as described by the Association of Official and Analytical Chemist (25).

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 [26]

3. RESULTS AND DISCUSSION

The water activities used for this study ranged from 0.043 to 0.973 for both oven dried and fried cheese. Equilibrium moisture content for oven dried cheese ranged from 11.27 to 43.31. A gradual increase in equilibrium moisture content was observed from water activity of 0.043 to 0.432 while a sharp increase occurred from 0.432 to 0.576 a_w as equilibrium moisture rose from 19.35 to 33.55. This sharp increase continues till 0.689 water activity with equilibrium moisture content of 44.12. Retardation in equilibrium moisture content was however observed between the water activities of 0.689 and 0.753 as equilibrium moisture content drops to 39.98 from 44.12. There was a recovery in the retardation of the equilibrium moisture content as water activity moves from 0.753 to 0.843 and further to 0.973. The results of equilibrium moisture contents move from 39.98 through 41.15 to 43.31 for the water activities; 0.753, 0.843 and 0.973 respectively. The water activity of moisture for oven-dried cheese ranged from 0.0038 to 0.0225. The highest water activity of moisture; 0.0225 corresponds to the highest water activity of 0.973 while the lowest water activity of moisture; 0.0038 corresponds to the lowest water activity of 0.043. However, highest equilibrium moisture content (44.12) as revealed in this study does not correspond to the highest water activity neither to highest moisture content of moisture in oven dried cheese.

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Equilibrium moisture content of fried cheese as revealed in this study shows that it traversed between 21.35 and 45.32. There was a progressive increase in equilibrium moisture content from 21.35 to 29.03 which corresponds to the water activities from 0.043 to 0.576 respectively. Tremendous increase in equilibrium moisture content from 0.576 to 0.689 water activities was observed. Equilibrium moisture content increased from 29.03 to 50.15 as water activity moves from 0.676 to 0.689. Equilibrium moisture content drops to 45.25 and further to 43.22 at water activity of 0.73 and 0.843 apiece. This downward movement in equilibrium moisture content recovered at 0.973 water activity which recorded; 45.32 equilibrium moisture content.

The water activity of moisture for fried cheese as revealed in this study shows three phases of sorption behavior; increase, decline and further increase over the range of water activities of 0.043 to 0.973 tested. The first phase covers the range of water activities of 0.043 to 0.432 which had a progressive increase in water activity of moisture (0.0020 to 0.0160). Second phase spans through water activities of 0.576 to 0.689 which equally had water activity of moisture from 0.0151 to 0.0137. The third phase was a recovery from a decline experienced an the second phase which resulted in a further increase in water activity of moisture from 0.0166 through 0.0195 to 0.0125 of the water activities; 0.753, 0.843, and 0.973 respectively. Similarly, highest equilibrium moisture content (50.15) does not correspond to the highest water activity (0.973).

However, lowest equilibrium moisture content corresponds to the lowest water activity as observed in this study. Both the water activities of oven-dried and fried cheese had the same pattern of progress with increase in water activity.

Table 2 Equilibrium moisture content and water activity of moisture of oven-dried and fried cheese

a_w	Oven-Dried Cheese EMC (M) ±SD (%)	$a_{w/M}$	Fried Cheese EMC (M) ±SD (%)	$a_{w/M}$
0.043	11.27±0.02^{a}	0.0038	21.35±0.05^{a}	0.0020
0.113	13.31±0.59^{b}	0.0085	22.42±0.01^{b}	0.0050
0.225	15.52±0.01^{c}	0.0145	24.98±0.02^{c}	0.0090
0.328	17.38±0.02^{d}	0.0189	25.41±0.66^{c}	0.0129
0.432	19.35±0.01^{e}	0.0223	27.04±0.02^{d}	0.0160
0.576	33.55±0.00^{f}	0.0171	29.03±0.03^{e}	0.0151
0.689	44.12±0.01^{j}	0.0156	50.15±0.05^{i}	0.0137
0.753	39.98±0.01^{g}	0.0188	45.25±0.10^{f}	0.0166
0.843	41.15±0.02^{h}	0.0204	43.22±0.21^{g}	0.0195
0.973	43.31±0.01^{i}	0.0225	45.32±0.10^{f}	0.0215

$a_{w/M}$ = water activity of moisture, EME= Equilibrium moisture content. Each value is expressed as mean ± standard deviation (n=3) of triplicate analysis. Means within column followed by different superscripts indicate significance difference (p<0.05) by post hoc multiple comparisons of ryan-einot-gabriel-welsch f' test.

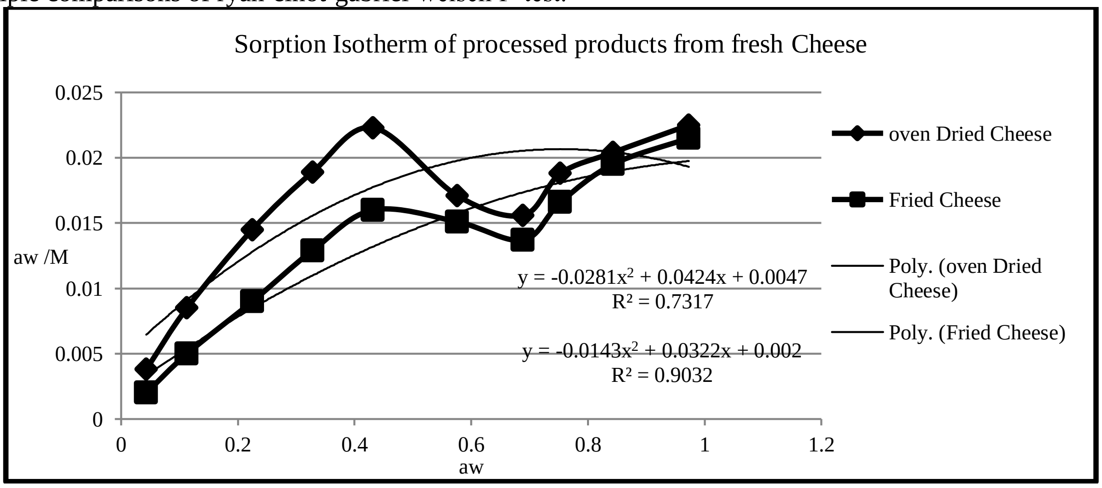

Figure 1: Sorption Isotherm of processed products from fresh local soft Cheese

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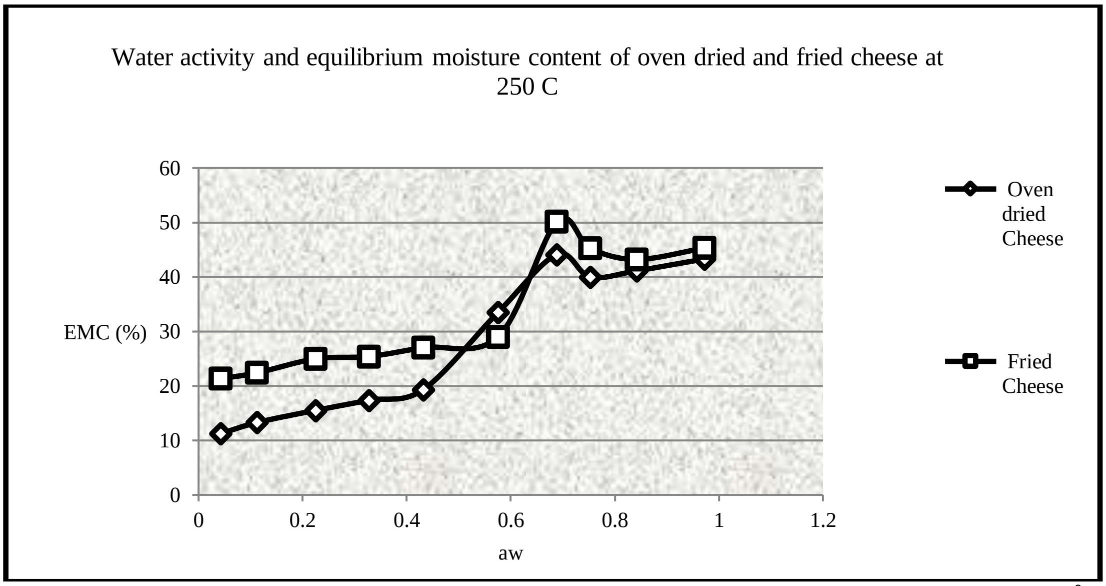

Figure 2: Water activity and equilibrium moisture content of oven dried and fried cheese at 25^0 C

Table 3: Analysis of sorption data of cooked local cheese according to GAB Model

Product sample	Water activity (a_w)	Critical Water activity (RHc)	Monolayer value (Mo) (g H_20/g Solid)	R^2
Oven Dried Cheese	0.299	0.432	21.26	0.731
Fried Cheese	0.32	0.432	29.67	0.903

R^2 = Fitness of curve

Table 4: Proximate composition of oven-dried and fried cheese (%)

Components	Oven-dried cheese	SEM	Fried cheese	SEM
Crude protein	52.00	0.00	38.37	0.20
Moisture content	22.00	0.58	35.97	0.03
Ash	5.33	0.33	7.73	0.13
Fat	12.00	0.58	10.10	0.10
Carbohydrate	8.67	0.33	7.83	0.17

Each value is expressed as mean ± standard error of mean (n=3) of triplicate analysis. Post hoc tests were not performed because there were fewer than three groups SEM=standard error of mean.

Table 5 Sensory characteristics of oven-dried and fried cheese (%)

Components	Oven-dried cheese	SEM	Fried cheese	SEM
Aroma	6.00	0.23	5.71	0.42
Flavour	5.86	0.46	5.57	0.48
Texture	5.43	0.43	5.86	0.96
Tenderness	5.14	0.14	6.14	0.60
Juiciness	3.13	0.51	4.86	0.14
Overall acceptance	6.57	0.20	6.29	0.18

Each value is expressed as mean ± standard error of mean (n=3) of triplicate analysis. Post hoc tests were not performed because there were fewer than three groups; SEM=standard error of means

The moisture adsorption data are useful in selection of appropriate packaging materials, determining the permeability of appropriate packaging materials and predict their shelf life [27]). The analysis of adsorption data of oven-dried and fried cheese shows that water activity, monolayer values and fitness of curve for these two products are different. The water activity and monolayer values as determined by GAB equation are as presented in Table 3. The equilibrium moisture content of oven-dried cheese was found to be relatively lower compared to fried cheese. This shows that oven-drying removes a considerable amount of moisture from the product. The water activity of fried cheese was also higher than that of oven dried cheese, suggesting that oven-dried cheese would be more stable and have a lower risk of microbial growth. Oven-dried cheese had 0.299 water activity and 21.26 monolayer moisture while fried cheese had higher water activity of 0.32 and monolayer moisture of 29.67. Fitness of curve (R^2) of 0.731 0.903 were computed for oven-dried and fried cheese (Figure 1). This study revealed that the monolayer moisture was higher in fried cheese even at a temperature higher than oven drying temperature as investigated in this study, a contradiction to a report of decrease in monolayer moisture with increasing temperature [28]. This might be due to short time used to fry cheese compared to long time of oven drying used in this experiment. Both the oven dried and fried cheese products will be most stable at their monolayer moisture contents, which largely depends on the chemical composition and structure [17].

Fried cheese sample had the higher value of equilibrium moisture content than oven dried cheese at all the water activities tested in this experiment. The variation in the results obtained from this study could be due to the different processing methods for the production of fried and oven dried cheese [12]

The water activities at which the growth of microorganisms becomes active for oven dried and fried cheese were calculated at 0.299 and 0.32aw respectively using the GAB models for each sorption isotherm are good values which indicate that only lower water activities will be appropriate for the growth limitation of microorganisms and subsequently for the extension of shelf life these products. Shelf life of these products at the water activities of 0.299 and 0.32 for oven dried cheese and fried cheese apiece requires packaging materials that will limit water vapour transmission as lack of good storage can lead to microbial contamination and spoilage. Higher temperature of storage should be avoided as high temperature will increase the transmission rate of water vapour. The water activities, the critical water activities of the products and the storage conditions are essential parameters for the prediction of shelf life. Moisture imparts mobility of molecules and enables microbial growth as water activity enables for proper monitoring of moisture so that products are stored at safe water activity. In this study, foil lined packaging materials should be considered for long term storage of these products as protection from physical damage, microbial contamination, oxygen, light and moisture are very essential due to their low water activities [29]. Sorption which refers to the process of adsorption or desorption of moisture by food materials plays a major role in the science of preservation and storage of cheese products. In fried cheese, high temperature causes water content to evaporate during frying, which resulted in a golden and crispy exterior. The fried cheese product however, has capacity to absorb moisture from atmosphere if exposed to air of high relative humidity which can lead to breakdown of texture and loss of crispness in storage if appropriate packaging materials are compromised. To maintain sensorial parameters, hermetic packaging to minimize moisture uptake should be considered. Oven-dried cheese product in this study made use of relatively low heat for an extended period to lower moisture content of the product and prolong its shelf-life. Oven-dried cheese has lower water activity compared to fried cheese which suggests it is less prone to absorbing moisture from the atmosphere. This behaviour contributes to its longer shelf life compared to fried cheese. Development of airtight package to reduce exposure to moisture uptake from the environment will enhance and promote good shelf-life of these products as over time they may experience changes in their sensorial properties.

Proximate analysis which involves the determination of basic composition of a food product, typically moisture, ash, protein, fat, and carbohydrates carried out for oven dried and fried cheese shows that the processing methods affected the nutrient composition of the products (Table 4). Lower moisture content of oven dried cheese as evaluated in this study may be connected to the longer processing time oven dried cheese passed through. Similar, the protein, fat and carbohydrate content were more concentrated in oven-dried cheese as more water was removed during oven drying than in fried cheese. In this study, both oven drying and frying preserve the nutrients substantially but oven drying method retains more nutritional contents than frying [30]. This might be as a result of low temperature used for oven drying in this study as oven drying at 50°C and 70°C have been adjudged the best method for retaining the highest volatile oil, protein, calcium, and magnesium contents of food materials [31]. The reduction in fat content of fried cheese may be connected to possibility of lipid oxidation due to heat as high temperature accelerates lipid oxidation. The low content of ash in oven dried cheese is proportional to increase in protein content [32].

An understanding of the chemical and sensory properties of cheese can help manufacturers develop desirable products. Oven dried cheese had the best sensory acceptability in terms of aroma, appearance and flavor. This agrees with the submission of Ndife et al. [33] who reported oven drying method to improve the concentration of nutrients and antioxidant activities, with preservation of the sensory acceptability of food materials. However, aroma should not only be attributed to change in temperature, it is also a function of the type of microorganism used in cheese making and chemical changes such as lipid hydrolysis and proteolysis that occur in the curd during the early stages of ripening.

4.CONCLUSION

In conclusion, the sorption isotherm curves had sigmoidal shapes for both oven-dried and fried cheese, which indicates that the composition and structure of these products influenced water sorption behavior. The sorption isotherms of oven-dried cheese showed lower equilibrium moisture content and water activity compared to fried cheese. This difference could be attributed to decrease in porosity and surface area of oven dried cheese due to the processing method, which could enhance its shelf life in storage. Hence, this study contributed to knowledge sorption behavior of cheese products.

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5. CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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