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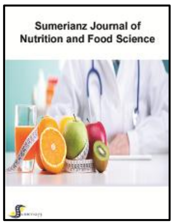

Original Article Open Access

Moisture Sorption Isotherm and Shelf Life Prediction of Shredded Cassava (*Ighu*) Using Different Packaging Materials

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Abstract

Ighu was produced from three different improved cassava varieties (TME419, TMS30572 and NR8082) NRCRI, Abia state. The moisture sorption isotherms of the *ighu* were obtained by standard gravimetric methods using concentrated sulfuric acid (H_2SO_4) of 66% relative humidity conditioned at 40o C. *Ighu* was packaged in HDPE, LDPE and Laminated nylon for shelf life prediction using moisture sorption characteristics and water vapour permeability coefficient of the packaging material. Result of the moisture content analysis of the *ighu* varieties showed that the initial moisture content were 12.8 %, 11.6 % and 10.2 % for TME419, NR8082 and TMS30572 respectively, while the critical moisture content were 6 %, 5.92 % and TME419, NR8082 and TMS30572 respectively. *Ighu* varieties have shelf life prediction of 519, 403, and 342 days for TME419, TMS30572 and NR8082 respectively. The sorption kinetics showed slower rate of absorption at lower concentrations. The monolayer moisture content of the *Ighu* also showed that all the varieties could be stored for a longer time using LDPE as the recommended packaging material.

Keywords: Cassava; Moisture; Sorption isotherm; Shelf life; Packaging material.

1. Introduction

Cassava (*Manihot esculenta)*, a short-lived perennial plant, stands between 1 and 5 m tall. The main food product is the tuberous roots, which can be retrieved from the soil (Lebot, 2009), and it is for these roots that the crop is cultivated (Bradbury and Holloway, 1998). The roots deteriorate quickly from the internal heat generated from high respiration rate of the tissue (Ikujenlola and Opawale, 2007), high moisture content and subsequent infection and rottening by microbes. This rapid post-harvest deterioration means that processing is more important than any other root crop (Andrew, 2002). Cassava is one of the major starchy food and source of Carbohydrate in the tropics after rice and maize (Fauquet and Farguette, 1990). Traditionally, cassava roots are processed by various methods into numerous products and utilized in various ways according to the peoples' culture and food habits (Akoproda and Arene, 2000). The main products derived from processing cassava are *garri*, *Ighu (*abacha*)*, cassava flour, *fufu or akpu* and other cassava-based products (Oji, 1994).

Shredded cassava known variously within the eastern part of Nigeria as *Ighu*, *Nsisa*, *eerebejiapu*, *mpataka*, *asharasha*, *abacha and jiapummiri* in different Igbo dialects (John *et al.*, 2006) is a convenient food and local delicacy. *Ighu* is produced from cassava, it contains high moisture content which makes it spoil fast. Dry *Ighu*, which is usually soaked in water and eaten as a diet with coconut, groundnut, palm kernel, dry fish, and meat, could also be pre-soaked or partially wetted with water, prepared into a meal with vegetable, palm oil or its emulsion, dry fish, *ugba* (fermented oil bean), onion, and beans as a local salad (Adepoju and Nwangwu, 2010).

Oxford English Dictionary defined shelf life as the length of time that a commodity may be stored without becoming unfit for use, consumption, or sale. Shelf life depends on the degradation mechanism of the specific product. Most can be influenced by several factors: exposure to light, heat, moisture, transmission of gases, mechanical stresses and contamination by things such as micro-organisms. Product quality is often mathematically-modeled around some parameters (concentration of a chemical compound, a microbiological index, or moisture content (Azanha and Faria, 2005). For some foods, health issues are important in determining shelf life. Bacterial contaminants are ubiquitous, and foods left unused too long will often be contaminated by substantial amounts of bacterial colonies and become dangerous to eat, leading to food poisoning. However, shelf life is not an accurate indicator of how long the food can safely be stored. For example, pasteurized milk can remain fresh for five days after its sell-by date if it is refrigerated properly).

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Moisture sorption isotherm is the relationship between water content and equilibrium relative humidity of a material which can be displayed graphically by a curve. For each humidity value, a sorption isotherm indicates the corresponding water content value at a given constant temperature and pressure. If the composition or quality of the material changes, then its sorption behaviour also changes. The isotherms cannot be determined by calculation because of the complexity of sorption processes but must be recorded experimentally for each product (Bell and Labuza, 2000). The typical shape of an isotherm reflects the way in which the water binds the system. Weaker water molecule interactions generate a greater water activity, thus, the products become more unstable.

Passive barrier packaging can often help control or extend shelf life by blocking the transmission of deleterious substances, like moisture or oxygen, across the barrier. When moisture content is a mechanism for product degradation, packaging with a low moisture vapour transmission rate help keep the moisture in the package within acceptable limits (Forcino and Hallie, 2018). Thus, the main purpose of packaging is to hold its contents securely to prevent breakage and leakage, to protect the food from different hazards like germs, heat, moisture loss or moisture pick-up (Dotugo, 2019). In other to reduce rapid post-harvest deterioration and improve food security, processing such as moisture content reduction (to inactivate the activity of microbes that spoil the foods) should be carried out quickly (Andrew, 2002). A suitable packaging material is needed to prevent the re-absorption of moisture after drying it. More so, the right packaging material should be used to prevent further deterioration and loss of nutrient. Therefore, this study is aimed at determining the moisture isotherm and the prediction of the shelf life of *Ighu* using different packaging materials.

2. Materials and Methods

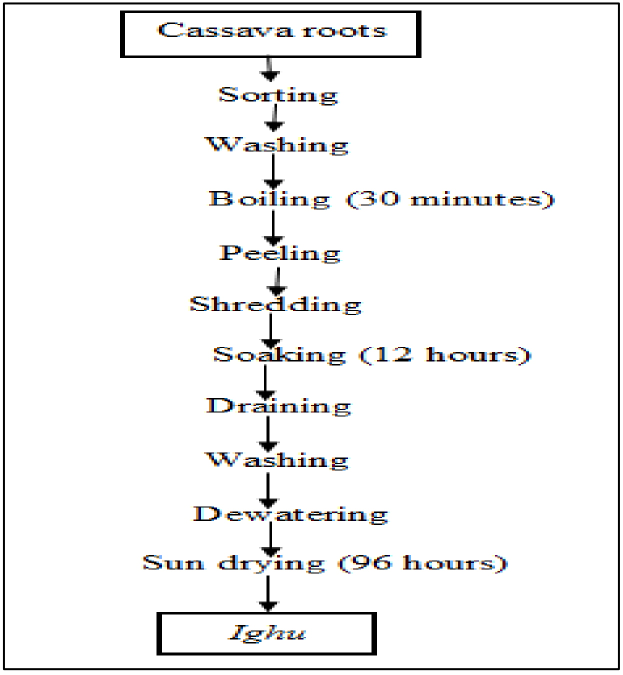
2.1. Source of Raw Materials

Three cassava roots of different improved varieties viz: Tropical *Manihot esculenta* (TME419), National Root (NR8082) and Tropical *Manihot specie* (TMS30572) were sourced from National Root Crop Research Institute (NRCRI), in Umudike, Abia state, Nigeria. The salts used in this work were Sodium nitrate ($NaNO_3$) and Sodium chloride (NaCl). These salts were obtained from analytical laboratory of Food Science and Technology Department of Michael Okpara University of Agriculture, Umudike, Umuahia Abia state. The sulphuric acid (H_2SO_4), a laminated polythene (nylon bag), commercial low and high density polyethylene (LDPE and HDPE) for packaging were purchased from School road market, Aba, Abia state.

2.2. Preparation of Ighu

The cassava varieties were washed and boiling for 30 minute in a pot and later cooled. When cooled, the boiled roots were peeled. These peeled roots were shredded using manual shredding machine. The cassava shreds were soaked for 12 hours during which the water was changed twice; and were then thoroughly washed. The washed samples were spread in very thin layer on a flat basket constructed from palm frond material and sun dried for 96 hours; and then packaged.

Figure-1. Flow chart for production of *Ighu*



2.3. Analyses

2.3.1. Determination of Initial and Critical Moisture Contents

Five grams of *ighu* was placed in aluminum dishes, the dishes were then placed in the vacuum oven and dried at 98-100^{o} C and at 0.08 M pa for 8 hours. After drying the dishes were weighed on dry basis and the initial moisture content of the samples calculated according to AACC (2000).

$$\%M_i = W_f - W_p/W_d \times 100 \quad (1)$$

Where:

M_i is the initial moisture content of the *ighu*

W_f is the weight of the *ighu* with the dish weight

W_p is the weight of the empty dish

W_d is the weight of the *ighu.*

The critical moisture of *ighu* was determined following sensory evaluation of its crispiness described by Kulchan *et al.* (2010). The product was placed over saturated salt (NaCl) solution of known relative humidity at 30 ^oC and evaluated for crispness for about 3 days. Twenty panelists were used for the test using a 9-point Hedonic scale (9 = extremely crisp, 5 = neither like nor dislike, 1= soggy). The critical moisture content was determined when the panelist established a reject level of the crispness of the sample; this is where the panelist scored the crisp level of the sample below point 5 of the hedonic scale which indicated that the samples absorbed moisture and became soggy.

2.4. Determination of Moisture Sorption Kinetics and Isotherms

The moisture sorption kinetics and isotherms of *ighu* was determined according to the standard gravimetric method described by Kulchan *et al.* (2010). Three (3) grams of the samples was placed into small aluminum dishes and placed over different concentrations (10 %, 20 %, 30 %, 40 % and 50 %) of sulfuric acid solution in a desiccator at 40 ^oC. The solutions were prepared according to the method described by Roman and Hensel (2010), which involved dilution of 10, 20, 30, 40, and 50 ml of the acid in 100 ml of water respectively.

For moisture sorption kinetics, the samples placed at 40 ^oC were weighed daily and the weight changes obtained were used for the kinetic graph. Weight of samples placed in relative humidities; 10, 20, 30, 40 and 50 % concentrations were used for the determination of the moisture sorption kinetics.

For moisture sorption isotherms, the weight of samples placed at 40 ^oC (weighed at two days intervals) was used. When the samples attained equilibrium weights, the equilibrium moisture content was determined by oven method described by Kulchan *et al.* (2010). The samples were dried in an oven at 105 ^oC for 3 hours, and the moisture content expressed in dry weight basis as H_2O/100 g dry sample. The water activities were then calculated according to the equation given by Pandey *et al.* (2004) as:

$$a_w = ERH/100 \quad (2)$$

Where;

a_w = water activity

ERH = equilibrium relative humidity.

The mathematical models selected for modeling the experimental data of the sorption isotherms of *ighu* includes; Bruner-Emmett-Teller (BET), Guggenheim-Anderson-de-Boer (GAB), Halsey and Oswin models.

2.5. Determination of Water Vapour Permeability Coefficient of the Packaging Material

The water vapour permeability rate (WVTR) of the test packaging materials (LDPE, HDPE) and laminated polyethylene or nylon bags) was determined at various storage conditions as described in the method of ASTM (1987) as follows: Six grams of desiccant was added to each bag heat-sealed and weighed. The bags were stored over saturated salt solution of $NaNO_2$ RH of 66 % and maintained at 30 ˚C and reweighed every two days until they attained a constant weight. At the end of the storage period the amount of water vapour absorbed by the desiccant was calculated.

The equation below was used to calculate the WVTR:

$$WVTR = W/(A \times t) \quad (3)$$

Where:

WVTR= Rate of water vapor transmission in g/m^2.day

W= Weight gain or loss in g

A= Exposed area of the package material (total area of the two sides of bag) in m^2

t= Time during which gain or loss was observed in hours.

2.6. Shelf life Simulation of Ighu

The equation for the simulation of the shelf life of the packaged product was determined according to method as described by Kulchan *et al.* (2010) as follows:

$$t = GL/AP\Delta P \quad (4)$$

Where:

$G = d\,(M_C - M_O)$

d = mass of dry product (g)

M_C = Critical moisture content (%)

M_O = initial moisture content (%)

$$\text{Therefore, } t\ (\text{days}) = d(M_C - M_O)L/AP\Delta P \quad (5)$$

Where: t = shelf life (days)

L = thickness of the packaging materials (mm)

A= Area (m^2)

P = Permeability coefficient ($gmmd^{-1}m^2mmHg^{-1}$)

ΔP = Vapour pressure difference (mmHg)

2.7. Experimental Design and Statistical Analysis

A Completely Random Design (CRD) was employed in this experiment. The analytical determinations were conducted in duplicate. Graphs of weight change against time (days) and equilibrium moisture content against water activities was plotted for the sorption kinetics and sorption isotherms respectively in Excel 2013 office package.

3. Results and Discussion

3.1. Initial and Critical Moisture Contents of Ighu

The results presented in Table 1 show the initial and critical moisture contents of *Ighu*. The results revealed that the *ighu* which weighed 5 g had initial moisture content of 12.8 % for TME419, 11.6 % for NR8082 and 10.2 % for TMS30572 samples. The critical moisture contents of *ighu* was determined when the panelists scored the crisp level of the *ighu* below 5 which determined the level of sogginess of the product. This means that the *ighu* samples absorbed moisture. However, at this level a dry product has said to have absorbed moisture (Pisuchpen, 2008). The critical moisture content of *ighu* produced from TME419, TMS30572 and NR8082 were 6.00 g, 5.92 g and 5.87 g respectively. The critical moisture content of *ighu* were determined by sensory approach only, unlike (Kulchan *et al.*, 2010) who combined mechanical measurement and sensory score to determine the critical moisture contents of cassava flour-based cookies.

Table-1. Result of Initial and Critical Moisture Contents

Cassava variety	Initial moisture content (%)	Critical moisture content (g)
TME419	12.8	6.00
TMS30572	10.2	5.92
NR8082	11.6	5.87

Key:
TME = Tropical *manihot esculenta*; TMS = Tropical *manihot* specie; NR = National Root

3.2. Moisture Sorption Kinetics and Isotherms

The rate at which the various samples attained weight are presented in Figure 1 2 3 4 5 as a plot of weight change against time (days). The samples all had initial notable changes within the first 2 days at different concentrations of desiccant (H_2SO_4) used. In Figure 1 2 3 4 5 it was observed that at higher concentrations the samples were shown to attain constant weight rapidly. For the cassava varieties (TME419, TMS30572 and NR8082), it was observed that the weight change in moisture at 10 % and 20 % concentrations were gradual but rapid at 30 %, 40 % and 50 % concentrations. The above implied that the products lost moisture at different concentrations depending if the change was rapid or not. The desorption obtained was as a result of the temperature used (40^{o}C). There was loss of moisture to zero at higher concentrations of the desiccant (H_2SO_4). At higher concentrations, the samples equilibrated within the range of 1 to 3 days. The equilibrium was attained by sorption from the surrounding. The difference in the time taken for equilibration depended on the presence of soggy sites and concentrations of desiccant (Dhanalakshmi *et al.*, 2011).

Figure-1. 10 % concentration of moisture sorption kinetics at 40^o C

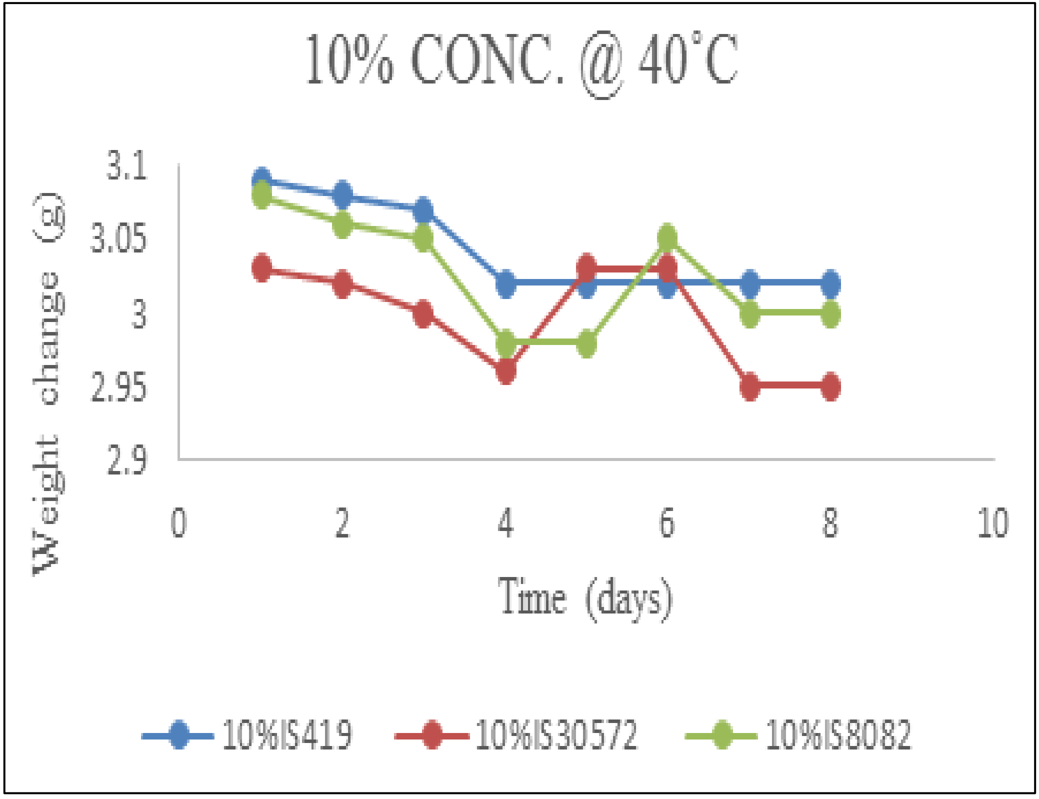


Figure-2. 20% concentration of moisture sorption kinetics at 40° C

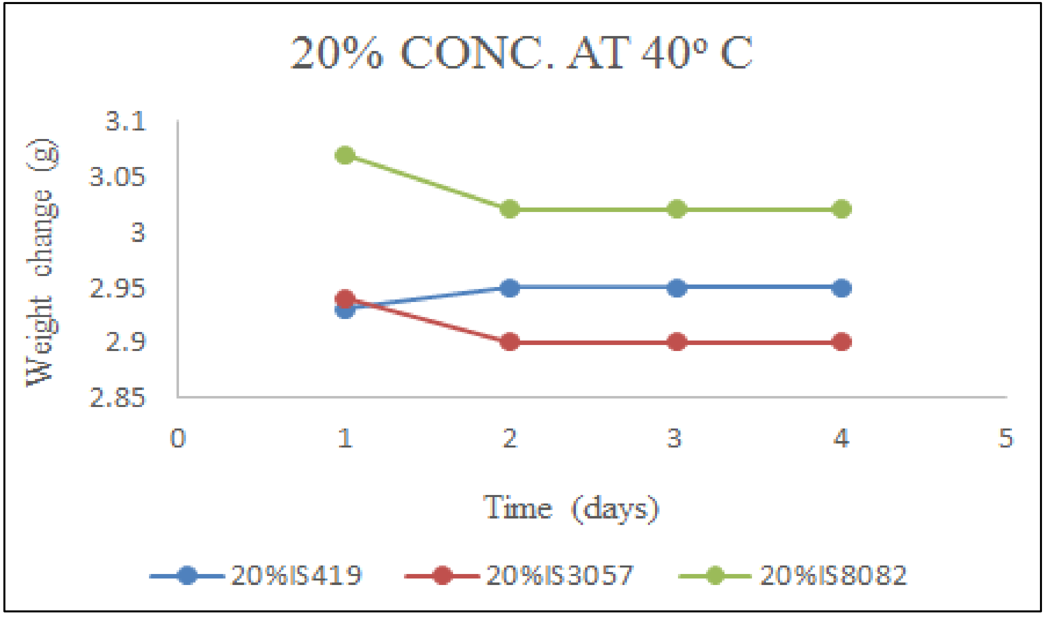


Figure-3. 30% concentration of moisture sorption kinetics at 40° C

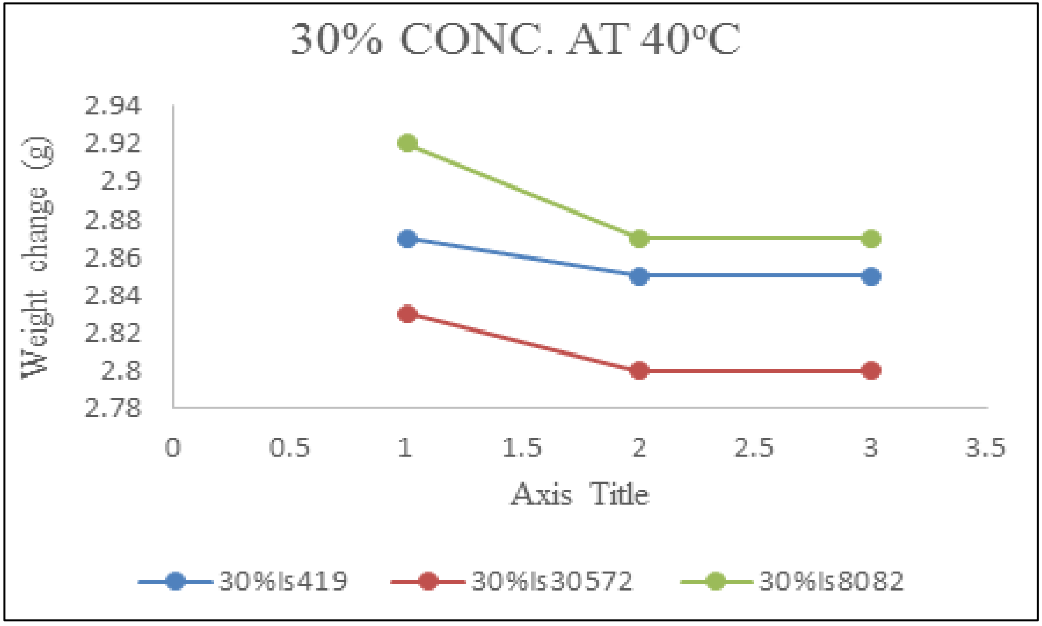


Figure-4. 40% concentration of moisture sorption kinetics at 40° C

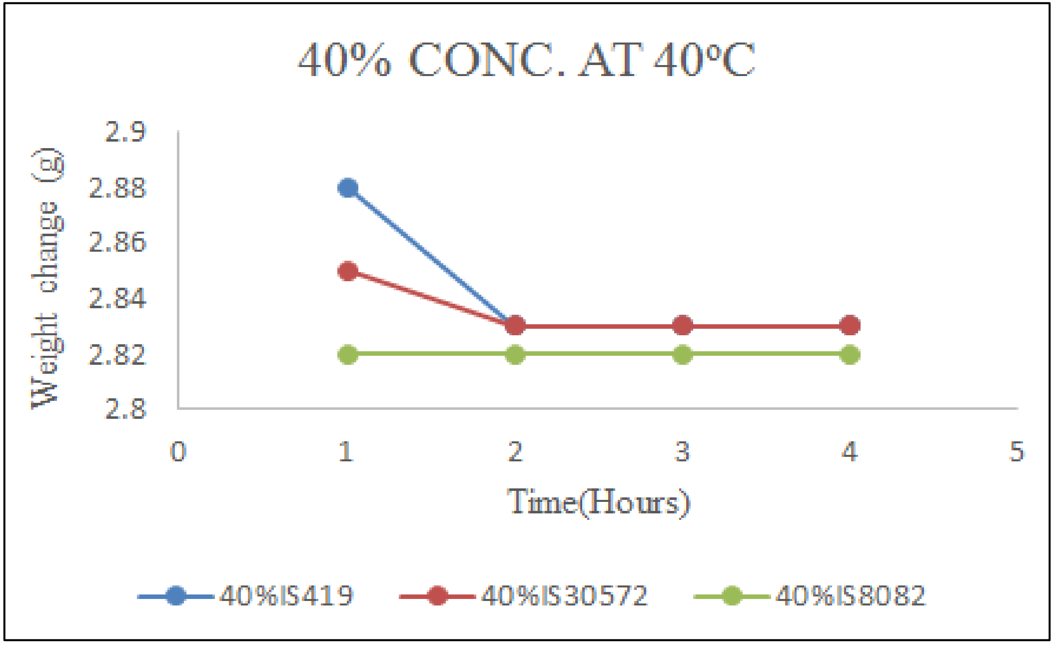
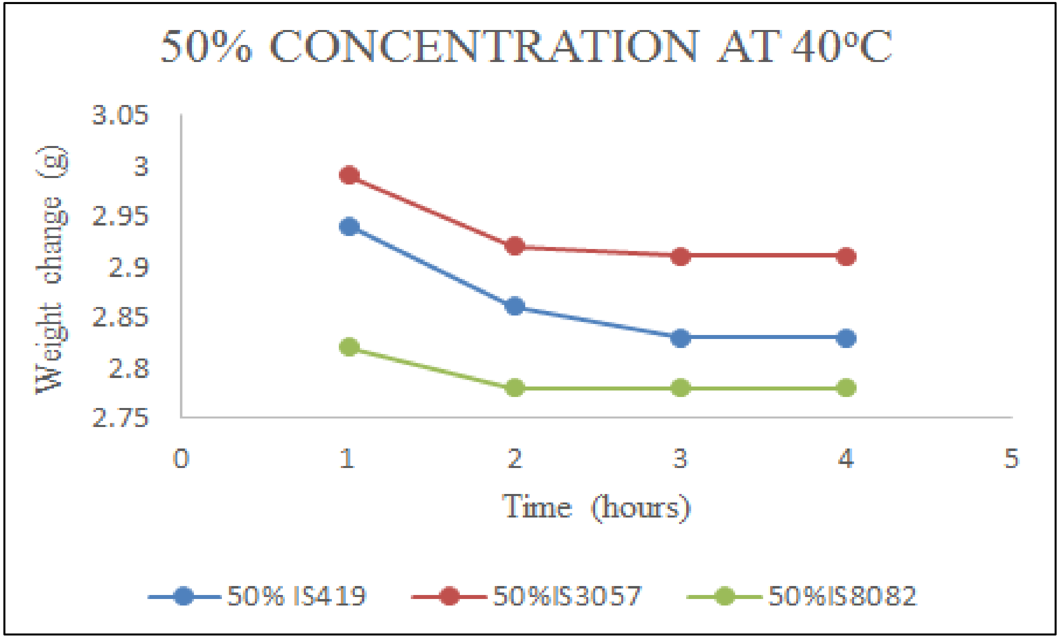


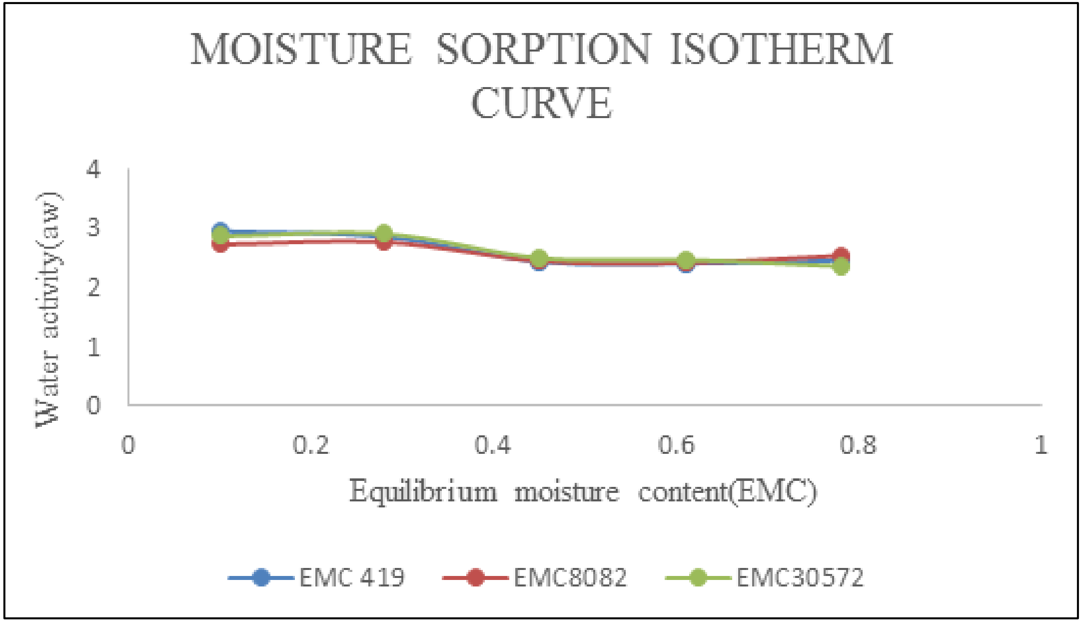
Figure-5. 50% concentration of moisture sorption kinetics at 40^{o}C



3.3. Moisture Sorption Isotherms

The moisture sorption isotherm curve presented in Figure 6 shows the storage stability of the product which indicated that the product can last for a long time if the moisture content is relatively low. It also shows that the equilibrium moisture content was attained gradually until it became constant; this implied that there is no chance for microbial proliferation. The equilibrium moisture content decreased slightly with an increase in the water activity. The shapes and values of moisture sorption isotherms can be different in foods as they are related to the components properties, physical structure, pre-treatment and temperature (Al-Muhtaseb *et al.*, 2004).

Figure-6. Experimental moisture sorption isotherm of *Ighu*



3.4. Water Vapour Permeability of the Packaging Materials

The result water vapour permeability of the packaging material is presented in Table 2. The water vapour permeability of the packaging material with combined permeability of the constituent 0.20 mm for LDPE, 0.15 mm for HDPE and 0.08 mm for laminated nylon at 30˚C. The water vapour coefficient of the LDPE, HDPE and laminated nylon were 1.03×10^{-5} g/m^2/day, 1.29×10^{-5} g/m^2/day and 5.5×10^{-6} g/m^2/day with a packaging surface area of 13.5 m^2, 7.2 m^2 and 8.4 m^2 respectively. This implies that for LDPE, the amount of water vapour penetration during storage was 1.03×10^{-5} g/m^2/day, for that of HDPE was 1.29×10^{-5}g/m^2/day, while that of laminated nylon was 5.5×10^{-6} g/m^2/day. In a study conducted by Pisuchpen (2008), he reported that the different vapour permeabilities of 0.09 mm for LDPE at 30˚C and 38˚C are 7.8×10^{-7} and 8.40×10^{-7} gmmd^{-1}cm^{-2}mmHg respectively. These values are lower than those obtained in this report. This implied that the higher the temperature, the higher the rate of water vapour permeability of the packaging materials.

Table-2. Water vapour permeability of the packaging material

Test material	Thickness	Permeability (g/m^2/day)
HDPE	0.15	1.29×10^{-5}
LDPE	0.20	1.03×10^{-5}
LAMINATED NYLON	0.80	5.5×10^{-6}

Key:
HDPE = High Density Polyethylene; LDPE = Low Density Polyethylene

3.5. Shelf Life Simulation of Ighu

The predicted shelf lives of the samples were calculated using equation 5 above as 519, 403 and 342 days for TME419, TMS30572 and NR8082 *ighu* varieties respectively. These were within the range of 320 to 597 days achieved by Kulchan *et al.* (2010) for cassava flour-based cookies. The initial and critical moisture contents of the *ighu* were presumably expected to favour longer shelf lives compared to the initial and critical moisture contents of cassava flour-based cookies. The difference in the result obtained is suspected to be as a result of the differences in water vapour permeability coefficient of the various packaging materials used.

4. Conclusion

Ighu was produced from the selected cassava varieties. The shelf life simulation of the products showed that TME419 cassava variety, which has the longest shelf life is an indication that the variety can be stored safely for longer period without deterioration and also improve food security. More so, the reduced moisture content of the product implied that the activity of microbes that spoil the food will be inactivated. However, the synergy of moisture impermeability offered by LDPE can enhance the best shelf life of packaged *ighu*. This also implied that LDPE packaging material which has the lowest water vapour permeability is the most preferred packaging material for *ighu* to other packages. Therefore, the use of low density polyethylene (LDPE) in the packaging of *ighu* is recommended.

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Conflict of Interest

None declared.

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