Experimental Determination of Moisture Sorption Isotherms of Okro Fruit

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Abstract: The sorption isotherm (desorption and adsorption) of okro fruit was determined at three temperatures of 300C,400C and 500C within the range of 10- 90% Relative humidity (RH). Thymol solution was placed inside the desiccators to prevent microbial growth, particularly at the relative humidity above 65%. Gravimetric method was used for the sorption isotherm where the reading and recording was taken at three days interval and the equilibrium moisture content was reached after thirty (30) days. Constructed moisture sorption plots showed a tendency of executing a close loop (hysteresis loop) of which size appears to decrease as temperature increase because, the effect of temperature were significant on the isotherm which appeared sigmoidal.

Keywords: Okro fruit, Relative humidity, Sorption isotherm, Equilibrium moisture content, Monolayer moisture content,

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1. INTRODUCTION

Okro is a vegetable commonly found in the market. There are three major varieties of okro these are: Lady's finger (*Abelmoschus esculentus*), Local cultivar (*Hibiscus esculentus*) and Perkin which has long pod. In tropical regions, this vegetable is notable on the basis of the feeding of populations where it can be consumed fresh or dry notably in the confection of gluey soup. It is a very good source of dietary fibre, vitamin A, vitamin C, vitamin K, thiamin, riboflavin, folate, calcium, magnesium, potassium and manganese and a good source of niacin, iron, phosphorus, zinc and copper.

The knowledge of moisture sorption isotherms data is important for all aspects related with food technology in the prediction of microbiological, enzymatic and chemical stability, selecting of packing materials, design of drying and concentration processes and choosing adequate storage conditions [1]. Meanwhile, the moisture sorption isotherms of most dehydrated food is therefore important for storage and selection of packaging materials for retail purposes [2, 3, 4, 5, 6].

The shape of sorption isotherms depends basically on the structure and composition of the food material and experimental determination which is necessary because the methods of prediction cannot simulate complex systems as food; other factors like temperature and pressure are also important and for these reasons many works report data about sorption isotherms of different products and some recompilation can be find in the bibliography[7, 8].

Water sorption isotherms illustrate the steady-state amount of water sorbed by food solids as a function of water activity (a_w) or storage relative humidity (RH) at constant temperature [9]. In addition, water sorption isotherm models are useful for predicting water sorption behaviour and evaluation of its effects on food stability.

As food products dries, both moisture content and water activity changes. At any given relative humidity of air used for drying, there is equilibrium moisture content (EMC) with the product. At this point, the vapour pressure of water in the air is the same as that in the product. The relationship between the EMC in the food and the relative humidity of air is important in drying process. Whenever water content of a food is plotted against the water activity at content temperature, a sigmoid curve usually results. The curve is known as the sorption isotherm for that product [10]. Isotherms for different foods vary both in shapes of curve and in the water present at each relative humidity [11].

According to [12], the need for reliable sorption data has always been useful in the formulation of shelf stable food products. Temperature has a significant effect on sorption isotherm and its knowledge is essential for the efficient design and operation of several processing operation and storage. The shelf life of packaged food involves the reactivity of the food and capacity of the package to protect the food from these influences. Meanwhile, for the prediction of shelf life of a particular packaged food, properties of the food product and package are important. The permeability of the package is the most important property to be considered, so, the knowledge of sorption is of great importance in food processing [13]. Therefore, a study on the moisture sorption isotherms of okro is very important in food processing and storage, since it is widely consumed in tropical regions like Nigeria.

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2. MATERIALS AND METHODS

2.1 Source of sample

The fresh okro used for sorption isotherm experiment was purchased from Oja oba market , Akure, Nigeria.

2.2 Preparation of samples

The cleaned okro was cut into 1 cm thick of 5 slices weighing about 5 g deposited on each Petri dish which were labeled from A to E. The salts shown in table 1 were used for the sorption isotherm experiment to maintained the relative humidities of samples in desiccators and were prepared by a warm water of 25 – 40^{o}C for salts dissolution and based on the environment and size of the different desiccators, 75 ml used for the smallest, 100 ml for the medium, and 120 ml for the biggest desiccators.

Table 1: Weight of salt to saturate 100ml of warm water.

Salt names	Compound names	Temperature (^{o}C)	Weight (g)	RH (%)
Barium Chloride	$BaCl_2.2H_2O$	0	39.30	91.0
Calcium Chloride	$CaCl_2$	20	74.50	35.5
Potassium Chloride	KCl_2	40	63.90	86.0
Lithium Chloride	$LiCl_2$	30	46.30	11.2
Potassium 84.7 Chromate	K_2CrO_4	20		84.00
Sodium Nitrate	$NaNO_2$	0	163.00	64.0
Sodium Chloride	NaCl	20	36.00	75.4
Potassium Bromide	KBr	20	39.20	84.0
Magnesium 35.0 Nitrate	$MgNO_3.\ 6H_2O$	38		52.80

Source: [14]

Thymol in a small container were kept in the desiccators to reduce microbial growth of the samples which might affect the experiment.

2.3 Determination of moisture content

The direct static method for determining the moisture content of agricultural materials was used for okro fruit, carried out by removing the moisture from the product in an air – oven. The initial and final moisture content of samples were determined for each drying run using the oven method for 24 hours at 105^{0} C until equilibrium was attained and readings were taken appropriately. Equations (1) and (2) were used for moisture content determination in both wet and dry basis.

$$\%Mc_{wb} = \frac{M_w}{M_{ws}} \times 100 \qquad (1)$$

$$\%Mc_{db} = \frac{M_w}{M_{ds}} \times 100 \qquad (2)$$

Where, $M_w = M_{ws} - M_{ds}$

Mc_{wb} = Moisture content wet basis

Mc_{db} = Moisture content dry basis

M_{ws} = Mass of net sample

M_w = Mass of water

M_{ds} = Mass of dry sample

2.4 Determination of sorption isotherm

The sorption method employed was the gravimetric method, based on the nine different salts to maintain a fixed relative humidity. The relative humidity of different concentration of salts that ranges from 10 to 90% and certain amount of sample (okro) already in Petri-dishes labeled were placed inside the desiccators containing prepared salts solution and eventually placed in thermal chamber, of temperature, 30^{o}C±2^{o}C (Room temperature), 40^{o}C±2^{o}C (Wooden incubator) and 50^{o}C±2^{o}C (Electronic incubator). The same process was used for both desorption and adsorption isotherms. Fresh okro samples was used for desorption isotherm while dry okro samples was used for adsorption isotherm. In all, 27 samples was made available for the sorption isotherm determination, 9 samples for each temperature. The readings and recordings were taken every three (3) days to investigate the loss and gains of moisture by the samples at intervals.

2.5 Monolayer Moisture Content

The original isotherm development by [15] was developed to look at the adhesion of gas to a porous surface. Better

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understanding of the monolayer values was found by fitting a theoretical equation to the measured data and using the theory to calculate the monolayer values.

The BET equation can be written as shown in equation (3);

$$\frac{a_w(1-a_w)}{m_e} = \frac{1}{m_0 c} + \frac{a_w(c-1)}{m_0 c} \quad (3)$$

Where,

a_w = Water activity

M_e= Equilibrium moisture content (%)

M_o = BET monolayer

C = Model constant

3 RESULTS AND DISCUSSIONS

3.1 Moisture Content

From table 2, okro contains higher moisture content values which implies that the product contain high mass of mater and high affinity for water desorption.

Table 2: Moisture content values of okro

Samples	Weight of dishes (g)	Weight of samples (g)	Weight of dishes & wet samples	Weight of dishes & dry samples	Moisture content of wet basis (%)
A	37.66	5.06	42.68	38.10	91.23
B	44.23	4.95	49.18	44.65	91.51
C	37.30	5.03	42.35	37.77	91.05
D	46.97	4.81	51.78	47.37	91.68
E	36.36	4.75	41.11	36.68	93.26
Average	40.51	4.91	45.42	40.91	91.75

3.2 Equilibrium Moisture Content of Okro (Desorption Isotherm Data)

The equilibrium moisture content (EMC) values of the okro fruit is shown in table 3

It is widely accepted that an increase in temperature results in decrease equilibrium moisture content [16]. The moisture content of okro increase considerably at high water activity values based on the table 3 information. Temperature and relative humidity also affect the equilibrium moisture data of biomaterial under sorption conditions [17].

Table 3: EMC value of okro for Desorption Isotherm

Salts	RH (%)	30°C±2°C	40°C±2°C	50°C±2°C
ZnCl	10.00	41.46	40.05	39.03
$KC_2H_3O_2^{43}$	20.40	48.00	46.45	45.45
$MgCl_2.6H_2O$ 51.83	31.40		50.43	52.80
$CaCl_2.6H_2O$	40.00	60.82	59.25	58.20
$Ca(NO_3)_2.4H_2O$ 64.60	50.40		67.24	65.62
$NaNO_2$	65.30	73.64	72.05	71.03
NaCl	75.50	80.07	78.48	77.43
$(NH_4)_2SO_4$	80.00	86.44	84.85	83.85
$BaCl_2.2H_2O$	90.00	92.85	91.25	90.23

The desorption Isotherm curves for okro was shown in figure 1 at temperature 1 for 30°C±2°C, temperature 2 for 40°C±2°C and temperature 3 for 50°C±2°C . The shape of the curves are slightly sigmoidal, a condition which is in accordance with sorption curve for agricultural products.

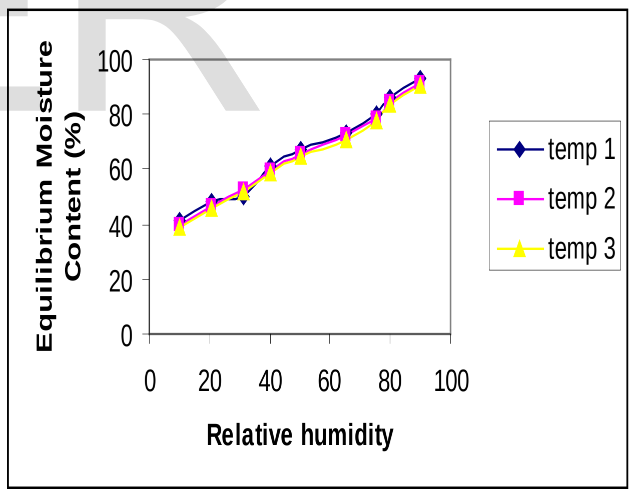

Figure 1: Desorption isotherm curve for okro

3.3 Equilibrium Moisture Content of okro (Adsorption isotherm data)

The equilibrium moisture content of okro, adsorption Isotherm data was shown in table 4.

Table 4: EMC value of okro for Adsorption Isotherm

Salts	RH (%)	30°C±2°C	40°C±2°C	50°C±2°C

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$ZnCl_2$	10.00	29.00	24.08	23.52
$KC_2H_3O_2$[43]	20.40	32.32	27.40	26.84
$MgCl_2.6H_2O$	31.40	36.40	31.48	30.92
$CaCl_2.6H_2O$	40.00	44.40	39.49	38.25
$Ca(NO_3)_2.4H_2O$	50.40	54.45	49.52	47.92
$NaNO_2$	65.30	67.66	62.75	60.73
NaCl	75.50	76.44	71.54	70.52
$(NH_4)2SO_4$	80.00	86.45	79.55	77.93
$BaCl_2.2H_2O$	90.00	95.24	86.35	84.75

The value of moisture content attained in the desorption Isotherm is greater than the equilibrium moisture content value for adsorption Isotherm, though they both obey the rule of "increase in temperature results in decrease equilibrium moisture content".

The adsorption Isotherm curve for okro was shown in figure 2 at different temperatures. The shape of which is sigmoidal, this is a condition with sorption isotherm curve for agricultural products. The adsorption curve shows that storage of okro between 12.52% and 13.85% will be good enough to disallow fungi growth and control microbial growth, where this region can be described as the most stable region for storage of the product.

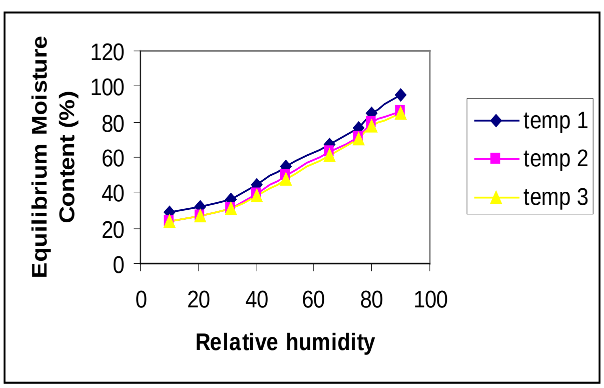

Figure 2: Adsorption isotherm curve for okro

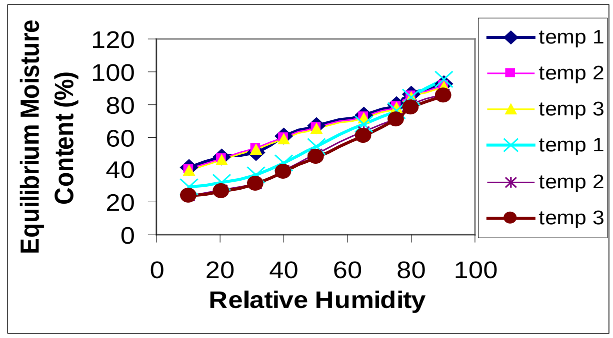

Figure 3: Sorption isotherm curve for okro at different temperatures

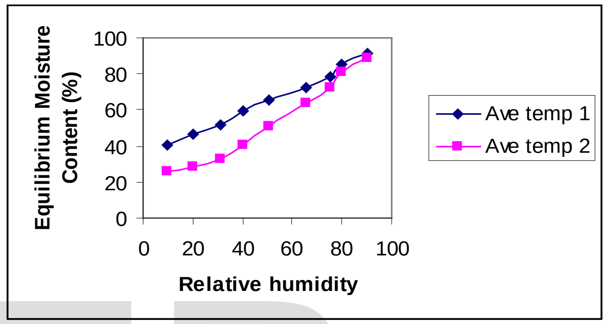

Figure 4: Average sorption isotherm curve for okro

3.4 Monolayer Moisture Content determination

The optimum moisture content was calculated from the equilibrium moisture data shown in tables 3 and 4 for desorption and adsorption isotherm respectively, using the linearized BET equation. The isotherm in the RH ranging from 10 – 90 % was transformed to give a straight line BET plot using the LHS of the equation. From the linearized BET equation, the graph of a_w / M_e [1- a_w] was plotted against a_w which produces slope and intersect of a straight line used to determine monolayer value M_o as shown in equations 4 and 5 . The optimum moisture level for storage stability of fresh okro was therefore, determined to the following values, 13.89% at $30^0C\pm2^0C$, 13.61% at $40^0C\pm2^0C$, and 13.46% at $50^0C\pm2^0C$ and also for dried okro; 13.85% at $30^0C\pm2^0C$, 12.77% at $40^0C\pm2^0C$, and 12.52% at $50^0C\pm2^0C$.

$$M_o = \frac{C-1}{SC} \times 100 \quad (4)$$

$$C = \frac{S+1}{I} \quad (5)$$

Where,

M_o = Monolayer moisture content

S = Slope of the graph

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I = Intersect of graph on y axis

C = Product constant

It was noted that, equilibrium moisture content decreases as the temperature increases, however the higher the temperature the lower the monolayer moisture content as the product (okro) was exposed to oxidative changes.

4. CONCLUSION

The moisture sorption isotherm of okro at different temperatures and relative humidity was determined by standard gravimetric method using various saturated salts solutions. The equilibrium moisture content increased with decreasing temperature.

In summary, okro is better stored when dried to moisture content of about 12.5 % (wet basis) to reduce the effect of microbial growth (micro organism). More so good packaging materials such as nylon, wrappers, papers etc which will prevent moisture adsorption from the environment should be used to extend the shelf life of the product.

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