Moisture sorption isotherms of Mesquite seed (Prosopis africana)

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Abstract: Moisture profoundly influences product attributes such as quality and safety. The knowledge of moisture sorption isotherm is essential to determine products stability, and needed for design of storage, packaging and drying systems for extension of shelf lives. This study is to develop sorption isotherms of Prosopis africana.
The moisture sorption isotherms of the seed were determined at temperatures of 20 ℃, 25 ℃ and 30 ℃, over a relative humidity range of 11%-100% using the static gravimetric technique. A linear regression programme was used to fit five isotherm models; GAB, Oswin, Halsey, Henderson, and Chung Pfost to the experimental data and compared using the root mean standard error, regression coefficient, standard error of estimate, and randomness of residuals.
The adsorption and desorption isotherms of the seed followed the type II isotherm which exhibited a sigmoidal curve and also resulted in a hysteresis effect. At 20oC, Chung Pfost gave the best for the Prosopis africana in the adsorptive mode while at 25oC, the GAB, Henderson and Chung Pfost models gave the best fit. At 30oC, the Henderson and Chung Pfost had a good fit. Through all the temperatures for the prosopis Africana in the adsorptive mode, the Chung Pfost model has the best fit all through. In the desorption mode of Prosopis africana at 20oC and 25oC, the r2 for Chung Pfost, Henderson, GAB, Halsey, and Oswin range from 0.854 to 0.956 and 0.896 - 0.966 respectively. All the five models gave a good fit. At 30oC, the Chung Pfost, GAB and Henderson gave the best fit.

Keywords: Prospis africana, equilibrium moisture content, water activity, adsorption, and desorption

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1 Introduction

Prosopis are pod bearing trees and shrubs that occur in the arid and semi-arid regions of America, Asia and Africa. It is a perennial leguminous tree of the sub family *Mimosoidae* (Keay *et al.*, 1964) and is mostly found growing in the savanna regions of West Africa. In Nigeria, they can be found between latitude 7^o and 10 ^{o} N (Agboola, 1995). In Nigeria, *Prosopis africana* is variously called *Okpei* (Igbo), *Ayin* (Yoruba), *Okpeghe* (Idoma and Tiv), and *Kiriya or Kiriaya* (Hausa).

It is a multipurpose tree of great economic value among the rural communities in the Guinea savanna of Nigeria. Seeds are fermented and used as seasoning as those of *Parkia biglobosa*. A poultice of the boiled seeds is usually applied externally to relieve sore throat, while the fermented seed is used as a seasoning agent in food (Oguntoyinbo *et al*, 2007). In traditional medicine practice, juice expressed from the stem bark is applied on open wounds as an astringent and to cleanse the wound surface. The bark is also crushed to a pulp and placed on the wound surface as a dressing.

Water is the major component in food and biological materials, playing predominant role in physical and chemical properties. The importance of water in food properties is due to its ability to bind with other food components through various chemical bonding such as ionic, covalent and hydrogen bonding that has effect on the solubility and transition state of food (Lewicki, 1997). Water activity relates with storage condition thus it must be controlled to fit with the particular food type in order to minimize the deterioration rate. One of the importances of water activity in food products is its use as a tool for predicting food stability and food safety. Water activity also represents the state of water which provides

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significant information to food processing. In addition, it describes the energy state of water in foods products.

Gazor (2010) worked on moisture desorption isotherms (EMC/ERH) of canola cultivar of ‘Option 500’ were determined at 30°C, 40°C, 50°C and 60 °C using the standard gravimetric static method over a range of relative humidity from 11% to 81%. Iguaz and V ́rseda (2007) determined moisture desorption isotherms of medium-grain rough rice (*Lido* cultivar) at temperatures from 40°C to 80°C and water activity from 0.14 to 0.90 using the static gravimetric method.

Oil seeds and grains are crops of high economic value but the role of fungi associated with them during storage brings about deterioration which has been an issue of great concern for many years. Hot and humid environment and unscientific storage conditions usually affect oilseeds adversely. The relationship between equilibrium moisture content (EMC) and equilibrium relative humidity (ERH) is essential in drying, storing, mixing, and packaging of agricultural products and in modelling seed longevity. High EMC and ERH favour the growth of mould and fungi which lead to deterioration of product quality. Hence, this study is aimed at determining the sorption characteristics of *Prosopis africana* at temperatures of 20°C, -30°C and relative humidity of 11% and 100%.

2 Materials and methods

Samples of *Prosopis africana* (Figure 1) were purchased from Lokoja International Market in Lokoja metropolis of Kogi-State, Nigeria. The seeds were sorted by separating the dirt and unwholesome seeds from the wholesome seeds. Their moisture content was determined using the oven method recommended by ASABE standards (ASABE 2003). The seed was divided into two portions. The first portion was used as samples to determine desorption process while the second was rehydrated by keeping them over a solution of sodium chloride (NaCl) for two months in a desiccators at room temperature. The EMC of the seeds were determined at 20°C, 25°C and 30°C. The sorption method was done using the static gravimetric technique (European Cooperation Project COST 90) (Spiess and Wolf, 1983).

Figure 1 *Prosopis africana* seeds

Eight saturated salt solutions (LiCl, $KC_2H_3O_2$, $MgCl_2$ .6H2O, K_2CO_3, Mg $(NO_3)_2$, $NaNO_2$, NaCl and K_2CrO_4) were prepared corresponding to a wide range of water activities ranging from 0.1 to 1.0 in dessicators. Each desiccator was provided with a perforated and raised platform and the level of saturated salt solutions in it were be kept below the perforated platform in order to avoid contact of the salt solution with the sample holder. Relative humidity of all saturated salt solutions were measured using humidity sensor (Datalogger) with a range of -35 °C to +80 °C and 0% to 100% RH with accuracy of ±0.5°C and ±3.0% RH. The relative humidity in the moisture sorption isotherm containers were constantly monitored till the end of experimental time. The samples were weighed and kept in the desiccators and kept in the incubator set at different temperatures. The weight were monitored every three days and terminated when they showed no significant difference, and EMC was subsequently determined by oven method. (ASABE, 2003).

The experimental data for these agricultural products were analyzed using five equations [GAB (Guggenheim-Anderson-de Boer) and Modified Oswin, Halsey, Chung & Pfost and Henderson models] proposed by Chen and Morey (1989a) to evaluate their utility for agricultural products. The choice of these equations to fit the sorption data took into account the different factors which include: agreement between the sorption data and the model; range of applicability; theoretical basis of the parameters; simplicity; and the desired objectives..

The modified Chung Pfost, modified Henderson, modified Halsey, modified Oswin and Guggenheim-Anderson-de Boer (GAB) equations, incorporates the temperature effect. They are:

1. Modified Henderson Equation

$$M = \left\{\frac{-ln(1-a_w)}{A(T+B)}^{\frac{1}{C}}\right\} \quad (1)$$

2. Modified Chung Pfost Equation (1967)

$$M = \left(-\frac{1}{C}\right) ln\left[-\left(\frac{T+B}{A}\right)\right] \ln RH \quad (2)$$

3. Modified Halsey Equation (1948)

$$M = \left[\frac{A}{ln(^1/_{a_w})}\right]^{\frac{1}{B}} \quad (3)$$

4. Modified Oswin Equation (1946)

$$M = (A + BT)\left[\frac{a_w}{1-a_w}\right]^{\frac{1}{C}} \quad (4)$$

5. Guggenheim-Anderson-de Boer (GAB) Equations (1985)

$$M = \frac{ckm_o a_w}{(1-Ka_w)(1-Ka_w+C_1\, ka_w)} \quad (5)$$

Where;

C = constant

$$K = k_1\ Xexp\left[\frac{(H_1-H_n)}{RT}\right] \quad (6)$$

M = moisture content , g/100g

A_w = water activity

M_o = monolayer value

H_m = molar sorption enthalpy of the monolayer, kJ/mol

H_n = molar sorption enthalpy of the multilayer on top of the monolayer, kJ/mol

H_1 = molar sorption enthalpy of the bulk liquid, kJ/mol

R = universal gas constant, 8.314 J/mol/K

T = temperature

RH = equilibrium relative humidity, decimal

M= percent moisture content (dry basis)

A, B, C, C_1 and K_1 are constants

The model constants were estimated using a linear regression analysis. The best suitable model were evaluated by coefficient of determination (R^2), standard error of estimate (SEE), and residual sum of squares (RSS) and residual plots which were used by (Ghodake et al., 2007).

3 Results and discussion

3.1 Moisture sorption isotherms and hysterisis of *Prosopis africana* seeds

The moisture adsorption/desorption isotherms are shown in Figures 2, 3 and 4. All samples exhibited the classic Type II sigmoidal adsorption and desorption isotherms. However, the *Prosopis africana* seeds exhibited a behaviour which made it to follow different path during the adsorption and desorption processes, resulting in a hysteresis effect. Hysteresis can influence the quality and stability of dehydrated foods in several ways and might be a consequence of an irreversible process of physico-chemical changes during dehydration (Vazquea, et al., 2003; Arslanand Togrul, 2005).

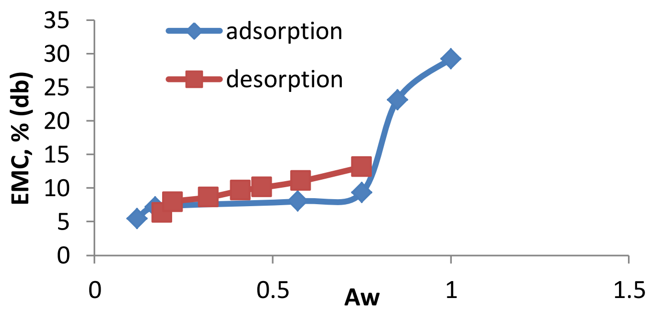

Figure 2 Moisture sorption isotherm of *Prosopis africana* at 20°C

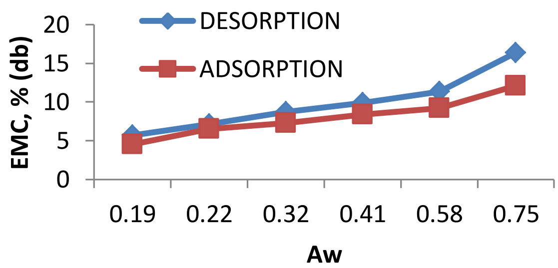

Figure 3 Moisture sorption isotherm of *Prosopis africana* at 25°C

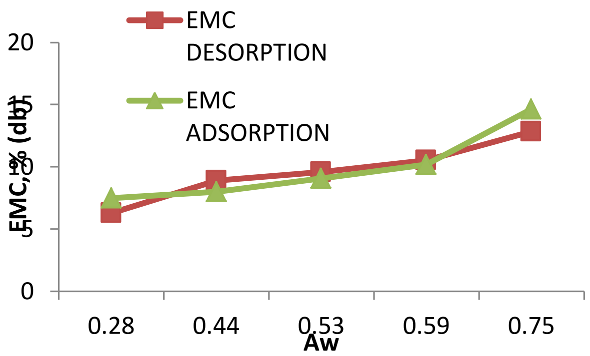

Figure 4 Moisture sorption isotherm of *Prosopis africana* at 30°C

A considerable difference is shown in the total amount of moisture present in the samples of *Prosopis africana* at a given aw water activity. This observation is in agreement with reports in the literature (Iglesias and Chirife, 1982; Onayemi and Oluwamukomi, 1987 and Ogbonnaya, 2010). The desorption isotherm lies above the adsorption isotherm and therefore more moisture is retained in the desorption process compared to adsorption at a given equilibrium relative humidity.

Moisture sorption hysteresis is the phenomenon according to which displacement exists between the adsorption and desorption isotherms. Hysteresis is present to some degree in almost every food system, with magnitude, shape, and extent of the loop dependent on the processing temperature (Iglesias and Chirife, 1976b). Hysteresis can influence the quality and stability of dehydrated foods in several ways. The hysteresis might be a consequence of an irreversible process of physico-chemical changes during dehydration (Vazquea et al., 2003; Arslan and Togrul, 2005). Low hysteresis magnitude, found at high temperature was due to a high energy level of absorbed water molecules. These molecules were broken away from sorption sites when compared with low energy molecules (Aviara, et al., 2006).

3.2 Effect of temperature on the equilibrium moisture content and local isotherms of *Prosopis africana* seeds in the adsorptive mode

From Table 1, at constant temperature, the equilibrium moisture contents of the *Prosopis africana seeds* increased as the water activity increased. The sorbed water within the local isotherm I and II was small relatively to that at the local isotherm III. It was observed that at 20°C, 25°C, and 30°C, for the water activity between 0.12 and 0.75, the sorbed water ranged from 5.40% to 9.30% (db), 4.58% to 13.81% (db), and 7.49% to14.68% (db), respectively for the three constant temperatures. This implies that at low water activities, there is less water available for adsorption by the p. *africana seeds*. This is similar to the trends observed for *vigna subterranean* by Alkali and Satimehin (2007).

Table 1 Adsorption equilibrium moisture contents of *Prosopis africana* seeds at different water activities and temperatures

Temperature, °C	Water Activity	EMC % (db) Adsorption
20	0.12	5.4065
	0.17	7.1919
	0.57	8.0230
	0.75	9.3056
	0.85	23.1367
	1	29.2370
25	0.19	4.5814
	0.22	6.9234
	0.32	7.8700
	0.41	9.2934
	0.58	10.1702
	0.75	13.8491
30	0.28	7.4914
	0.44	7.9873
	0.53	9.0503
	0.59	10.1989
	0.75	14.6383
	0.85	47.3592

The sorption isotherm of *Prosopis africana* depicted by Figure 5 revealed that they follow the type II isotherm which exhibits a sigmoidal curve. This is according to the Brunauer, Emmet and Teller (BET) classification (Labuza, 1968).

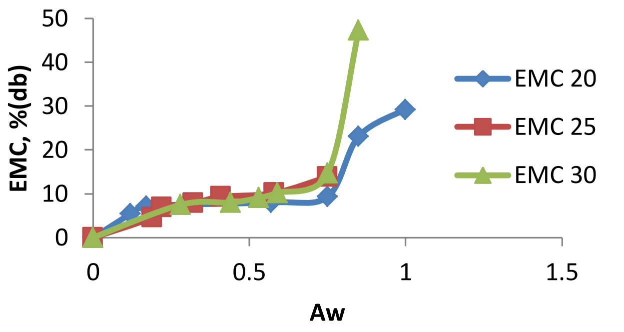

Figure 5 Moisture adsorption isotherm of *Prosopis africana* at 20°C, 25°C, and 30°C

The graph in Figure 5 illustrates the moisture isotherm of the *Prosopis africana* at three different temperatures. At the local isotherm I it was observed that at higher temperatures, the equilibrium relative humidity was lower while at lower temperatures the Equilibrium relative humidity were higher. For instance, at 20°C, A_w of 0.12 had equilibrium moisture content of 5.40% (db), while at 25°C, the water activity of 0.19 had Equilibrium moisture content of 4.58% (db). This implies that within the local isotherm I, the product adsorbs less at higher temperature than it would at lower temperatures. This conforms to the observation of several researchers who observed increase in water activity with an increase in temperature (Menkov and Durakov, 2005) for defatted pumpkin seed, (Palou *et al.*, 1997) for cookies and corn flaxes. They postulated that as the temperature increased, the structure and constituent of the materials were affected resulting in surface plasticization and reduction in sorption sites and hence the reduction in equilibrium moisture content.

On the contrary, between the local isotherm II and III, at higher temperature, the equilibrium moisture content were higher while at lower temperatures, the equilibrium moisture content were lower. For instance, for water activities of 0.57 and 0.75, the equilibrium moisture contents of the product were 8.022% and 9.3055%, 10.17% and 13.84%, and 10.19% and 14.63% at 20°C, 25°C, and 30°C respectively. This conforms to the observations of several Researchers. This implies that higher temperatures, the product will deteriorate more than at lower temperature.

3.3 Effect of temperature on the equilibrium moisture content of *Prosopis africana* seeds in the desorptive mode

At higher temperatures of 30°C, the moisture absorbed by the *Prosopis africana* seeds in the desorptive mode is lower while at lower temperature, the sorbed moisture is higher as shown in Table 2 and Figure 6. This is similar to the trends observed by various authors; (Gazor, 2010; Lahsasni et al., 2003). The equilibrium moisture content increased at the same aw as temperature decreased, since samples absorbed more water at low temperatures than at high temperatures, and water molecules at lower temperatures have a lower kinetic energy which is not enough to overcome the corresponding sorption energy (Lagoudaki et al., 1993).

Table 2 Desorption equilibrium moisture contents of *Prosopis africana* seeds at different water activities and temperatures

Temperature, °C	aw	EMC
20	0.19	6.3116
	0.22	7.8979
	0.32	8.6125
	0.41	9.6180
	0.47	10.0681
	0.58	11.0244
	0.75	13.1308
25	0.19	5.6684
	0.22	7.1678
	0.32	8.6914
	0.41	9.8951
	0.47	10.5280
	0.58	11.3556
	0.75	16.3471
30	0.28	7.4914
	0.44	7.9872
	0.53	9.0502
	0.59	10.1989
	0.75	14.6383

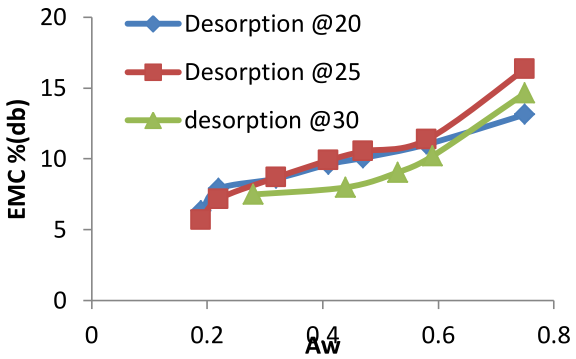

Figure 6 Moisture desorption isotherm of *Prosopis africana* at 20°C, 25°C, and 30°C

3.4 Suitability of selected sorption models for *Prosopis africana* in the adsorptive mode

Tables 3, 4, and 5 below give the detailed summary of the regression analysis of adsorption for *Prosopis africana* based on the five different models. At 20°C, Table 3 showed that Chung Pfost gave the coefficient of determination (R^2) of 0.879 with a standard estimated error (SEE %) of 0.364 with a root mean square residual of 0.132 which is lower than 0.5 while the Oswin gave R^2 of 0.815 but has an SEE% of 23.6737 and RMSE of 560.44. The value of r^2 closes to 1, and that of RMSE closes to 0, indicated a better fit, and appears to be indicative of a good fit for practical purposes (Lomauro et al., 1985). The points in the residual plot for the Chung Pfost are randomly dispersed around the diagonal axis and have r^2 of 1.000. This makes a linear regression model appropriate for the data and also indicates a good fit for a linear model. Therefore, the Chung Pfost model gave the best fit at 20°C.

Table 3 Suitability of selected adsorption models for *Prosopis africana* at 20°C

Parameters	Sorption Models at 25°C				
	Oswin	GAB	Henderson	Chung Pfost	Halsey
R^2	0.915	0.796	0.899	0.904	0.923
SEE%	1.031	0.189	0.133	0.1666	0.977
RMSE Residual	1.062	0.036	0.018	0.028	0.9555
A	-6.696	1.667	2.472	-2.444	14.445
B	-0.956	-0.892	0.948	0.961	0.961
Plot of predicted vs observed	Random	Random	Random	Random	Random

At 25°C, Table 4 showed that the coefficient of determination of the models Oswin, GAB, Henderson, Chung Pfost and Halsey ranged from 0.796 – 0.923. The models, GAB, Henderson and Chung Pfost have r^2 of 0.796, 0.899, and 0.904 with SEE of 0.189, 0.133, and 0.1666 and residuals of 0.036, 0.018, and 0.028. The standard estimate of error and the residuals or root mean square error is less than 0.5 and 0.15. This implies that GAB, Henderson and Chung Pfost models have the best fit. Their residual plots are randomly dispersed across the horizontal axis as well which indicates linear model appropriate for the data. Their regression r^2 Chung Pfost, Henderson and GAB are also 1.000, 0.941 and 0.915 respectively which is also an indication that they gave the best fit at 25°C.

Table 4 Suitability of selected adsorption models for *Prosopis africana* at 25°C

Parameters	Sorption Models at 25°C				
	Oswin	GAB	Henderson	Chung Pfost	Halsey
R^2	0.915	0.796	0.899	0.904	0.923
SEE%	1.031	0.189	0.133	0.1666	0.977
RMSE Residual	1.062	0.036	0.018	0.028	0.9555
A	-6.696	1.667	2.472	-2.444	14.445
B	-0.956	-0.892	0.948	0.961	0.961
Plot of predicted vs observed	Random	Random	Random	Random	Random

At 30°C, Table 5 showed that the coefficient of determination (r^2) of the five models ranged from 0.444 – 0.772. For all the models only Henderson and Chung Pfost has SEE of 0.490 and 0.322 with RMSE of 0.240 and 0.11. Though their R^2 statistic is 0.601 and 0.444 but they still indicate a better fit for the models. This is considered because RMSE indicates the absolute fit of the model to the data–how close the observed data points are to the model's predicted values. Whereas R-squared is a relative measure of fit, RMSE is an absolute measure of fit. Lower values of RMSE indicate better fit. RMSE is a good measure of how accurately the model predicts the response, and is the most important criterion for fit if the main purpose of the model is prediction.

Table 5 Suitability of selected adsorption models for *Prosopis africana* at 30°C

Parameters	Sorption Models at 30°C				
	Oswin	GAB	Henderson	Chung Pfost	Halsey
R^2	0.580	0.772	0.601	0.444	0.444
SEE%	11.247	19.498	0.490	0.322	12.928
RMSE Residual	126.5	380.22	0.240	0.110	167.182
A	-16.553	160.790	9.549	-5.499	151.593
B	-0.761	0.879	0.775	0.667	0.667
Plot of predicted vs observed	Random	Random	Random	Random	Random

Through all the temperature range which the *prosopis africana*, was subject to in the adsorptive mode, the Chung Pfost model has the best fit all through and the regression of its residual plots from 20°C to 30°C is 1.000. This implies that the Chung Pfost model is suitable for the desorption of *Prosopis africana at* 20°C, 25°C and30°C. The Chung Pfost model is adequate and could be used to plan and evaluate storage conditions and moisture regime in the drying and handling of *Prosopis africana* seeds.

3.5 Suitability of selected sorption models for *Prosopis africana* in the desorptive mode

The five models were analyzed using the SPSS16.0 (Statistical Package for Social Sciences). Table 6 depict the statistical data and the constants of the desorption of *Prosopis africana* at 20°C. At 20°C, the r^2 for Chung Pfost, Henderson, GAB, Halsey, and Oswin are 0.954, 0.956, 0.854, 0.954, and 0.929. Their SEE% is 0.118, 0.0546, 0.099, 0.522, and 0.644 respectively while their RMSE are 0.014, 0.003, 0.010, 0.273 and 0.415. The R^2 , SEE and RMSE and of the five models indicate that all the five model fit best. The residual plots of the 5 models are randomly dispersed around the diagonal axis and their regressions rage from 0.929 to 1.000. This implies that all the models are suitable for the desorption of *Prosopis africana at* 20°C. The constants of the models: Chung Pfost, Henderson, GAB, Halsey, and Oswin are (-3.073, 0.221, 0.976), (2.468, 0.346, and 0.978), (1.906, -0.533, -0.924), (13.715, 4.319, 0.976) and (6.37, -5.180, -0.968) respectively. At 20°C, all the models fit best for desorption of *Prosopis africana*.

Table 6 Suitability of selected models for desorption *of Prosopis africana* at 20°C

	Chung Pfost	Henderson	GAB	Halsey	Oswin
R^2	0.954	0.956	0.854	0.954	0.929
SEE%	0.118	0.055	0.099	0.522	0.644
Residual	0.014	0.003	0.010	0.273	0.415
A	-3.073	2.468	1.906	13.715	6.37
B	0.221	0.346	-0.533	4.319	-5.18
C	0.976	0.978	-0.924	0.976	-0.964
Residual plot	Random	Random	Random	Random	Random

At 25°C, the R^2 for Chung Pfost, Henderson, GAB, Halsey, and Oswin as shown in Table 7 are 0.897, 0.965, 0.896, 0.897 and 0.966 respectively. Their SEE are 0.176, 0.069, 0.119, 1.21, and 0.694, while their RMSE are 0.031, 0.005, 0.014, 1.465, and 0.482. Among the models, the Halsey model does not have a good fit because their SEE and RMSE are 1.21 and 1.465 respectively. The standard estimate of error and the root mean square error are not less than 0.5 and 0.15 respectively. Lower values of RMSE indicate better fit. Since RMSE is a good measure of how accurately the model predicts the response, it implies that Halsey does not have a good fit. Therefore, the models: Chung Pfost, Henderson, GAB, and Oswin have the best fit for desorption of *p. africana* at 25°C. Their residual plots are randomly dispersed with regression of 0.937 to 1.000**.** Their constants A, B, C are (-2.341, 0.138, 0.947), (2.59, 0.497, 0.982), (1.772, -0.781, -0.947), (16.267, 6.509, 0.947) and (4.955, -8.207, 0.983) respectively for Chung Pfost, Henderson, GAB, Halsey, and Oswin.

Table 7 Suitability of selected models for desorption *of Prosopis africana* at 25°C

	Chung Pfost	Henderson	GAB	Halsey	Oswin
R^2	0.897	0.965	0.896	0.897	0.966
SEE, %	0.176	0.069	0.119	1..21	0.694
Residual	0.031	0.005	0.014	1.465	0.482
A	-2.341	2.590	1.772	16.267	4.955
B	0.138	0.497	-0.781	6.509	-8.207
C	0.947	0.982	-0.947	0.947	-0.983
Residual plot	Random	Random	Random	Random	patterned

At 30°C, the r^2 for Chung Pfost, Henderson, GAB, Halsey, and Oswin are 0.709, 0.850, 0.974, 0.709, and 0.947 in Table 8. Their SEE are 0.23, 0.118, 0.049, 1.782, 0.758, while their RMSE are 0.053, 0.014, 0.002, 3.176, and 0.574 as shown in Table 8. The Halsey and Oswin models don't have good fit because their SEE and RMSE are (1.782 and 3.176) and (0.758 and 0.574) respectively. The standard estimate of error and the root mean square error are not less than 0.5 and 0.15 respectively. It implies that the models; Chung Pfost, Henderson and GAB gave a good fit for the desorption of *Prosopis africana* at 30°C. The regressions of residual plots are 1.00, 0.722 and 0.93. Their constants A, B, C are (-1.783, 0.109, 0.842), (2.418, 0.458, 0.922), (1.739, -0.661, -0.987), (14.491, 6.514, 0.842) and (4.319, -7.047, -0.973) respectively for Chung Pfost, Henderson, GAB, Halsey, and Oswin respectively. These models are adequately suitable for planning and evaluation of storage conditions and moisture regime in the drying and handling of *Prosopis africana* seeds

Table 8 Suitability of selected models for desorption of *Prosopis africana* at 30°C

	Chung Pfost	Henderson	GAB	Halsey	Oswin
r^2	0.709	0.850	0.974	0.709	0.947
SEE, %	0.230	0.118	0.049	1.782	0.758
Residual	0.053	0.014	0.002	3.176	0.574
A	-1.783	2.418	1.739	14.491	4.319
B	0.109	0.458	-0.661	6.514	-7.047
C	0.842	0.922	-0.987	0.842	-0.973
Residual plot	Random	Random	Random	Patterned	patterned

4 Conclusions

The *prosopis africana* exhibited the classic Type II sigmoidal in the adsorption and desorption isotherms. The behaviour of the seeds followed a different path during the adsorption and desorption processes which resulted in a hysteresis effect.

At constant temperature, the equilibrium moisture contents of the *Prosopis africana seeds* increased as the water activity increased. The sorbed water within the local isotherm I and II was small relatively to that at the local isotherm III. This implies that at low water activities, there is less water available for adsorption by the p. *africana seeds.*

At the local isotherm I it was observed that at higher temperatures, the equilibrium relative humidity was lower while at lower temperatures the Equilibrium relative humidity were higher. On the contrary, between the local isotherm II and III, at higher temperature, the equilibrium moisture content were higher while at lower temperatures, the equilibrium moisture content were lower. This implies that at higher temperatures, the seeds will deteriorate more than at lower temperature. The equilibrium moisture content increased at the same aw as temperature decreased, since samples absorbed more water at low temperatures than at high temperatures.

The data also serve as parameters for the determination of shelf life and packaging calculations for the seeds. The sorption isotherms serve as a guide for moisture relations in these products and bring about products that maximize safety, quality, and profitability. The application of the sorption isotherms of the seeds in storage enhances longevity of the seeds which help in the genetic conservation and profitability.

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