ISSN: 2338-1345 – Vol. 12 (2) 61-69 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Moisture sorption isotherm modelling and thermodynamic functions of White Maize *Ogi* enriched with Drumstick (*Moringa oleifera*) seeds

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Received: 17th Aug 2024 | Revised: 16th Dec 2024 | Accepted: 21st Dec 2024

Abstract—The study predicted the behaviour of enriched white maize ogi during storage at different temperature and; evaluate thermodynamic functions and fitness of experimental data into sorption models. Moisture sorption isotherm of sample products was determined for different water activities, a_w, (0.1-0.8) at room temperature RT, (28±2), 35 and 40 ^oC using gravimetric method. The experimental data was fitted into four models (GAB, BET, Hasley and Oswin), fitness of the models assessed statistically by calculating coefficient of determination (r^2), root mean square (RMS), and mean relative percent deviation modulus (E) and thermodynamics properties determined using Clausius-Clapeyron equation. Results showed that equilibrium moisture content of the product increased with increasing water activity, showing type II sorption isotherm, and decrease with increase in temperature at the same water activity. Statistical parameters revealed that GAB and Oswin models had better fit (r^2 > 97%, E < 10%) for the experimental data than other models. Monolayer moisture contents, M_o, energy requirement and spontaneity of moisture sorption behaviour of *Moringa oleifera* seeds enriched maize products (Ogi-Moringa) were affected by method of incorporation of *Moringa oleifera* seed during processing. Sample with fermented *Moringa oleifera* seed had higher optimum keeping moisture content (3.928-7.33) as presented by M_o and require greater energy, to remove water molecules than required for the other sample.

***Keywords*—sorption isotherm models; isosteric heat; enthalpy-entropy compensation; monolayer moisture; isokinetic temperature, white maize *Ogi*.**

INTRODUCTION

Fermented maize product such as *Ogi* is usually consumed in Africa, either in liquid form (porridge) as pap or solid (stiff gel) called *Eko* or *Agidi*. *Ogi* has a very low nutritive value because the cereal from which it is produced is of low protein quality, especially, the amino acids, yet it is consumed as convenient meal by many, including infant and the convalescence (Oladeji *et al.*, 2017). This may be because of its smooth texture and easy to swallow. Several efforts have been made to enrich *Ogi* with other nutritious crops such as soybean, okro, bambara nut, and *Moringa oleifera* seed, in other to meet the consumers' nutritional requirement (Oladeji *et al.*, 2017; Adeniyi *et al.*, 2018). *Moringa oleifera* (*M. oleifera*) seed is rich in edible oil, essential micronutrients and quality protein. Behaviour of enriched *Ogi* either with *M. oleifera* seeds or other food materials, to the surrounding air, considering moisture content, water activity, temperature dependence and, energy required by the process, has not been reported. Regarding the improved nutrients in the *M. oleifera* seeds enriched *Ogi* and the consumers, it is important that sorption isotherm and thermodynamic studies be performed for prediction of stability and storage conditions of the product.

Sorption isotherm of a particular food is essential in studying the dehydration process of the food and evaluating changes in quality during storage (Al-Muhtaseb *et al.*, 2002; Aouaini *et al.*, 2015). Thermodynamic attributes of food which include differential enthalpy and entropy are important to determine the level of dehydration of a food product in order to achieve a stable product with optimal moisture content and energy required to remove a given amount of water from food. Differential enthalpy is an indication of the state of water adsorbed by the solid particles of food, which in turn greatly determines the physical, chemical, and microbiological stability of the food during storage. Understanding these properties offers insight into the stability and functionality of food products and packaging materials, the energy requirement for the dehydration process, water-food interactions, and the state of water in food systems (Cahyanti and Pattiserlihum, 2018). A number of models are used to describe the moisture sorption isotherms of foods. The most common ones are the Languimar equation, Brunauer-Emmett-Teller (BET) model, Oswin model, Smith model, Halsey model, Henderson model, Iglesias-Chirife equation, Guggenheim-Anderson-deBoer (GAB) model, Peleg model, etc. The moisture sorption isotherm of a particular food can be described by more than one sorption model, while the most suitable one is chosen by degree of fit to the experimental data. BET, GAB, Oswin, and Halsey models were chosen for this study based on simplicity and previous use in sorption of starch-containing foods. Halsey and Oswin models are simple but are reported to have limited water activity range. GAB and BET models are closely related and commonly used to estimate monolayer moisture content. However, various researchers showed that monolayer capacity by BET is less while the energy constant by BET is greater than the GAB (Sandoval *et al.*, 2020). There is limited study reported on thermodynamic properties and moisture sorption isotherm of starchy food enriched with other nutritious food, especially of protein source (Adeoye *et al*., 2020). Report has shown that biological variation in foods and pre-treatment of food usually cause variation in sorption properties of foods (Chinma *et al*., 2013). Hence, in this study, moisture sorption isotherms of *Ogi* (starchy food) enriched with *M. oleifera* seeds (protein, fat and other essential mineral source) in water activities, a_w, range 0.1-0.8 at room temperature RT, (28±2), 35 and 40 ºC is determined. The study also evaluated monolayer moisture content, fitness of experimental data into moisture sorption models and thermodynamic attributes of the enriched products.

MATERIALS AND METHODS

A. Sample Preparation

Sample of *Ogi* enriched with *M. oleifera* seeds (*Ogi-Moringa*) was produced following the method of Oladeji *et al*. (2017). The incorporation of *M. oleifera* seeds was done in two ways in ratio 20:80 (*M. oleifera* seed: Maize). Firstly, *M. oleifera* seeds (20%) were co-fermented together with the maize (80%) and processed into *Ogi* flour to obtain sample CFMMS. Secondly, maize (80%) and *M. oleifera* seeds (20%) were processed separately to *Ogi* flour and *M. oleifera* seeds flour respectively and both flour mixed together, using dry mill blender for uniformity, to obtain sample OFMS. The process methods chosen were described by Oladeji *et al*. (2017) to be suitable processes for incorporating *M. oleifera* seeds into ogi for optimal nutritional quality and consumer acceptability of the sensory attributes.

B. Sorption Isotherm Determination

Gravimetric technique was used for the determination of equilibrium moisture content (EMC) of the O*gi-Moringa* flour (Peng *et al*., 2007). Two replicates of each sample of enriched *Ogi* flour (2 g) was weighed in a drying can and placed in an air tight glass jar, having different glass jar for each water activity. Sulphuric acid solutions of 20-65% concentration in water activity range of 0.1-0.8 was placed in the glass jars at each temperature of RT (28±2), 35, and 40 ºC by placing the glass jar in a temperature control cabinet. The weight was monitored continuously every alternate day until constant weight was obtained (about 30 days). Oven drying method was used to determine the initial moisture content and the equilibrium moisture content and calculation was done on a dry weight basis using equation 1 (AOAC, 2005).

$$\frac{weight\ of\ water\ in\ sample}{dry\ weight\ of\ sample} \times 100 \qquad (1)$$

C. Modelling of Sorption Isotherms and Determination of Monolayer Moisture Content

Four sorption isotherm models (Table 1) were used to determine the fitness of the experimental data obtained from moisture adsorption of two samples of enriched *Ogi*, CFMMS and OFMS. The models were estimated using linear and nonlinear regression function of Microsoft excel 2007. The coefficient of determination (r^2), mean relative error (MRE) as percentage and mean relative percent deviation modulus (E), defined by the equations (2, 3 and 4) stated below were used to evaluate goodness of fit of the models. The GAB and BET models were used for the determination of monolayer moisture content (M_o). The empirical models are selected based on their common use in sorption of food.

Table 1. Isotherm Models for Experimental Data Fitting

Isotherm	Model	Source
Oswin (1946)	$M_w = C\left[\frac{a_w}{1-a_w}\right]^n$	Sahin and Sumnu, 2006
Halsey (1948)	$M_w = M_o\left[-\frac{C}{RT\ \ln a_w}\right]^{1/n}$	Sahin and Sumnu, 2006
BET (1938)	$M_w = \frac{M_o\, C\, a_w}{(1-a_w)[1+(C-1)a_w]}$	Sahin and Sumnu, 2006
GAB (1984)	$M_w = \frac{M_o\, C\, Ka_w}{(1-Ka_w)(1-Ka_w+CKa_w)}$	Sahin and Sumnu, 2006

a_w= water activity; M_w = moisture content (g/g dry basis); C and n = empirical constant and M_o = monolayer moisture content (g H2O/g db); K = GAB model parameter; R = universal gas constant; T= temperature (K).

$$MRE\ (\%) = \frac{100}{N}\sum_{i=1}^{N}\left|\frac{x_{ei}-E_{pi}}{x_{ei}}\right| \qquad (2)$$

(Kaymak-Ertekin and Gedik, 2005)

$$r^2 = \frac{\sum_{i=1}^{N}(x_{pi}-\bar{x}_{ei})^2}{\sum_{i=1}^{N}(x_{ei}-\bar{x}_{ei})^2} \quad (3)$$

(Akanbi *et al.,* 2006)

$$E\% = \frac{\left[100\sum_{i=1}^{n}\left(\frac{x_{ei}-x_{pi}}{x_{ei}}\right)^2\right]}{n} \quad (4)$$

(Akanbi *et al.,* 2006)

where x_{ei} is experimental equilibrium moisture content; x is the predicted equilibrium moisture contents, and N is the number of experimental data. A model is considered acceptable if it has MRE and E values less than 10% (Kaymak-Ertekin and Gedik, 2005). A model is considered good when r^2 is high, and MRE and E are low (Yogendrarajah *et al*., 2015).

D. Thermodynamic Properties

Thermodynamic properties determined are net isosteric heat of sorption, differential entropy, isokinetic temperature and Gibbs free energy of the enriched products.

Isosteric Heat of Sorption and Differential Entropy Determination

The net isosteric heat of sorption, Δh_d, was determined from the experimental data using the Clausius-Clapeyron equation (equation 5) as reported by Akanbi *et al*., 2006.

$$-\Delta h_d = R\left[\frac{d(\ln a_w)}{d(1/T)}\right]_x \quad (5)$$

Where
R = gas constant.
T = absolute temperature (K) at corresponding a_w, level

The plot of experimental data, *ln* a_w versus 1/*T*, to obtain net isosteric heat of sorption was based on assumption reported by McMinn *et al*. (2007). The differential entropy ΔS_d was determined at different equilibrium moisture contents using equation 6

$$(-\ln a_w)_x = \frac{\Delta h_d}{RT} - \frac{\Delta S_d}{R} \quad (6)$$

Enthalpy-entropy Compensation Theory for Determination Isokinetic Temperature and Gibbs Free Energy

Enthalpy-Entropy compensation was determined as reported by Kane *et al*. (2008); and Thanuja and Ravindra, (2012) based on equation 7, in which linear regression was used to calculate

T_β (isokinetic temperature) and ΔG (free energy)

$$\Delta h_d = T_\beta \Delta S_d + \Delta G \quad (7)$$

The true compensation was further tested using equation 8 to calculate harmonic mean temperature (T_{hm}) and compare with the isokinetic temperature (T_{hm})

$$T_{hm} = \left[\frac{n}{\sum_{i=1}^{n}\frac{1}{T}}\right] \quad (8)$$

Where n is the total number of isotherms used and T is the temperature in Kelvin.

E. Stastitical Analysis

SPSS statistical package was used to analyse the experimental data and the model parameters. Fitness of the experimental data into the models was analysed using linear and non-linear regression.

RESULTS AND DISCUSSIONS

Moisture Sorption Isotherm Modelling of Enriched Ogi-Moringa Samples

The adsorption isotherm of two samples (CFMMS and OFMS) of *Ogi-Moringa* for different water activities (0.1-0.8) at three temperatures – RT (28±2), 35 and 40 ºC are presented in Figures 1a and b. These figures show that as water activity increased, equilibrium moisture content also increased but decreased with increase in temperature at the same water activity which is similar to the trend reported for tigernut by Zhang *et al*. (2022). Ahmed and Islam (2018) also reported similar trend, as observed in this study, for wheat, corn flour and rice flour. The trend observed in this study indicated that increase in temperature resulted in the enriched *Ogi-Moringa* becoming less hygroscopic due to activation of water molecules as temperature increased (Yogendrarajah *et al*., 2015). As explained by Zhang *et al*. (2022), increasing temperature may lead to increase energy level and activity of water molecules. This may cause the water molecules to easily detach from the water-binding sites of the food, thereby leading to decrease equilibrium moisture content. Rosa *et al*. (2021) also explained that such behaviour may be due to reduction in the number of active sites due to physicochemical changes induced by temperature. Adsorption isotherms obtained for enriched *Ogi-Moringa* products in this study are of type II isotherms (having a sigmoidal shape), according to the classification reported by Bell and Labuza (2000). Adsorption of the samples (CFMMS and OFMS) might have been influenced by the protein and fat content of the samples reported by Oladeji *et al*. (2017).

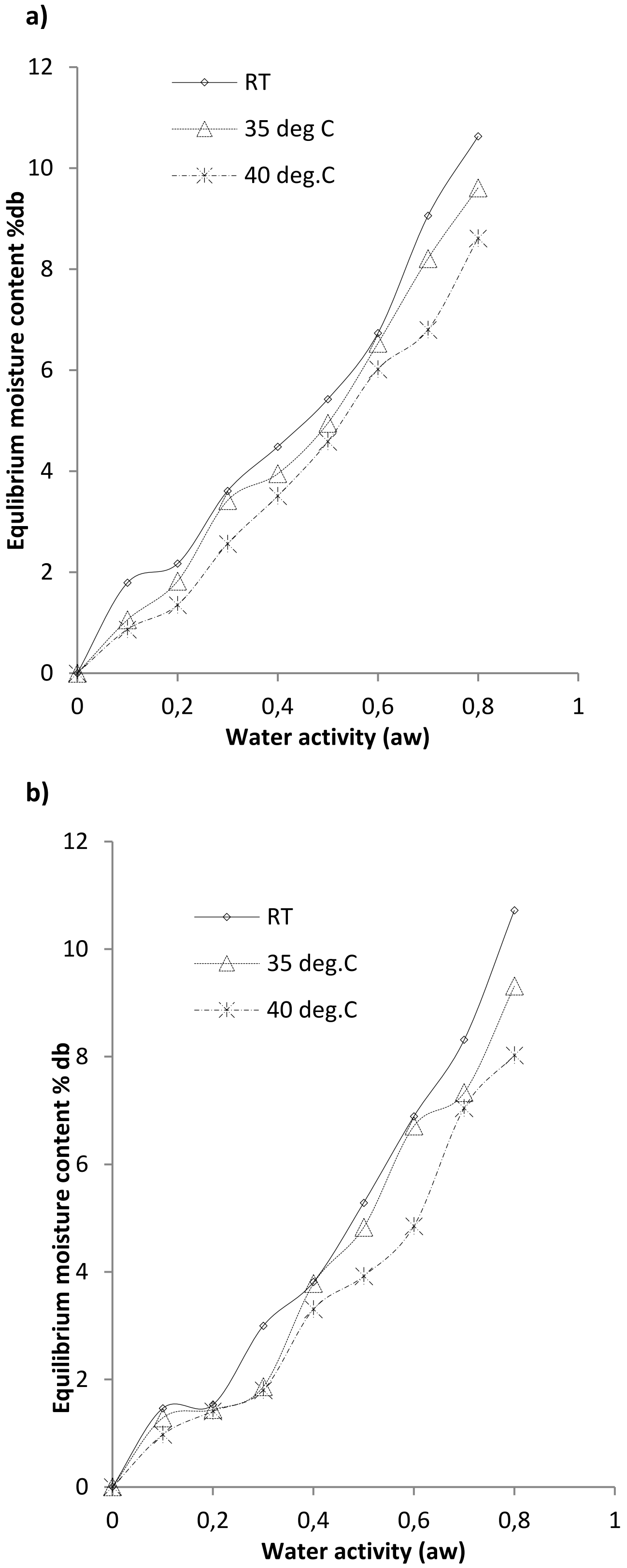


Fig. 1: Moisture adsorption isotherms of enriched *ogi*:
a) sample (CFMMS) obtained by co-fermentation of maize and *Moringa oleifera*
(b) (OFMS) obtained by homogeneous mixing of *ogi* flour and *Moringa oleifera* flour

Experimental data of sorption isotherm of two *Ogi-Moringa* (CFMMS and OFMS) samples were fitted into sorption model as shown in Table 2. The table also showed the value of parameters (E, MRE and r^2 as defined in equations 2 to 4 used for the fitness of experimental data into the models. Generally, high r^2 value, and E value less than 10% is acceptable. Value of r^2 for all the models ranged from 0.942 to 0.9971. GAB models had the highest r^2 (0.9909 to 0.9971) for each representative sample at the corresponding temperature (RT, 35 and 40ºC). This is followed by Oswin (0.9773 to 0.993), BET and then Halsey model. This is an indication that all the models may be acceptable with GAB being the best. On considering other parameters used to test the fitness, E % values of all the models used were lower than 10% while GAB and Oswin had an average MRE less than 10% for sample CFMMS. MRE (%) value for BET was greater than 10 for the two samples but less than 10% in GAB and OSWIN models for the two samples except at some temperature.

Table 2: Sorption models parameters and statistical function fitted into adsorption parameters of two samples of *Moringa oleifera* seed enriched *ogi*

Models	**CFMMS**			**OFMS**		
	RT	35 ºC	40 ºC	RT	35 ºC	40 ºC
GAB 1984						
K	0.843	0.663	0.6014	0.916	0.9437	0.922
C	6.163	2.555	1.744	4.315	4.119	4.138
M_O	3.928	6.210	7.333	3.417	2.858	2.596
% E	0.8537	0.3874	1.2227	2.3407	3.1718	1.4450
% RME	6.3159	4.9034	8.3095	10.637	17.1804	10.2563
R^2	0.9947	0.9971	0.9928	0.9909	0.9704	0.983
BET						
C	36.273	12.727	7.767	8.52	7.016	7.697
M_O	2.51	2.38	2.146	2.551	2.299	1.968
% E	2.789	5.1420	3.767	3.0768	4.132	1.968
% RME	14.5722	19.1106	17.0862	10.0612	18.3653	12.947
R^2	0.9666	0.9590	0.9603	0.9759	0.9559	0.9669
OSWIN						
C	5.387	4.759	4.063	4.879	4.293	3.706
N	0.533	0.628	0.670	0.618	0.635	0.638
% E	0.649	1.271	1.628	2.085	3.446	1.198
% RME	6.032	9.573	11.842	9.843	15.97	9.592
R^2	0.993	0.982	0.9773	0.991	0.974	0.983
HALSEY						
C	4.879	3.040	2.385	3.248	2.656	2.375
N	1.206	0.996	0.934	1.023	0.972	1.000
% E	1.306	4.553	5.221	2.833	4.195	2.352
% RME	9.696	17.218	20.321	14.181	18.677	12.09
R^2	0.9767	0.950	0.942	0.970	0.943	0.958

E%-mean relative percent deviation modulus; RME- relative mean error; and r^2- coefficient of determination. C and N are constant;

M_o is the monolayer moisture content ($gH_2O/100g$ db.); K is GAB model parameter; CFMMS (co-fermented Maize + *Moringa Oleifera* seed); OFMS (*ogi* flour + *Moringa Oleifera* seed flour).

Parameters used to examine the quality of fitness of the models examined in this study indicated GAB and Oswin models had good fit for the experimental data obtained for *Ogi-Moringa* products with GAB being the best. Halsey model also had good fit only at room temperature. Oyelade *et al*. (2008) reported that GAB model had good fit for sorption data of maize flour while Choque-Quispe *et al*. (2022) reported GAB and Halsey having good fit for Purple corn.

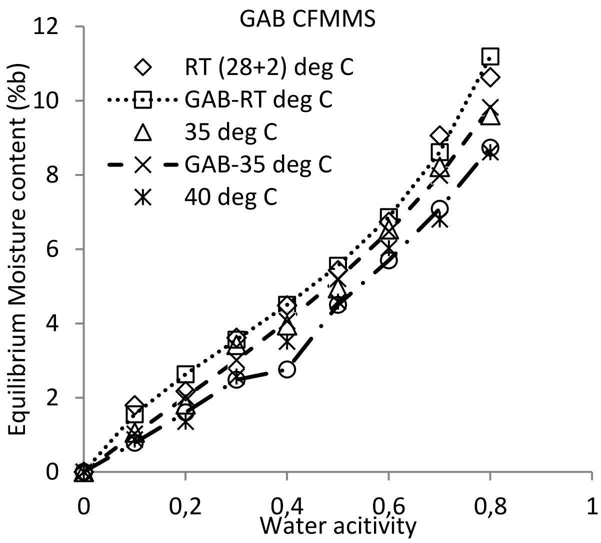
Figures 2 presented the best fit models (GAB and Oswin) for the experimental sorption data, confirming the fitness of the two models at a wide range of a_w. The figures showed a wide range of deviation between the predicted values and experimental values. However, the GAB model seems to be fitted for a wider water activity range for the two samples than obtained in the Oswin model.

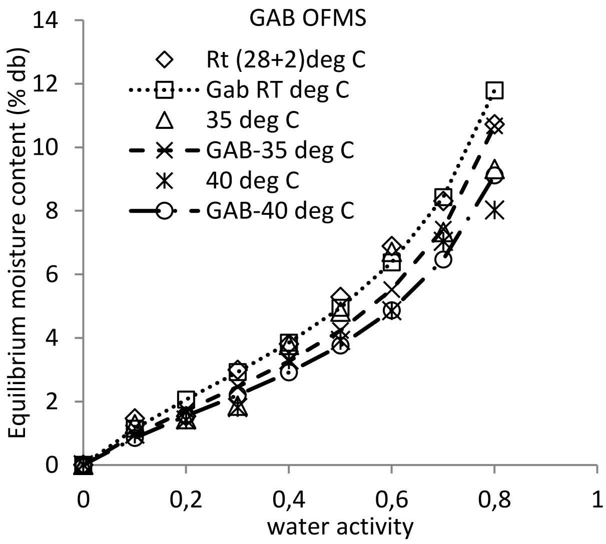
The constant, C in GAB model is called Guggenheim constant and is referred to as the energy of sorption of the monolayer water molecules. The C values ranged from 1.744 to 6.163 for sample CFMMS and ranged from 4.119 - 4.315 for sample OFMS. The high values (greater than 1) observed for parameter C in this study indicated energy of sorption at monolayer is high and adsorption of water molecules will therefore be fast. This therefore means that the samples will be prone to mould attack while storage last especially at low temperature where parameter C is higher. However Sample CFMMS will keep better at high temperature, because of its low C value, than sample OFMS. C values greater than unity has also been reported by other researchers for maize grains and grains starch (Talla 2014; Saberi *et al*.2015; Choque-Quispe *et al*., 2022).

Parameter K in GAB model corresponds to properties of the multilayer molecules (Seid and Hensel, 2012). Values obtained for parameter K in this study ranged from 0.6014 to 0.9437. The low values (less than 1) implies that heat of sorption of the multilayer is low especially when compare with that of first layer presented by parameter C. Such low values for parameter K in GAB model also align with the reports of other researchers (Choque-Quispe *et al*., 2022; Yogendrarajah *et al*., 2015).

The monolayer moisture (M_o) content of GAB and BET models of the *Ogi-Moringa* samples studied at different temperature is presented in Table 2. Calculated M_o by GAB model at different temperatures were 3.928, 6.210 and 7.33 g/100g (db) for sample CFMMS and 3.417, 2.858 and 2.596 g/100 g (db) for sample OFMS at RT (28ºC ± 2), 35 and 40 ºC respectively (Table 2). M_o obtained by BET model at RT (28 ºC ± 2), 35 and 40 ºC were 2.51, 2.38 and 2.146 respectively for CFMMS and 2.551, 2.299 and 1.968 for sample OFMS. M_o obtained by GAB model (2.596 -7.33 g/100g) was higher than M_o values (1.968 – 2.51 mg/100g) for BET model. However, M_o obtained by BET models is limited in application to a_w range of 0.5 to 0.45 while GAB models has been used extensively up to a_w of 0.9 (Al-Muhtaseb *et al*., 2002).

Monolayer moisture content of sample CFMMS (2.146 – 7.33 g/100g) increase with temperature and the value higher than that of sample OFMS (1.968 -3.417 g/100g) which decrease with temperature for both models. The variation observed in the range of M_o values obtained for samples CFMMS and OFMS may be due to the fat content of the samples which is higher in sample OFMS than sample CFMMS (Oladeji *et al*., 2017). This is also an indication that water molecules in sample OFMS attained, at higher temperature, the energy required to break away from sorption site (Al-Muhtaseb *et al*., 2002; Chowdhury *et al*., 2006) while reverse case was obtained for sample CFMMS. Decrease observed in M_o of sample OFMS corresponds with report for soy-melon gari by Oluwamukomi (2009), and walnut by Togrul and Arslan, 2007. The increase observed for sample CFMMS may be due to extraction rate and fermentation process undergone by *M. oleifera* seeds being an oil-containing seed. The optimum moisture content at which *Ogi-Moringa* samples may be stored is presented by M_o values obtained in this study. This showed that sample CFMMS will keep better at higher range of Mo value than sample OFMS.





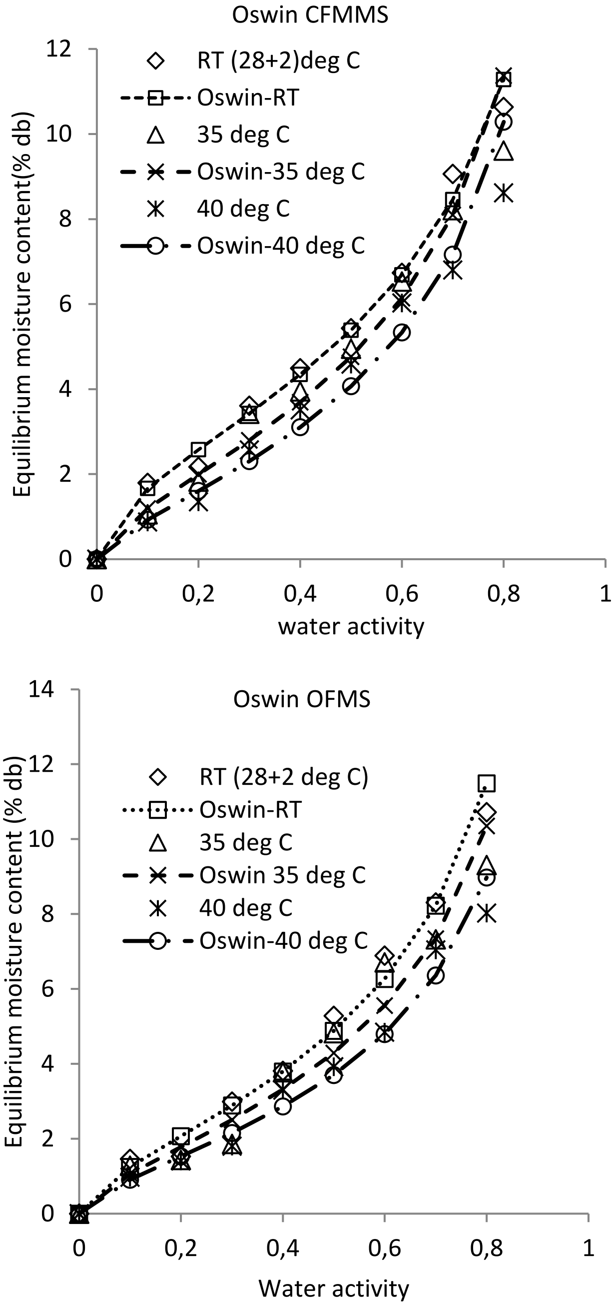


Fig 2: Experimental and predicted value of GAB and Oswin models

Thermodynamic Functions of Enriched Ogi-Moringa Samples

Thermodynamic functions determined from sorption isotherm data obtained in this study are net isosteric heat of sorption or differential enthalpy (Δh_d) and differential entropy (ΔS_d). These were then used to determine the existence of enthalpy-entropy compensation (Kane *et al*., 2008). The thermodynamic properties of foods including enthalpy and entropy of sorption are essential for the design and optimization of unit operations and further help in understanding and interpretation of sorption mechanisms and food-water interactions.

Isosteric heat of sorption (Δh_d) and differential entropy (ΔS_d) were obtained from the slope and intercept of ln (a_w) and 1/T using water activity data generated with GAB and Oswin models. Figures 3a and b showed the graph of differential enthalpy and entropy for samples CFMMS and OFMS, respectively, while the linear regression with the equation is shown in Figure 4. Generally, differential enthalpy and entropy were high at low moisture contents. The maximum differential enthalpy and entropy for the models and the samples were obtained at the moisture content of 2% dry basis followed by an exponential decrease, except for the GAB model of sample CFMMS which is at a moisture content of 1% db. Report has shown that sorption usually occur initially at low moisture content between 1 and 2 %. (Samapounda *et al*., 2007). At low equilibrium moisture content, differential enthalpy was higher in sample CFMMS (54.77 and 54.71 kJ/mol/K) than in OFMS (27.75 and 30.56 kJ/mol/K) for both models. This is an indication that the energy requirement for the adsorption process at such moisture content is greater for sample CFMMS than sample OFMS. The Maximum differential enthalpy obtained in this study (54.77 kJ/mol/K) was higher than value reported by Choque-Quispe *et al*. (2022) for purple corn. This variation could be due to different processing methods and composition of the samples.

The enthalpy-entropy compensation was determined by the plot of differential enthalpy against differential entropy. The slope of the equation of the linear regression is called isokinetic temperature (T_β) while the intercept is the free energy (ΔG) at isokinetic temperature (Al-Mahasneh *et al*., 2007). The values obtained for isokinetic temperature and free energy are presented in Table 3. The isokinetic temperature from the linear regression of GAB and Oswin models for CFMS was almost the same (338.3 and 339.2 K respectively). The negative of (ΔG) found in sample OFMS suggest that adsorption of enriched *ogi* flour with the addition of *M. oleifera* seeds flour was spontaneous indicating little or no energy will be required for binding of water molecules to take place during adsorption. And the positive (ΔG) found in sample CFMMS is an indication that the adsorption isotherm of enriched *ogi* obtained by fermenting *M. oleifera* seeds with maize before further processing into *Ogi* is non-spontaneous meaning that there will be need for driving force before the onset of any reaction during adsorption process (Choque-Quispe *et al*., 2022). Non-spontaneous sorption process observed in sample CFMMS could be due to the effect of fermentation process undergone by *M. oleifera* with the maize during *Ogi* processing.

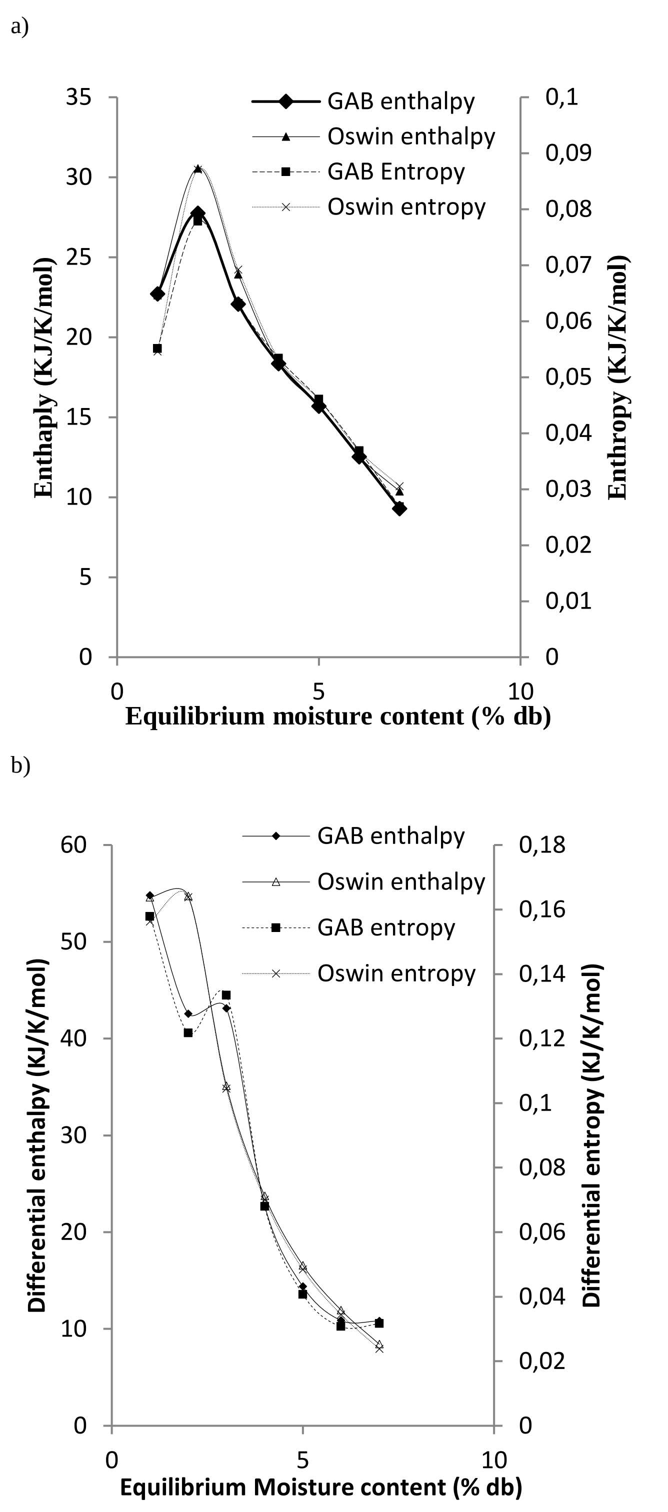


Fig. 3: Differential enthalpy and entropy of adsorption as a function of equilibrium moisture content for; a) Sample CFMMS and b) Sample OFMS

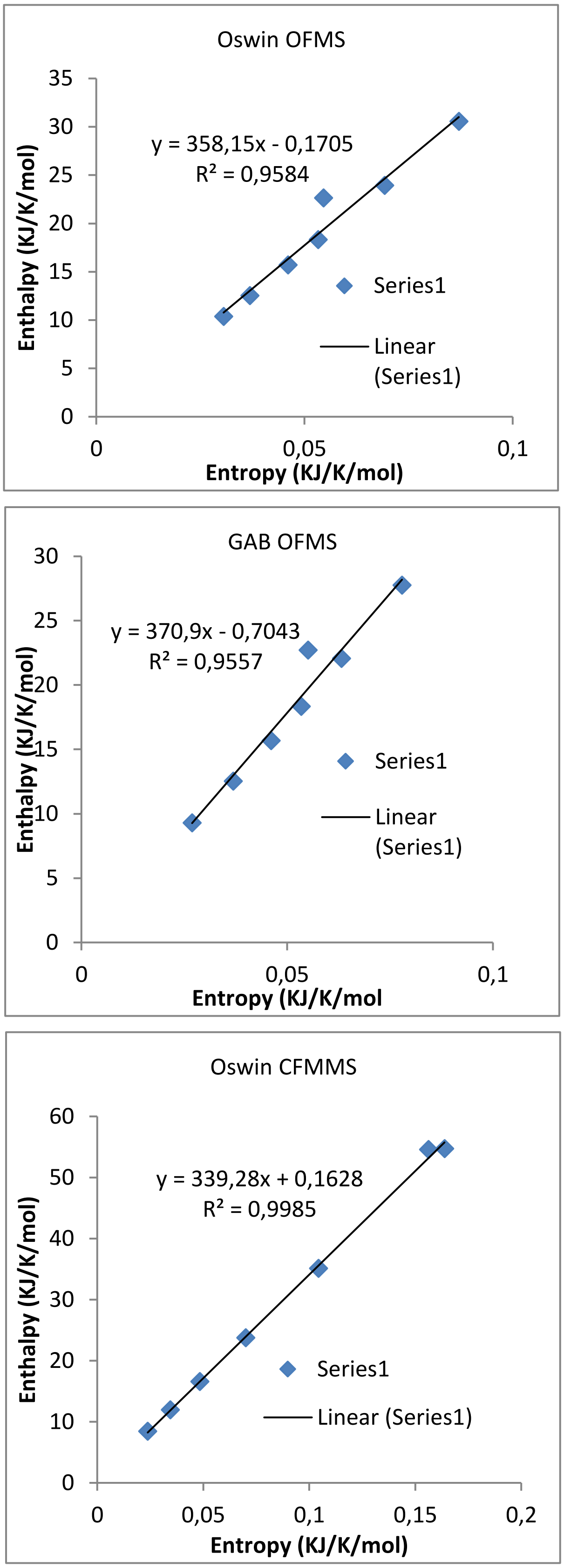
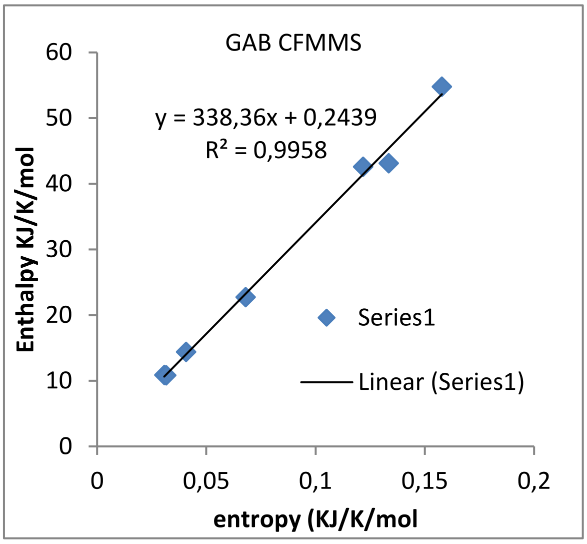


Fig. 4: Linear regression plot of enthalpy and entropy of



samples OFMS and CFMMS for GAB and Oswin models

Table 3: Isokinetic and free energy value of GAB and Oswin models for samples CFMMS and OFMS

Sample	GAB			Oswin		
	T_β (K)	ΔG (KJ/mol)	r^2	T_β (K)	ΔG (KJ/mol)	r^2
CFMMS	338.30	0.243	0.995	339.20	0.162	0.998
OFMS	370.90	-0.704	0.955	358.10	-0.170	0.958

CFMMS (co-fermented Maize + *Moringa Oleifera* seed); OFMS (*ogi* flour + *Moringa Oleifera* seed flour): T_β is isokinetic temperature; ΔG is free energy; r^2-coefficient of determination

The compensation theory is said to exist if the calculated harmonic mean temperature, T_{hm} (Equation 7) was significantly different from isokinetic temperature, T_β . McMinn *et al*. (2007) reported that if $T_\beta > T_{hm}$ the process is enthalpy driven and if $T_\beta < T_{hm}$, the process is entropy driven. T_{hm} Obtained in this study was found to be 307.9 K and the value lower than isokinetic temperature (338.3 - 370.9 K) obtained from the plot of Δh_d versus ΔS_d (Table 3) for the samples examined and for the two models. This is an indication of the existence of compensation theory and sorption process of the products is enthalpy driven meaning that the enriched products will remain stable irrespective of structural modification that may be taken place during drying or storage at temperature studied (Wang *et al*., 2017). The trend obtained in this study was in line with the trend reported by other researchers on starchy materials (McMinn *et al*., 2007; Choque-Quispe *et al*., 2022).

CONCLUSIONS

The adsorption isotherms of the *Ogi* enriched with *M. oleifera* seed showed type II isotherms. GAB and Oswin were the best fit models for both samples, with GAB model being preferred for sample CFMMS and Oswin for sample OFMS. Moisture adsorption isotherm was enthalpy driven for both samples but the reaction was spontaneous in sample OFMS and non-spontaneous in sample CFMMS. Sorption isotherm study of *Ogi-moringa* revealed that the products shall be stable during storage though sample CFMMS may be more stable and may require more energy, than for sample OFMS, for the binding of water molecules to take place. Also, spontaneity of the sorption process in the products may be dependent on the mode of inclusion of *M. oleifera* seeds. Industrial application of good fitness of sorption isotherm models includes prediction of behaviour of Ogi-moringa under different moisture conditions, leading to improved quality, process efficiency, and cost effectiveness during industrial production of the product and storage.

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