NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS SOUTH WEST ZONE
(A DIVISION OF NIGERIAN SOCIETY OF ENGINEERS)

IBADAN
2023

MAIDEN Zonal Conference & FIRST Annual General Meeting

INNOVATIONS IN AGRICULTURAL ENGINEERING: SOLUTIONS TO FOOD, ENERGY AND ECONOMIC CHALLENGES IN NIGERIA

CONFERENCE PROCEEDINGS

EDITED BY:
ENGR. PROF. J.A.V. OLUMUREWA,
ENGR. PROF. YAHAYA MIJINYAWA,
ENGR. DR. O. O. OLABINJO

UNIVERSITY OF IBADAN LIBRARY

IBADAN 2023

NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS

SOUTH WEST ZONE

(A DIVISION OF THE NIGERIA SOCIETY OF ENGINEERS**)**

PROCEEDINGS OF THE MAIDEN CONFERENCE ANDTHE FIRST ANNUAL GENERAL MEETING OF THE NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS SOUTH WEST ZONE (NIAE SW)

INNOVATIONS IN AGRICULTURAL ENGINEERING: SOLUTIONS TO FOOD, ENERGY AND ECONOMIC CHALLENGES IN NIGERIA

HELD AT THE

FACULTY OF TECHNOLOGY, THE UNIVERSITY OF IBADAN, IBADAN

UNIVERSITY OF IBADAN LIBRARY

EDITED BY
ENGR. PROF. J.A.V. OLUMUREWA,
ENGR. PROF. YAHAYA MIJINYAWA,
ENGR. DR. O. O. OLABINJO

MOISTURE SORPTION ISOTHERM OF MORINGA (*MORINGA OLEIFERA* LAM.) SEED

Akintunde Akintola[1*], Ademola Kabir Aremu[2] and Babatunde Olayinka Oyefeso[2]
[1]Department of Agricultural and Bio-Environmental Engineering, Oyo State College of Agriculture and Technology, Igboora, Nigeria.
[2]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria.
*Corresponding author: akintunde.akintola@yahoo.com

ABSTRACT
This study was designed to investigate and model the moisture sorption isotherm of moringa seed during storage. An important factor in the quality loss of dried moringa seeds during storage is the water activity (a_w) which influences the stability of the product. Knowledge of sorption isotherms is necessary to correctly carry out drying and storage operations. Sorption Isotherms (SI) of moringa seed were obtained by determining the Equilibrium Moisture Content (EMC) at a temperature range of 20-40℃ and nine a_w (0.09-0.92) levels using thermostatic water bath and concentrated H_2SO_4. The sorption data were fitted into four selected models namely: Brunauer-Emmett-Teller (BET), Guggenheim-Anderson-De Boer (GAB), Hailwood-Horrobin (HH) and Modified Henderson (MHM) models. The performance of the models was tested using Root Mean Square Error (RMSE), co-efficient of determination (R^2) and Residual Sum of Squares (RSS). The SI curves generated were sigmoidal in shape indicating Type-II isotherm. The GAB was the best-fitted model and predicted the EMC at all temperatures with highest R^2 (0.9994) in adsorption and (0.9994) in desorption processes. The BET and HH models did not fit well at all temperatures with R^2 (0.6957) and (0.8439), respectively. The GAB gave the least RMSE and RSS and it ranged 0.0775-0.2124 and 0.0060-0.0431, respectively. Experimental isotherm obtained demonstrated Type-II behaviour, which is typical for most agricultural materials.
Keywords: Moringa seed, Equilibrium moisture content, Sorption models, Water activity

INTRODUCTION

Moringa seed is rich in nutrition owing to the presence of a variety of essential phytochemicals present in its leaves, pods and seeds (Aremu and Akintola, 2014; Fadele *et al.,* 2018). In fact, Moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach (Fahey, 2005; Akintola *et al.,* 2022).

Besides having many medicinal and nutritional values within M. oleifera seeds have anti-microbial activity (Balbir, 2006; Aremu and Akintola, 2016) and are utilized for wastewater treatment in Sudan by rural women to treat highly turbid Nile water (Musa and Njidda, 2021). Moringa oleifera exhibits excellent properties of treating water (Lea, 2010; Yin, 2011; Ghebremichael and Gebremedhin, 2011). It has therefore been used by the public as a water

UNIVERSITY OF IBADAN LIBRARY

purifier because of its coagulant properties (Oluwalana *et al.,* 1999; Ayotunde *et al.,* 2011; Mustapha *et. al*., 2012; Musa and Njidda, 2021).
Moisture sorption isotherm indicates the quantity of water that a material imbibed or desiccated at equilibrium with an established water activity at a specific temperature (Bell and Labuza, 2000). Every bio-material (including *Moringa oleifera* Lam.) have their own specific and unique moisture sorption isotherms (Singh and Kumari, 2014). The relationship that exists between water activity and equilibrium moisture content at a constant temperature is considered a very important criterion to take cognisance of during storage of food materials and ingredients.
The moisture sorption isotherms of food and agricultural products play a significant role in the conception and implementation of preservation and storage methods. These methods include packaging, drying, mixing, and a number of other procedures that include the prediction of food stability and shelf life (Khalloufi *et al.*, 2000). Moisture sorption isotherm is of utmost importance in so many kinds of processing and product stability applications (Falade and Aworh, 2004).

Several researchers have investigated the adsorption and desorption behaviour of several food products. Few among them include: Ajibola and Dairo, 1998 (sesame seed); Menkov, 2000 (vetch seeds); Aviara and Ajibola, 2002 (melon seed and cassava); Ajibola *et al.*, 2003 (Cowpea); Falade and Aworh, 2004 (Osmo-oven dried African star apple); Aviara *et al.*, 2006 (Sorghum malt); Ajisegiri *et al.,* 2007 (parboiled rice); Ojediran *et al.,* 2014 (castor seed); Literature revealed that Moravec *et al.* (2008) reported on the adsorption isotherm of moringa seed at 25^{o}C while Alimi *et al.* (2018) gave information on adsorption isotherm of moringa seed at 25^{o}C and 60^{o}C only. However, there was no evident report on desorption characteristics of moringa seed. Therefore, this research was designed to investigate and model the moisture adsorption and desorption isotherm of moringa seed at five different storage temperatures levels between 20 and 40^{0}C.

METHODOLOGY

Evaluation of the Moisture Adsorption and Desorption of Moringa Seed

Matured moringa pods were harvested from its plantation at Oyo state college of agriculture and technology, Igboora. The kernels were shelled and the seeds were washed to eliminate any unnecessary materials before being dried until equilibrium moisture content was attained. Equilibrium moisture content was determined for both adsorption and desorption at five temperature levels (20, 25, 30, 35, 40^{o}C) and nine levels of water activities using concentrated tetraoxosulphate (IV) acid (H_2SO_4) as shown in Table 1 to provide constant water activities at the temperature levels.
Glass desiccators (16cm diameter by 16cm height) containing 350ml of concentrated H_2SO_4 to provide constant relative humidity. The desiccators were placed in a thermostatic water bath at the desired temperature and allowed to reach equilibration. 30g of moringa seed was placed in petri dish and was used for each experimentation (both desorption and adsorption). The samples were weighed at intervals of four hours until uniform weight is attained thereby getting the equilibrium moisture content. The experiment was replicated three times and the average was recorded and fit into four common sorption models. Table 2 shows the mathematical expressions of each of the models.

UNIVERSITY OF IBADAN LIBRARY

Table 1: Percentage concentrated H_2SO_4 and their corresponding water activity values at different temperatures.

Percent H_2SO_4	Temperature (^oC)				
	20	25	30	35	40
15.00	0.9237	0.9241	0.9245	0.9253	0.9261
25.00	0.8218	0.8218	0.8252	0.8285	0.8317
35.00	0.6607	0.6651	0.6693	0.6773	0.6846
40.00	0.5599	0.5656	0.5711	0.5816	0.5914
45.00	0.4524	0.4589	0.4653	0.4775	0.4891
50.00	0.3442	0.3509	0.3574	0.3702	0.3827
55.00	0.2440	0.2505	0.2563	0.2685	0.2807
60.00	0.1573	0.1625	0.1677	0.1781	0.1887
65.00	0.0895	0.0933	0.0972	0.1052	0.1135

Rizvi, 1986; Bell and Labuza, 2000 as reported by Aviara, 2020

Table 2: Mathematical models applied to the sorption isotherms to analyze EMC-a_w data

Model	Mathematical equation
BET	$M = \frac{M_o C a_w}{(1-a_w)[1+(C-1)a_w]}$
GAB	$M = \frac{ABCa_w}{[1-Ba_w][1-Ba_w+BCa_w]}$
Hailwood-Horrobin	$M = \left(\frac{A}{a_w} + B - Ca_w\right)^{-1}$

UNIVERSITY OF IBADAN LIBRARY

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

Where a_w represents the equilibrium relative humidity in decimal; M is the equilibrium moisture content in % (db); T is the temperature in °C; A, B, C are sorption isotherm constants specific to each equation.

Validation of the Sorption Isotherm Models

Statistical measures such as the root mean square error (RMSE), co-efficient of determination (R2), mean relative error (MRE), and residual sum of squares (RSS) were used to assess the statistical validity of the fit to the models as shown in Equations 1, 2, 3 and 4 respectively.

$$RMSE = \sqrt{\frac{\sum(M_e - M_p)^2}{N}} \quad (1)$$

$$R^2 = \frac{\sum(M_e - M_p)^2}{\sum M_e^2 \sum M_p^2} \quad (2)$$

$$MRE = \frac{100}{N}\sum\frac{M_e - M_p}{M_e} \quad (3)$$

$$RSS = \frac{\sum(M_e - M_p)^2}{N} \quad (4)$$

where:
M_e is the experimental EMC
M_p is the predicted EMC
N is the number of experimental data.
The R^2 values closest to 1, and RMSE and RSS values closest to 0, depicts a better fit. Values of MRE below 10% shows a suitable fit for practical reasons (Sudathip *et al.,* 2009).

RESULTS AND DISCUSSION

Sorption isotherm characteristics of moringa seed

The adsorption and desorption isotherm of moringa seed at different temperatures are presented in Figures 1a and 1b respectively. There was an increase in the equilibrium moisture content with an increase in the water activity.

The sorption isotherm curve showed the typical sigmoid shape confirming type II classification which is the characteristic of the most biological material (Aviara, 2020). They absorb relatively small amount of water at lower activities and large amounts at high relative humidity. This agrees with Kumar *et al.,* (2005) for products rich in oil content. The moisture sorption characteristics of a product have been shown to be influenced by its composition, processing treatment, temperature and relative humidity (Vishwakarma *et al.*, 2011).

It was observed from both figures 1a and 1b that storage temperature had varying impact on the

UNIVERSITY OF IBADAN LIBRARY

behaviour of moringa seeds. This suggests that the ability of the seeds to absorb and retain water during storage could decrease with an increase in the storage temperature. The reduction in EMC with the temperature rise could mean that when the temperature is high, the energy of the water molecules may change to higher energy levels and this leads to breaking of the water binding sites of foods (Owo *et al*., 2016).

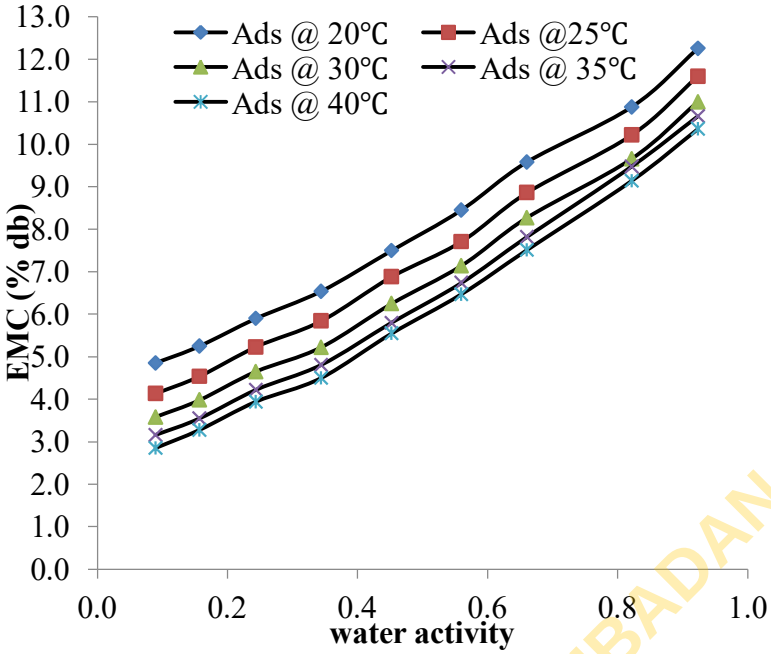

Figure 1a: Adsorption isotherm of moringa seed

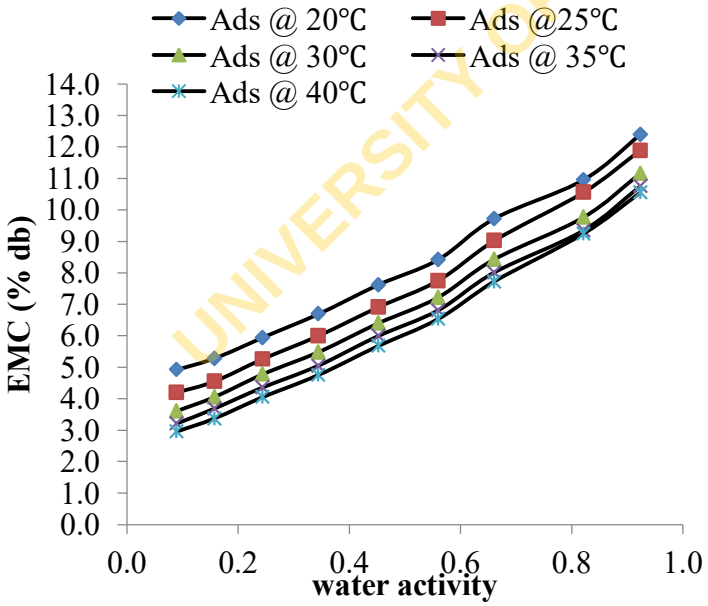

Figure 1b: Desorption isotherm of moringa seed

Sorption Parameters of Moringa Seed

The adsorption and desorption isotherm parameters of the moringa seed stored at different

UNIVERSITY OF IBADAN LIBRARY

temperatures based on the BET, GAB, Hailwood-Horobin and modified Henderson models are shown in Table 3. Quadratic relationships were established between the equilibrium moisture content and the water activity at different storage temperatures using the GAB, BET and Hailwood-Horobin models. Also, linear relationships were established for modified Henderson model. The magnitude of the aw/M increases with the increase in the storage temperature until 0.6 a_w when it starts decreasing for the GAB and Hailwood-Horobin models. The BET models, however, show a continuous increase in the magnitude of the aw/(1-aw)M with an increase in the storage temperature and a_w. The observed differences in the variable interaction may be due to the manner in which the models were constituted for sorption isotherm description. A similar result was reported by Moravec, (2008) on sorption isotherm for moringa seed at 25°C. Reports by Ajibola and Dairo, (1998) on relationship between relative humidity and EMC of sesame seed; Menkov, (2000) on moisture sorption isotherm of vetch seeds at four temperatures; Aviara and Ajibola, (2002) on moisture sorption of melon seed and cassava corroborates the findings of this study.

Table 3: Parameters of the adsorption and desorption models

		Temperature									
		20°C		25°C		30°C		35°C		40°C	
Models	Parameters	Ads	Des	Ads	Des	Ads	Des	Ads	Des	Ads	Des
BET	c	2190952	489369	205151	217807	231.006	133.579	97.106	76.394	55.365	56.847
	Mo	4.293	4.354	3.787	3.829	3.392	3.521	3.088	3.224	2.892	2.986
GAB	c	55.046	55.648	37.525	37.727	27.768	26.879	19.814	20.445	15.059	15.963
	k	0.582	0.581	0.604	0.616	0.624	0.614	0.646	0.630	0.653	0.650
	Mo	5.818	5.876	5.288	5.303	4.831	5.004	4.509	4.677	4.340	4.428
Hailwood-Horobin	A	0.0066	0.0065	0.0094	0.0091	0.0126	0.0127	0.0167	0.0165	0.0215	0.0204
	B	0.1607	0.1591	0.1757	0.176	0.1916	0.1842	0.206	0.1958	0.2125	0.2069

UNIVERSITY OF IBADAN LIBRARY

	C	-0.0943	-0.0931	-0.1091	-0.1117	-0.1256	-0.1184	-0.1439	-0.132	-0.1536	-0.1476
Modified Henderson	A	0.0007	0.0006	0.0011	0.0018	0.0016	0.0024	0.0025	0.0030	0.0032	0.0038
	B	6.4581	6.4268	6.4312	6.4268	6.2641	6.2875	6.1452	6.1874	6.0845	6.1047
	C	3.2846	3.2936	2.9296	2.7185	2.5278	2.5334	2.3742	2.3991	2.4769	2.4709

*Ads – Adsorption, Des -- Desorption

The sorption parameters obtained in Table 3 were fitted in the models at various water activities to derive the equilibrium moisture content (EMC) for each model.

Validation of Sorption Data

The observations of the model validation and calibration are presented in Tables 4. All the four models except BET and Hailwood-Horrobin models could be used to predict the sorption characteristics of moringa seed with coefficient of determination (R^2) values well above 90%. The GAB model was the best-fitted model for the seed and most accurately predicted the EMC at all temperatures with highest R^2 (0.9994) both in adsorption and desorption processes. This was followed closely by modified Henderson model model having least root mean square error (RMSE) values. The values of R^2 reduced as temperature increased. This result supports a study by Santalla and Mascheroni (2003) and Sahu *et al.* (2018), who reported that the GAB model provided the greatest fit to the data gotten experimentally on sorption isotherm of sunflower seeds and kernels and chironji kernels, respectively. Also, Hailwood-Horrobin model did not fit very well but performed better than BET model with R^2 value (0.8439. This did not agree with the study of Boquet *et al.* (1979) who stated that the Hailwood-Horrobin model extraordinarily fits the experimental data for the majority of food products as reported by Aviara, 2020. This is further supported by the variations in the RSS and MRE values derived from the evaluation of the four models. This indicates that the GAB and modified models would be accurate to demonstrate the sorption characteristics of moringa seed over the entire range of

UNIVERSITY OF IBADAN LIBRARY

water activity considered. It was also observed that the models better predicted the EMC for moringa seed at lower temperatures. This clearly shows that temperature had an effect on moisture adsorption and desorption. This supports the study by Gichau *et al.,* (2020) and Tavares *et al.,* (2021).

Table 4: Moisture sorption isotherm model predictive indicators

		Temperature									
		20°C		25°C		30°C		35°C		40°C	
Models	Parameters	Ads	Des	Ads	Des	Ads	Des	Ads	Des	Ads	Des
BET	R^2	0.6975	0.6957	0.7149	0.7197	0.7313	0.7272	0.7480	0.996	0.7576	0.7550
	RMSE	0.2033	0.1880	0.0981	0.1111	0.0758	0.1018	0.0720	0.0864	0.0864	0.0891
	MRE	0.9541	0.8826	0.2089	0.5542	0.5542	0.8530	1.0427	1.3525	1.6822	1.6868
	RSS	0.0413	0.0354	0.0096	0.0124	0.0058	0.0104	0.0052	0.0075	0.0075	0.0079
GAB	R^2	0.9994	0.9994	0.9993	0.9993	0.9994	0.9994	0.9993	0.9993	0.9992	0.9992
	RMSE	0.2064	0.2124	0.1974	0.2034	0.2077	0.1817	0.2072	0.1760	0.1946	0.1826
	MRE	0.2031	0.1419	0.1427	0.1998	0.1032	0.0648	0.0107	0.0030	0.0277	0.0550
	RSS	0.0426	0.0451	0.0389	0.0414	0.0431	0.0330	0.0429	0.0310	0.0379	0.0333
Hailwood	R^2	0.8860	0.8865	0.8745	0.8671	0.862	0.869	0.8469	0.8606	0.8439	0.8477

UNIVERSITY OF IBADAN LIBRARY

-Horobin						0	1				
	RMSE	0.1698	0.1165	0.1857	0.1828	0.1307	0.1282	0.1329	0.1092	0.1238	0.1195
	MRE	1.23	0.5673	0.5456	0.9384	1.2547	1.3071	0.8895	0.3733	0.4707	0.4907
	RSS	0.0288	0.0136	0.0345	0.0334	0.0171	0.0164	0.0177	0.0119	0.0153	0.0143
	R^2	0.9990	0.9989	0.9990	0.9989	0.9989	0.9992	0.9979	0.9979	0.9969	0.9976
Modified Henderson	RMSE	0.5271	0.5457	0.4745	0.5144	0.4232	0.4784	0.3736	0.3920	0.3468	0.3701
	MRE	6.384	6.5429	6.2033	6.6394	6.0089	6.6759	5.2515	0.5180	4.9668	5.2676
	RSS	0.2778	0.2978	0.2251	0.2645	0.1791	0.2289	0.1396	0.1537	0.1203	0.1370

UNIVERSITY OF IBADAN LIBRARY

CONCLUSIONS

Moisture sorption isotherm of moringa seed was determined at 20, 25, 30, 35 and 40^{o}C using sulphuric acid with different concentrations to maintain a constant water activity. Based on BET classification, an experimental isotherm demonstrated Type-II behavior, which typically presents in dry, oily materials and medicinal herb materials. Moringa seed demonstrated a capability of holding a small amount of water at low to moderate water activity, vice versa at high water activity. Four models were selected to describe the moisture sorption isotherm of moringa seed and GAB model was found to be the best-fitted model followed by Modified Henderson.

REFERENCES

Ajibola, O. O., Ajetumobi, O. E. and Aviara, N. A. 2003. Sorption equilibrium and thermodynamic properties of cowpea. *Journal of Food Engineering* 58: 317-324.

Ajibola, O. O., Dairo, O. U. 1998. The relationships between equilibrium relative humidity and moisture content of sesame seed using the vapour manometric method. *Ife Journal of Science and Technology* 8(1): 61-67.

Ajisegiri, E. S. A., Sopade, P. A. and Chukwu, O. 2007. Moisture sorption study of locally parboiled rice. *Australian Journal of Technology* 11(2):86-90.

Akintola, A., Oyefeso, B. O. and Aremu, A. K. 2022. Effect of temperature and hysteresis on monolayer moisture content of moringa seed grit during storage. *Proceedings of 22nd international conference and 42nd annual general meetings of the Nigerian Institution of Agricultural Engineers* 22: 444-451.

Alimi, B. A., Tesfay, S. Z., Oke, M. O. and Workneh, T. S. 2018. Moisture sorption isotherm of moringa seed at two different temperatures. *In Proceedings of International conference on managing quality in chains*. Eds.: U. L. Opara and E. W. Hoffman; pages 191-196.
Aremu, A. K. and Akintola, A. 2016. Drying kinetics of *Moringa oleifera* seeds. *Journal of Life Sciences and Technology* 4 (1):7-10.

Aremu, A.K. and Akintola, A. 2014. Effects of some drying methods on nutritional characteristics of *Moringa Oleifera* seeds. *International Conference on Biotechnology and Environment Management* 75 (12): 66-72.
Aviara, N. A. 2020. Moisture sorption isotherms and isotherm model performance evaluation for food and agricultural products. Intech Open: Pp 1-33.
Aviara, N. A. and Ajibola, O. O. 2002. Thermodynamics of moisture sorption in melon seed and cassava. *Journal of Food Engineering* 55(2): 107-113.

Aviara, N. A., Adedeji, M. A, Ajibola, O. O. and Aregbesola, O. A. 2006. Moisture sorption isotherms of sorghum malt at 40 and 50 °C. *Journal of Stored Products Research* 42:290-301.
Ayotunde, E. O., Adebanjo, O. T. and Fagbenro, O. A. 2011. Toxicity of aqueous extract of *Moringa oleifera* seed powder to Nile tilapia (*Oreochromis niloticus*) fingerlings. *International Research Journal of Agricultural Science* 1:142–150.
Balbir, M. 2006. Moringa for cattle fodder and plant growth. Tree for life available at www.treeforlife.org. Assesses on 14th May, 2019.

Bell, L. N. and Labuza, T. P. 2000. Moisture sorption: Practical aspects of isotherm measurement and use (2nd Edition). American Association of Cereal Chemists, Inc. St. Paul, MN. Pp 1-23.

Boquet, R., Iglesias, H. A. and Chirife, J. 1979. Equations for fitting water sorption isotherms of foods, Part III: Evaluation of various three-parameter models. *Journal of Food Technology* 14:527-534.
Fadele, O. K., Akintola, A., Oyefeso, B. O. and Aremu, A. K. 2018. Effect of moisture content, operation and design parameters on separation efficiency of moringa seed shelling machine: Optimisation approach. In: *Proceedings of International Commission of Agriculture and Biosystems Engineering, 12th CIGR Section VI International Symposium (Post Harvest Technology and Bioprocess Engineering),* IITA, Ibadan, Nigeria. Pages 213- 223.

Fahey, J. W. 2005. *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic and prophylactic properties. *Trees for Life Journal* 1: 5-12.

UNIVERSITY OF IBADAN LIBRARY

Falade, K. O. and Aworh, O.C. 2004. Adsorption isotherms of osmo-oven dried African star apple (*Chrysophyllum albidum*) and African mango (*Irvingia gabonensis*) slices. *European Food Research and Technology* 218: 278-283.
Ghebremichael, K. and Gebremedhin N. A. G. 2011. Performance of *Moringa oleifera* as a bio-sorbent for chromium removal, *Water Science Technology* 62: 1106–1111.
Gichau, A. W., Makokha, A. and Okoth, J. K. 2019. Moisture sorption isotherm and shelf-life prediction of complementary food based on amaranth–sorghum grains. *Journal of Food Science and Technology* 57(3):962-970.

Khalloufi, S., Ratti, C. and Giasson, J. 2000. Water activity of freeze-dried mushrooms and berries. *Canadian Journal of Agricultural Engineering* 42(1): 51-56.
Kumar, A. J., Patel A. A., Patil, G. R. and Singh, R. R. 2005. Effect of temperature on moisture desorption isotherms of kheer. *Journal of Food Science and Technology* 38 (3), 303-310.
Lea M., 2010. Bioremediation of turbidity surface water using seed extract from *Moringa oleifera* Lam. (Drumstick) tree, *Curr. Protoc. Microbiol* 16:1–14.

Menkov, N. D. 2000. Moisture sorption isotherms of vetch seeds at four temperatures. *Journal of Agricultural Engineering Research* 76:373-380.

Moravec, C. M., Laca, E. A. and Bradford, K. J. 2008. Water relations of drumstick tree seed (*Moringa oleifera*): imbibition, desiccation, and sorption isotherms. *Journal of Seed Science and Technology* 36: 311-324.
Musa, J. and Njidda, A. A. 2021. Chemical composition, anti-nutritive substances, amino acid profile and mineral composition of *Moringa oleifera* seeds subjected to different boiling duration. *Nigerian Journal of Animal Science and Technology* 4 (1):43 – 52.

Mustapha, H. B., Suleyman, A. M. and Jonan, C. A. 2012. Kinetics of water disinfection with Moringa seed extract, *Journal of Environment and Earth Science* 2(7): 224-231.

Ojediran, J. O., Aviara N. A. and Raji, A. O. 2014. Moisture sorption properties of castor seeds. *Agricultural Engineering Today* 38(1):38-44.

Oluwalana, S. A., Bolaji, G. A., Bankole, W., Alegbeleye, O. and Martins, O. 1999. Domestic water purification using *Moringa oleifera* Lam. *Nigerian Journal of Forestry* 1-2: 28-32.
Owo, H. O., Adebowale, A. A., Sobukola, O. P., Obadina, O. A., Kajihausa, O. E., Adegunwa, M. O., Sanni, L. O., Tomlins, K. 2016. Adsorption isotherms and thermodynamic properties of water yam flour. *Qual Assur Saf Crop*. 9 (2): 221-227.
Rizvi, S. S. H. (1986). Thermodynamic properties of food in dehydration. In: Rao MA, Rizvi SSH, editors. Engineering Properties of Foods. New York: Marcel Dekker Inc; pp. 133-214.

Sahu, S. N., Sahu, J. K., Tiwari, A., Baitharu, I. Kariali, E. and Naik, S. N. 2018. Moisture sorption isotherms and thermodynamic properties of sorbed water of chironji (*Buchanania lanzan* Spreng.) kernels at different storage conditions. *Journal of Food Measurement and Characteristics* 12(4): 2626–2635.
Santalla, E. M. and Mascheroni, R. H. 2003. Equilibrium moisture characteristics of high oleic

UNIVERSITY OF IBADAN LIBRARY

sunflower seeds and kernels. *Drying Technology* 21:147-163.

Singh, A. K. and Kumari, N. 2014. Moisture sorption isotherm characteristics of ground flaxseed. *Journal of Food Process Technology* 5: 319-328.
Sudathip, I., Pimpen, P. and Woatthichai, N. 2009. Moisture sorption of Thai red curry powder. *International Journal of Science Technology* 3(03): 486 –497.

Tavares, L. and Noreña, C. P. Z. 2021. Characterization of the physicochemical, structural and thermodynamic properties of encapsulated garlic extract in multilayer wall materials. *Powder Technology* 37(8): 388–399.

Vishwakarma, R. K., Nanda, S. K. and Shivhare, U. S. 2011. Moisture adsorption isotherms of guar (*Cyamposis tetragonoloba*) grain and guar gum splits. *Food Science and Technology* 44: 969-975.
Yin, C. Y. 2011. Emerging usage of plant-based coagulants for water and wastewater treatment. *Journal of Processing and Biochemistry* 45:1437–1444.

UNIVERSITY OF IBADAN LIBRARY

IBADAN 2023

MODELLING AND OPTIMIZATION OF THE AIR DESICCATION CAPACITY OF ADSORBENT FILTERS FOR CONTROLLING MOISTURE BUILDUP IN SOLAR DRYERS USING BOX-BEHNKEN DESIGN

Fasuan Titilope Modupe*[1, 2], Aregbesola Omotayo A[1]
[1] The Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ife, Nigeria
[2] National Horticultural Research Institute, P.M.B 5432, Idi-Ishin Jericho GRA, Ibadan.
Correspondence Email: titilope.olagunju@yahoo.com

ABSTRACT
This study explores the utilization of moisture adsorbent filters for enhancing air desiccation in solar dryers, to improve drying efficiency at night. Silica gel, calcium sulfate, activated charcoal, and activated clay filters, were explored for the influence of parameters, such as filter thickness (0 - 5 cm), air velocity (0 - 3 m/s), and air temperature (15 - 40°C), on their air desiccation performance using box Behnken design of response surface methodology. An experimental setup was designed to facilitate the investigation. The findings demonstrate that calcium sulfate and activated charcoal exhibit greater air desiccation ability at elevated temperatures (>27.5°C) and thinner layers (below 2.5 cm). Conversely, activated clay and silica gel show increased air desiccation at higher temperatures (40°C) and thicker layers (approximately 2.5 cm and 3.5 cm, respectively). Mathematical models developed demonstrate a strong correlation with the experimental data, achieving high R^2 values (0.913 - 0.954). Additionally, the study identifies silica gel as the most effective adsorbent material, with an optimal layer thickness of around 2