STUDY OF WATER ADSORPTION ISOTHERMS OF GALIA MELON PEEL

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ABSTRACT

This study aimed to determine the moisture adsorption isotherms of the powder derived from the residue of Galia melon peel (*Cucumis Melo var. Reticulatus*), aiming to investigate the stability of this by-product and identify the humidity range, at various temperatures, conducive to achieving water activity levels suitable for the growth and metabolite development of industrially relevant microorganisms. This investigation aimed to facilitate the production of fermentation products, such as enzymes, in a semi-solid state. The residue was processed through washing, drying, and crushing to produce the corresponding powder. Experimental data on water activity were collected at temperatures of 20°C, 30°C, and 35°C, and these data were analyzed using mathematical models including GAB, Peleg, Oswin, Kuhn Iglesias, and Chirife. The assessment of the models revealed that the GAB, Peleg, and Oswin models exhibited superior fits, with coefficients of determination (R^2) exceeding 0.9980. Notably, GAB model demonstrated the most favorable adjustment parameters, with R^2 greater than 0.9980 and $P < 2.3\%$. According to this model, a water activity level above 70%, conducive to the growth of most microorganisms, corresponds to humidities of 19.5% (20°C), 18.9% (30°C), and 18.6% (35°C).

Keywords: Lignocellulosic residue. Biotechnological potential. Enzymatic complex. Environmental sustainability.

1 INTRODUCTION

The constant growth of the agro-industrial sector, driven by population increase and technological advancement, has expanded environmental impacts due to the intensive production of waste. An allotment portion of this waste is often inadequately disposed of in the environment. According by Dilucia, Lacivita, and Conte (2020), fruit and vegetable by-products such as peel, pulp, seeds, or bagasse represent 10 to 35% of the gross mass of these foods. Therefore, the demand for the utilization of these residues is increasing, necessitating the expansion of alternative utilization studies and the pursuit of a balance between production and nature preservation.

In 2022, Brazil ranked third among the world's largest fruit producers, according to a study conducted by Embrapa, with a record of 58 million tons, equivalent to 5.4% of global production (Abrafrutas, 2023). Among these fruits, melon (*Cucumis melo* L.) stood out as one of the most exported in the year. The commonly disregarded elements of fruits mentioned above (peel, seeds, and pulp) represent losses of high nutritional value. In a study by Madeira (2017), flours obtained from melon peel and seeds showed significant cellulose content (19% and 35%, respectively), demonstrating great biotechnological potential. Melon is a fruit belonging to the Cucurbitaceae family, composed of 90% water and containing vitamins A, C, and E. It is also a good source of proteins (22%–39% w/w), lipids (30%–45% w/w), fibers (19%–34% w/w), and potassium-rich minerals, according to Zhang (2023). The residues from melon processing already demonstrate significant potential for generating value-added products, considering their excellent natural properties that can be applied as an alternative for obtaining industrially relevant products. Among them, enzyme production has stood out for ensuring sustainability through the utilization to renewable bioactive resources.

In the chemical composition of fruits, water plays a crucial role in their stability, sensory properties, and rate of deterioration. Water activity (Aw) is a vital parameter for determining the shelf life of foods and is essential in the development and enhancement of food products, as it indicates the water content available in a free state. In this context, considering the significant amount of melon residues produced in the Northeastern semiarid region, this study aims to evaluate the water activity of Galia melon peel flour. The objective is to offer new opportunities for reuse, management, and exploration of potential applications in enzyme production.

2 MATERIAL & METHODS

The raw material utilized in this study was cultivated on the farm situated at Federal University of Semi-Arid (UFERSA) campus in Mossoró, Rio Grande do Norte. We employed the static gravimetric method, as described by Capriste and Rotstein (1982), to derive the moisture adsorption isotherms at three temperatures (20, 30, and 35°C), utilizing an Aqualab hygrometer, specifically the model 3TE-Decagon Devices.

The equilibrium moisture content on a dry basis (Xe) was established through the division of the water mass by the dry mass of the samples, as outlined in Equation 1. The obtained results underwent analysis of variance to ensure interpretation and validation, thereby enabling conclusions to be drawn regarding the properties of the material under investigation. Subsequently, the models outlined in Table 1 were adjusted to fit the experimental data.

$$X_e = \frac{m_e - m_s}{m_s} \times 100 \qquad (1)$$

Xe - equilibrium moisture content, % dry basis; me - mass of the sample at equilibrium, g; ms - dry mass of the sample, g.

Table 1 Mathematical models of water adsorption isotherms.

	GAB	Peleg	Oswin	Kuhn	Iglesias e Chirife
Eq.	$X_e = \frac{X_m C K a_w}{(1 - K a_w) + (1 - K a_w + C K a_w)}$	$X_e = k_1 a_w^{n1} + k_2 a_w^{n2}$	$X_e = \left[\frac{(a_w)}{(1 - a_w)}\right]^b$	$X_e = \left(\frac{A}{log a_w}\right) + B$	$X_e = A + \left[B\left({}^{a_w}/_{1 - a_w}\right)\right]$
N°	(2)	(3)	(4)	(5)	(6)

Xe - equilibrium moisture content (% db); aw - water activity; Xm - water content at monolayer (% db); C and K - parameters depending on temperature and nature of the product; K1, K2, n1, n2, a, and b are constants of the models.

For analysis of the quality of the model that fits the experimental data, the coefficient of determination (R2) and the mean percentage deviation (P), given by the equation below, were used as a basis.

$$P = \frac{100}{n} \sum_{i=1}^{n} \frac{(X_{exp} - X_{pred})}{X_{exp}} \qquad (7)$$

P - mean percentage deviation (%), Xexp - experimental values obtained, Xpred - values predicted by the model, and n - number of experimental data points.

3 RESULTS & DISCUSSION

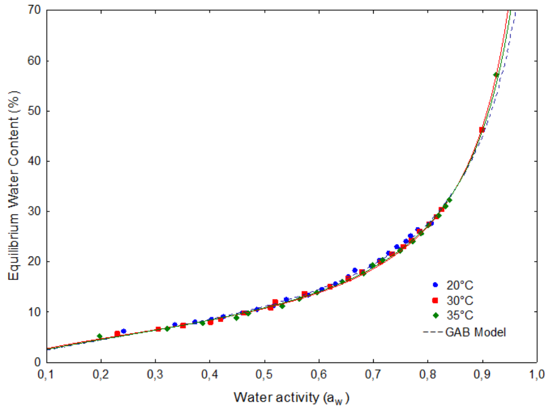
The parameters generated in the GAB, Peleg, Oswin, Kuhn, and Iglesias and Chirife models, the coefficients of determination, and the mean percentage deviations are presented in Table 2.

Table 2 Parameters, coefficients of determination (R2), and mean percentage deviations (P%) of the models fitted to the data of water adsorption isotherms.

Model	T(°C)	X_m	C	K	R^2	P(%)	
	20	7,748	3,867	0,929	0,9980	2,28	
GAB	30	7,066	4,675	0,947	0,9996	2,05	
	35	6,693	5,550	0,957	0,9995	2,42	
	T(°C)	**K_1**	**n_1**	**K_2**	**n_2**	**R^2**	**P(%)**
	20	42,935	3,720	9,299	0,305	0,9993	1,05
Peleg	30	63,327	9,184	24,850	1,172	0,9991	3,10
	35	76,023	10,721	26,405	1,254	0,9985	4,58
	T(°C)	**a**	**B**	**R^2**	**P(%)**		
	20	11,156	0,658	0,9980	2,60		
Oswin	30	10,905	0,658	0,9997	2,30		
	35	10,740	0,655	0,9996	2,44		
	T(°C)	**a**	**B**	**R^2**	**P(%)**		
	20	5,854	2,535	0,9944	3,50		
Kuhn	30	4,847	4,209	0,9888	9,80		
	35	4,381	5,434	0,9860	12,73		
	T(°C)	**a**	**B**	**R^2**	**P(%)**		
	20	4,974	5,969	0,9937	3,89		
Iglesias e Chirife	30	6,297	4,895	0,9875	10,45		
	35	7,361	4,410	0,9848	13,38		

Upon analysis of the data presented in Table 2, it is evident that the GAB model generally offered the most accurate fit to the experimental data. The values of the water contents at monolayer (Xm) decreased with increasing temperature. According to Robertson & Lee (2021), these values indicate that all primary adsorption sites have been saturated by water molecules. This phenomenon occurs because higher temperatures provide water molecules with increased kinetic energy. This enables a single molecule to interact with more active sites, leading to a decrease in the number of molecules occupying the monolayer (Tao et al., 2018). Observing the parameters C and K, it becomes apparent that both increase with temperature, suggesting a greater energy requirement for the binding of water molecules to active sites in mono and multilayers (Talens et al., 2018). Similar results, better fitted by the GAB model, were found by Souza, Macedo, and Costa (2017) for jackfruit peel flour at 25°C, Santiago, Conrado, and Almeida (2021) for jabuticaba peel residue at 25, 30, and 35°C, and Costa (2023) for beet powder. Figure 1 displays the isotherms of melon peel at temperatures of 20, 30, and 35°C. The graphical behavior, illustrated in Figure 1, reveals that the results obtained for the three temperatures were very close, presenting water activity values between 0.2 and 0.9. It was observed that the equilibrium moisture content gradually increased with the increase in water activity, with values ranging between 2% and 60% db, with the isotherm performed at 30°C standing out, with a final water content of approximately 60% db. For water activities exceeding 70%, conducive to the growth of most microorganisms, the equilibrium moisture contents estimated by the GAB model were 19.5% at 20°C, 18.9% at 30°C, and 18.6% at 35°C.

Figure 1. Adsorption isotherms of Galia melon peel at temperatures of 25, 30, and 35 °C by the GAB model.



4 CONCLUSION

The finding that the GAB model is more suitable for describing the adsorption isotherms within the studied temperature range is of great significance, as the analysis of these isotherms plays a crucial role in enzymatic complexes production. Maintaining an ideal level of water activity that supports cell growth and metabolism without surpassing the solid matrix's maximum water adsorption capacity. In the context of a potential fermentation process for enzyme production, for example, substrate moisture levels should fall within the minimum range of 18.6 to 19.5% for microbial incubation or inoculation. Therefore, the choice of the GAB model reinforces the reliability and effectiveness of predictions under the investigated conditions, contributing to the advancement of understanding and optimization of the processes involved in enzymatic complex production.

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