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EQUILIBRIUM MOISTURE CONTENT OF ONION PROCESSING WASTE POWDER

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Abstract: *The equilibrium moisture content of onion processing waste powder is studied and the sorption and desorption curves at 20, 40, 60 and 80°C are presented. Values of equilibrium moisture contents for temperatures higher than 20°C have been obtained by the Pass and Slepchenko's method. The adsorption and desorption isotherms were determined by the standard static gravimetric method. Analytical dependences describing the sorption and desorption curves have been derived. The results may be useful in determining the storage conditions and design of drying equipment and installations for the production of onion processing waste powder.*

Keywords: *equilibrium moisture content sorption and desorption isotherms onion processing waste.*

1. Introduction

Preservation of agricultural products and foods by drying is practiced as one of the important techniques [3], [11]. Prolong contact between dried product and the wet gas at constant external conditions leads to the establishment of thermal and diffusive equilibrium, which was maintained throughout the period of storage. The temperature of the product becomes equal to the ambient temperature, as well as the partial vapour pressure of the liquid is equal in the material and the environment. At this point the moisture of the material is constant and it is called equilibrium moisture content.

The equilibrium moisture content of a product (Wp) can be measured for different values of the relative humidity of the air (φ) at a constant temperature. The functional dependence of Wp = f(φ) could be plotted according to data obtained and it represents an isotherm of sorption or desorption, depending upon whether it is obtained by moistening or drying of wet material to an equilibrium state [6]. Several researches have been reported for the relationship between the equilibrium

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moisture content and equilibrium relative humidity to describe the sorption process mathematically and proposed more than 200 relationships [1], [7], [11].

The knowledge of sorption/desorption characteristics is the starting point for the investigation of quality variation during drying and storage processes and indispensable to food product and process development, food engineering and industrial quality control [10].

Moisture sorption isotherms are useful thermodynamic tools for determining interaction of water and food substances, and provide information to evaluate food processing operations, such as drying, mixing, packaging and storage. Sorption isotherms can also be used to investigate structural features of a food product [4].

The development of food products that contain value-added dietary fibre beside different classes of phytochemicals is of great interest nowadays. Onion processing waste consists mainly of the top and bottom of onion bulbs and the two outer fleshy scales together with the brown skins. Dried powder from this material could be potentially used as a value-added low calorie functional food ingredient rich in dietary fibre, total phenols and total flavonoids with good antioxidant activity [9].

To the best of our knowledge there were no data reported in the literature for equilibrium moisture content of onion processing waste powder (OPWP). Therefore, the equilibrium moisture content of OPWP at different relative humidity are determined and dependences describing the sorption/desorption isotherms at different temperatures are presented.

2. Materials and Methods

2.1. Sample Preparation

The material used in this study was obtained from a local Bulgarian canning plant after processing (peeling) of brown skin onion bulbs. The OPWP was prepared according to procedure described in our previous study [9].

2.2. Experimentation

The adsorption and desorption isotherms were determined by the standard static gravimetric method. The method comprises the following: a certain amount of material was placed in sealed vessel (exicator) at constant temperature (20°C) and relative humidity. The sample was periodically weighed. Upon reaching a constant weight the equilibrium moisture content of the material was determined. An analytical balance with accuracy of 0.0001 g was used for determining the mass of the material. The equilibrium moisture content of the samples was determined by the weight method by drying the sample to constant mass in an atmospheric oven at 105±2°C. The constant humidity of the air into each sealed vessel was maintained by means of saturated aqueous solutions of different salts, which have the ability to maintain a constant pressure of water vapour in the atmosphere above them. The relative humidity and the salts used in the experiment are shown in Table 1.

For determination of the equilibrium moisture content at 40, 60 and 80°C the Pass and Slepchenko's method was used [5].

Table 1

Salts used in the experiment and the corresponding relative humidity (φ, %) at 20°C

Salts	NaOH	LiCl	CH_3COOK	$MgCl_2$	K_2CO_3	NaBr	NaCl	Na_2SO_4
φ [%]	6,98	11,14	23,1	32,1	43,9	58,7	75,4	86,9

2.3. Analysis of Data

Analytical dependences describing the sorption and desorption curves was obtained from the experimental data by using standard statistical program (Table Curve 2D v.5.01). Coefficients of determination (R^2) and the mean statistical errors (MSE) are calculated.

All determinations were performed in triplicate and their means values are reported.

3. Result and Discussion

The results for equilibrium moisture content of OPWP determined by sorption and desorption at different temperatures are presented in Tables 2 and 3 and sorption/desorption isotherms are plotted in Figures 1 and 2, respectively.

Sorption/desorption isotherms of OPWP indicated that the increase of temperature leads to shift of the equilibrium isotherms to the left. There is also a pronounced sorption hysteresis.

Table 2

Equilibrium moisture content W_p [%] of OPWP determined by sorption at different temperatures

φ [%]	**Temperature [°C]**			
	20	40	60	80
10	4.00	3.41	2.70	2.43
20	5.42	4.72	4.06	3.64
30	6.61	5.82	5.19	4.65
40	7.94	7.03	6.38	5.73
50	9.62	8.56	7.84	7.05
60	11.97	10.68	9.81	8.84
70	15.62	13.98	12.76	11.55
80	22.19	19.93	17.87	16.28
90	37.74	34.09	29.07	26.89

Table 3

Equilibrium moisture content W_p [%] of OPWP determined by desorption at different temperatures

φ [%]	**Temperature [°C]**			
	20	40	60	80
10	8.90	6.46	5.20	5.09
20	11.12	10.24	9.02	8.52
30	11.75	11.42	10.77	9.87
40	12.69	12.11	11.81	10.95
50	13.78	13.20	12.82	12.50
60	14.91	14.29	13.58	13.58
70	19.16	16.66	15.16	14.09
80	36.85	29.37	24.56	20.46
90	90.52	78.45	61.71	54.38

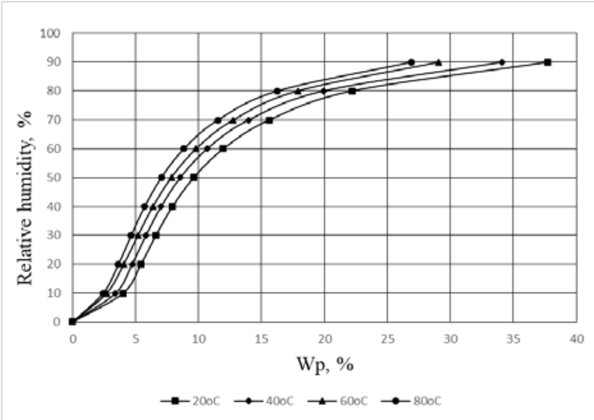

Fig. 1. *Sorption isotherms of OPWP at different temperatures*

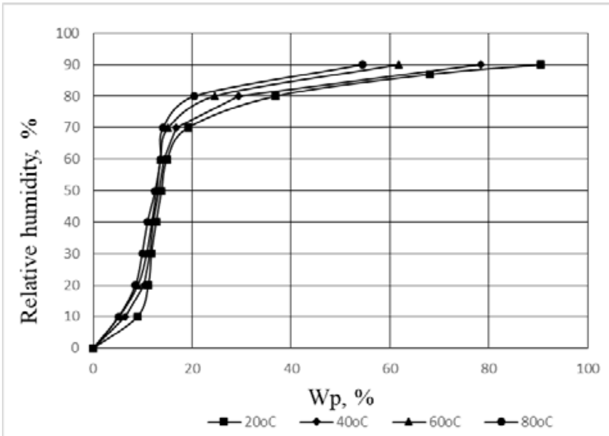

Fig. 2. *Desorption isotherms of OPWP at different temperatures*

The isotherms have clearly depicted S-shaped character, which indicates the existence of three types of bounding of moisture to the material, such as monomolecular adsorption, polymolecular adsorption and capillary condensation. The analysis of the character of the sorption and desorption curves indicated that the adsorption bound moisture in the material is a minor portion (Wp = 10%) and decreases with increasing the temperature, which is testified by convex section of the curve in the direction of the X-axis. This convex section decreases at high temperatures, which means that the major part of the moisture is related to the capillary and polymolecular adsorption. Similar trends for many foods have been reported in the literature [1], [4], [6], [8].

Although a large number of theoretical, semi-theoretical and empirical sorption models to describe the sorption behavior of foods or other materials have been proposed in the literature, no one equation gives accurate results throughout the whole range of water activities, and for all types of foods.

The equations of the BET (Brunauer, Emmet and Teller) or GAB (Guggenheim, Anderson and de Boer) type are the most commonly used. However, these equations have a common disadvantage that except their theoretical basis, they contain constants which must be experimentally determined [1-2, 6, 12].

The resulting analytical relationships describing the sorption/desorption curves for OPWP have the following forms:

- **For sorption curves:**

$$W_P = (a + c\varphi)/(1 + b\varphi + d\varphi^2) \quad (1)$$

- **For desorption curves:**

$$W_P = a + b\varphi + c\varphi^2 + d\varphi^3 + e\varphi^4 + f\varphi^5 + g\varphi^6 \quad (2)$$

where:

φ is the relative humidity of the air, in %;
W_p – equilibrium moisture of OPWP, in %;
a, b, c, d, e, f and *g* – equation coefficients.

The resulting equations are valid in the range 0 < φ < 0.9.

Values of the equations coefficients, coefficients of determination (R^2) and average statistical errors (ASE) are presented in Tables 4 and 5, respectively.

Table 4

Equation coefficients (a, b, c, d), coefficient of determination (R^2) and mean statistical error (MSE) for sorption

Coefficients	**Temperature [°C]**			
	20	40	60	80
a	-0.030404985	-0.0075450669	0.0014644683	-0.0012249316
b	0.17972514	0.15016608	0.085378734	0.086222298
c	1.0506571	0.80136054	0.47722868	0.43022338
d	-0.0018111493	-0.0015308306	-0.00088970249	-0.000903691
R^2	0.98939	0.99992	0.99978	0.99979
MSE	1.20147	0.119696	0.19678	0.19219

Table 5

Equation coefficients (a, b, c, d, e, f), coefficient of determination (R^2) and mean statistical error (MSE) for desorption

Coefficients	**Temperature [°C]**			
	20	40	60	80
a	-0.035056746	-0.00019093456	-0.0045129011	0.39893025
b	1.4904639	0.61777733	0.42336543	0.31563247
c	-0.075505737	0.02042316	0.026015056	0.036852416
d	0.001715004	-0.0023873721	-0.0021537266	-0.002837905
e	$-1.2091674.10^{-5}$	$7.1599161.10^{-5}$	$5.934005.10^{-5}$	$7.84629.10^{-5}$
f	$-1.0088386.10^{-7}$	$-9.1208791.10^{-7}$	$-7.2888849.10^{-7}$	$-9.569334.10^{-7}$
g	$1.3300025.10^{-9}$	$4.3014837.10^{-9}$	$3.375096.10^{-9}$	$4.3251172.10^{-9}$
R^2	0.99987	0.99999	0.99991	0.99976
MSE	0.37956	0.02138	0.43447	0.565587

4. Conclusions

The equilibrium moisture content of OPWP at the temperatures 20, 40, 60 and 80°C and relative humidity range of 10-90%, ranged from 2.43 to 37.74 % (db) and from 5.09 to 90.52 % (db) for sorption and desorption, respectively.

An analytical relationships (eqs. 1 and 2) for calculation equilibrium moisture content of OPWP for the range of relative humidity $0 < \varphi < 0.9$, and temperature range from 20 to 80°C has been obtained.

The results could be useful in determination of the storage conditions and design of drying equipment and installations for the production of OPWP.

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