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SORPTION CHARACTERISTICS OF PECTIN ISOLATED FROM PARSNIP (*PASTINACA SATIVA* L.) OF BULGARIAN ORIGIN

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Abstract

Modelling of sorption processes for foods of biological origin provides information about the choice of the regimes of their treatment, preservation and transportation. The equilibrium moisture content (EMC) is a main sorption characteristic of the product. The connection between the EMC and the water activity - a_w is represented through a sorption isotherm for a definite temperature. The monolayer moisture content (MMC) is a sorption characteristic influencing the food product stability. The aim of this research is to investigate the sorption characteristics of the pectin isolated from parsnip (*Pastinaca sativa* L.) of Bulgarian origin.

The analysis of the sorption characteristics of pectin extracted from parsnip (*Pastinaca sativa* L.) of Bulgarian origin is implemented for temperatures 10 ^{0}C, 25 ^{0}C, and 40 ^{0}C in water activities in the range from 0.11 to 0.85 respectively, for the processes of adsorption and desorption. The equilibrium moistures values for the both processes are increased with the higher temperatures with constant water activity. According to the Brunauer's classification the equilibrium isotherms of pectin extracted from parsnip are from II type. The modified models of Oswin, Halsey, Henderson and Guggenheim-Anderson-de Boer (GAB) are used for the sorption isotherms description. According to the commonly accepted criteria for evaluation of the models - average relative error, standard error of the mean and residues distribution, the modified model of Halsey is recommended for description of the sorption characteristics of the analyzed product. The linearization of the model of Brunauer-Emett-Teller (BET), based on the theory of polymolecular adsorption is used for the calculation of monolayer moisture content (MMC) in $a_w < 0.5$.

The received MMC for the three temperatures for the both processes as follows: adsorption - 10 ^{0}C - 6.54% dry mass, 25 ^{0}C - 5.93% dry mass, and 40 ^{0}C - 5.98% dry mass; desorption - 10 ^{0}C - 8.57% dry mass, 25 ^{0}C - 7.81% dry mass, and 40 ^{0}C - 7.07% dry mass. The equilibrium moistures values for the both processes are increased with the higher temperatures with constant water activity. According to the Brunauer's classification the equilibrium isotherms of pectin extracted from parsnip are from II type. According to the commonly accepted criteria for evaluation of the models - average relative error, standard error of the mean and residues distribution, the modified model of Halsey is recommended for description of the sorption characteristics of the analyzed product.

The present study determined the equilibrium and the monolayer moisture content of the pectin isolated from parsnip (*Pastinaca sativa* L.) of Bulgarian origin. Furthermore, this research proved the uniqueness of each food product and the need for individual determination of the sorption characteristics.

Key words: *Parsnip, Pectin, Sorption characteristics, Isotherms, Monolayer moisture content.*

1. Introduction

The interest towards processing of different unconventional plant crops with proved health benefits for the human organism is widely growing in the recent years. The parsnip (*Pastinaca sativa* L.) is a root vegetable growing in Eurasia which is used a lot in that region from ancient times. It is with high nutritional value, rich in: proteins, carbohydrates, cellulose, sodium, zinc, manganese, copper, folic acid, the vitamins PP, A, B, E and considerable amounts of vitamin B3 [1 - 3]. Its consumption has benefits for the nervous system; it possesses antirheumatic and antidote action and it acts as a natural diuretic. It regulates the activity of the gastrointestinal tract and contributes for the decrease of the risk of development of diabetes type II by lowering the cholesterol and the blood sugar. Half of glass of parsnip contains: 50 calories, 0 grams of fats, 0 milligrams of cholesterol, sodium, 12 grams of carbohydrates, 3 grams of dietary fibre, 3 grams of sugar, 1 gram of proteins, vitamin C, calcium and iron [4 - 6].

The parsnip is rich in antioxidant vitamins and organic compounds which protect the body from external toxins and from secondary toxic products produced by our own cell metabolism as well. The vitamins C and E act as antioxidants in the body and eliminate and neutralize the free radicals which can cause chronic diseases including tumour [7].

By the data from Castro *et al.*, [8], the parsnip contains considerable amounts of dietary fibre (30.4% of the dry matter), in that number 10% pectin substances. The pectin extracted from different growing sources differs in composition, texture, properties and etc., as in result differences in the physical and physico-chemical properties of the polysaccharide appear, which have particularly important meaning for its behavior in the food systems. The interest towards the study of the pectin substances is connected not only with their health effects but with their functional properties as well, which determines their wide application in the food technologies in their quality of jelling, thickening, emulsifying and foaming agents [9; 10].

Water in food products is a main and key component. The cell walls of the food products, in which composition the pectin enters, are in direct dependence with the interaction of the pectin macromolecules with ions and water molecules (hydration and dehydration) [11; 12]. The obtaining of pectin's sorption isotherms provides information for its behavior as a typical hydrocolloid used for making jellies, emulsions, edible films, etc. The sorption processes statics, based on the gravimetric method, is a calculation of the equilibrium and monolayer moisture content of the food products. The equilibrium moisture is a main sorption characteristic of the product [13]. The connection between the equilibrium moisture and the water activity a_w is represented through a sorption isotherm for a definite temperature [14]. The monolayer moisture content (MMC) is a sorption characteristic influencing the food product stability. In preservation conditions by bringing the food product to moisture corresponding to MMC, a preservation of its qualitative indices is achieved [15; 16]. Analysis and modelling of sorption processes provide information about the choice of the regimes of the treatment, preservation and transportation of the food products [13; 14].

Information about held experiments about the sorption characteristics of pectin extracted from parsnip of Bulgarian origin is not found in the literature inquire, which gave as the grounds for the carrying out of the current analysis.

2. Materials and Methods

2.1. Materials

In the current development pectin isolated from parsnip (*Pastinaca sativa* L.), delivered from Bulgaria, region of the town of Plovdiv, is used.

2.2. Methods

The roots of parsnip were preliminary cut, dried (in a dryer in 50 ^{0}C) and ground (laboratory sieve with dimension of the openings 1.0 mm). The pectin is isolated throughout extraction with 0.5 percentage water solution of oxalic acid for 30 min in 85 ^{0}C by described methods of Delchev *et al.*, [17]. Due to the high amount of starch the solution is treated with commercial preparation of α-amylase (LpHera, Novozymes). The sample is treated with 0.3 units amylase activity/g for 2 hours in 40 ^{0}C before the polysaccharide precipitation with ethanol.

The static gravimetrical method recommended for food products is used for the study of the sorption characteristics [18]. Samples of by 1 ± 0.01 g are measured in weighting containers. The containers are put in hydrostats over saturated solutions of the salts - LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, $Mg(NO_3)_2$, NaCl, KCl, maintaining over their surface constant water activity in the range of 0.11 to 0.85. The hydrostats are tempered in thermostats in temperature 10, 25 and 40 °C ± 0.1 °C. With the aim to prevent microbe spoiling crystals thymol are being added [19]. After reaching an equilibrium (20 to 30 days), the moisture of the samples is being defined gravimetrically (24 h in temperature 105 °C). All the experiments are being conducted with threefold repeatability [18; 20; and 21].

2.2.1 Statistical processing

The three parametric modified models of Halsey, Oswin, Henderson и Guggenheim-Anderson-de Boer (GAB) recommended by ASAE, 1997, which include the influence of the temperature, are used for he description of the sorption isotherms [22]:

Modified Halsey: $$a_{w=exp\left[\frac{-exp(A+B_t)}{M^c}\right]} \quad (1)$$

Modified Oswin: $$M = (A + B_t)\left(\frac{a_w}{1 - a_w}\right)C \quad (2)$$

Modified Henderson: $$1 - a_w = exp[-A(t + B)M^c] \quad (3)$$

GAB: $$M = \frac{AB'C'a_w}{(1 - B'a_w)(1 - B'a_w + B'C'a_w)} \quad (4)$$

In the GAB model the coefficients B' and C' are presented in the type:

$$B' = Bexp^{\left(\frac{h_1}{RT}\right)} \quad C' = Cexp^{\left(\frac{h_2}{RT}\right)} \quad (5)$$

Where: M - equilibrium moisture - % dry mass; a_w - water activity; t - temperature (°C); T - temperature (K); A, B, C, h1, h2 - constants; R = 8.314 - universal gas constant, kJ/(mol.K).

The models coefficients are determined by a computer program for nonlinear regression by the method of the smallest squares. The average relative error (P, %), standard error of the mean (SEM) and residues distribution ei,, described in details by Durakova *et al.*, [23], are used as criteria for the models' evaluation [23]. The model of Brunauer-Emmett-Teler (BET), fulfilled in linear type, valid for a_w < 0.5 [14; 18; 19; 21; 24; and 25].

$$\frac{a_w}{(1 - a_w)M} = P + Qa_w \quad (6)$$

is used for determination of the monolayer moisture content.

3. Results and Discussion

The initial moistures of the pectin extracted from parsnip (*Pastinaca sativa* L.) of Bulgarian origin for the processes adsorption and desorption are respectively 6.70 % and 23.24 %. The received equilibrium moisture content for temperatures 10 °C, 25 °C, and 40 °C are presented throughout equilibrium sorption isotherms on Figure 1 for adsorption, and Figure 2 for desorption.

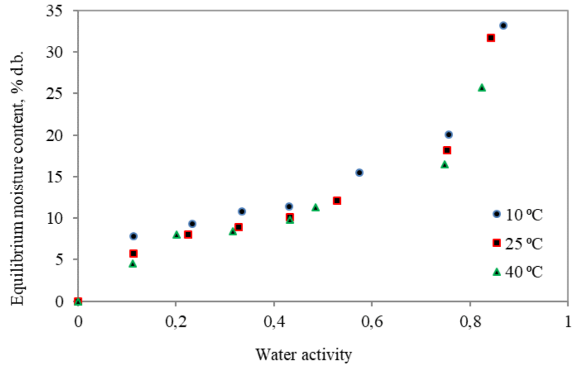

Figure 1. Adsorption isotherms of pectin from parsnip in temperatures 10 °C, 25 °C, and 40 °C, and water activities in the range of 0.11 to 0.85

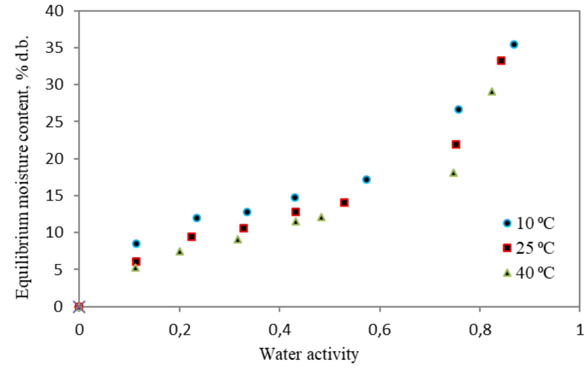

Figure 2. Desorption isotherms of pectin from parsnip in temperatures 10 °C, 25 °C, and 40 °C, and water activities in the range of 0.11 to 0.85

The received results show that the equilibrium moisture content of pectin from parsnip (*Pastinaca sativa* L.) of Bulgarian origin varies between 5% and 35% dry mass for the conditions of the experiment. With the increase of temperature, the equilibrium moisture decreases in a_w = const, a dependence characteristic for a large number of studies of food products [13; 14; 18; and 21]. In percentage correlation the decrease of the equilibrium moisture content is most notable with higher relative moistures a_w = 0.86 for adsorption - 7.42% dry mass and in moisture a_w = 0.75 for desorption with 8.47% dry mass. For the rest of the water activities the moisture decrease for adsorption varies about 4% dry mass, and for desorption - 5% dry mass.

Figures 1 and 2 show besides the received results that the sorption isotherms for the both processes are with the characteristic S-shaped form for the food products, i.e. they are from II type according to the Brunauer's classification [14; 20; and 25].

The received coefficients, the values of the evaluation criteria - average relative error (P, %), standard error of the mean (SEM) and residues' distribution ei,, of the used in the statistic processing three parametric models of Oswin, Halsey and Henderson are presented in Tables 1 and 2 respectively for the processes of adsorption and desorption. The received results for the model of Guggenheim-Anderson-de Boer (GAB) are presented in Table 3.

It is obvious from the statistical analysis that the lowest values of P and SEM and accident residues distribution (Figure 3) are received in the modified model of Halsey.

According to the commonly accepted criteria for evaluation and model suitability, we have ground to recommend the model of Halsey for description of sorption isotherms of pectin extracted from parsnip (*Pastinaca sativa* L.) of Bulgarian origin [13; 18; and 23]. On Figures 4 and 5 the linearization of the BET model respectively for adsorption and desorption with the experimental points for $a_w < 0.5$ is presented.

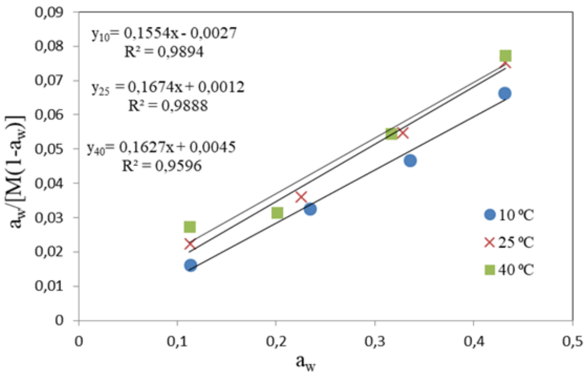

Figure 4. Linearization of the BET model for three temperatures for adsorption

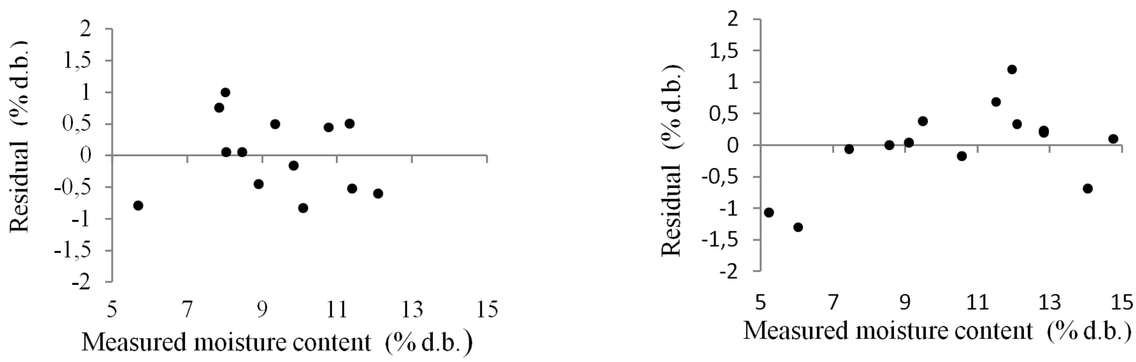

Figure 3. Residues distribution for the processes of adsorption and desorption in the modified model of Halsey

Table 1. Models' coefficients (A, B, C), P [%], SEM and residues' distribution for adsorption

Model	A	B	C	P	SEM	Residues
Oswin	14.08608	-0.05746	0.465602	10.39	1.9	**non acidentally**
Halsey	**4.479214**	**-0.010852**	**1.833183**	**8.12**	**1.85**	**acidentally**
Henderson	**0.000482**	**15.40537**	**1.416799**	**21.03**	**3.79**	**non acidentally**

Table 2. Models' coefficients (A, B, C), P [%], SEM and residues' distribution for desorption

Model	A	B	C	P	SEM	Residues
Oswin	17.10957	-0.094368	0.433218	7.25	1.64	**non acidentally**
Halsey	**4.747094**	**-0.017823**	**1.766271**	**6.54**	**1.81**	**acidentally**
Henderson	**0.0002**	**2.087432**	**1.846804**	**16.03**	**4.41**	**non acidentally**

Table 3. Coefficients (A, B, C, h1, h2), P [%] and SEM of GAB model

Process	A	B	C	h_1	h_2	P	SEM	Residues
Adsorption	5.903039	0.785777	33229.89	448.4204	6144.434	10.52	1.73	**non acidentally**
Desorption	**8.271189**	**0.574064**	**0.0003**	**1038.75**	**27806.15**	**7.16**	**1.69**	**non acidentally**

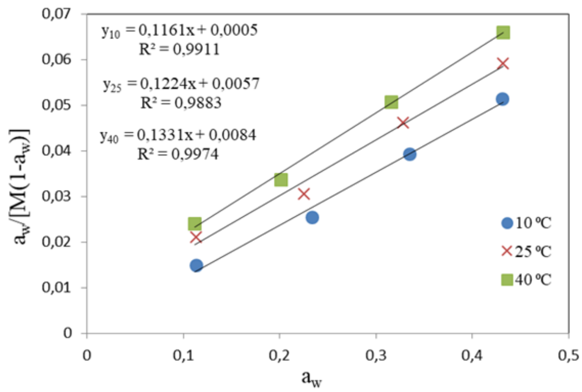

Figure 5. Linearization of the BET model for three temperatures for desorption

The values of MMC (Mm) [% dry mass], presented in Table 4 are calculated from the coefficients of the linear equations.

Table 4. BET monolayer moisture content (Mm), [% dry mass] in different temperatures t

t, °C	Adsorption	Desorprtion
10	6.54	**8.57**
25	5.93	**7.81**
40	**5.98**	**7.07**

The received results show that in the process desorption with the increase of temperature the value of the MMC decreases on the average by 0.75% for each temperature, whereas for the process adsorption that tendency is not observed. In the base of the received results we have grounds to think that there is no direct dependence between the temperature and the value of MMC of the examined product [15; 16; 24; and 25].

4. Conclusions

- The equilibrium moisture content of pectin extracted from parsnip (*Pastinaca sativa* L.) are received by experiments for the processes adsorption and desorption for temperatures 10 °C, 25 °C, and 40 °C and water activities in the range of 0.11 to 0.87.
- Temperature influences the sorption capacity of pectin extracted from parsnip. With its increase in constant water activity the equilibrium moistures decrease.
- Received sorption isotherms have clearly expressed *S*-shaped character, i.e. they are from II type according to the Brunauer's classification.
- Modified model of Halsey is recommended for the description of the sorption isotherms of pectin extracted from parsnip.
- Monolayer moisture content of pectin extracted from parsnip are calculated which for the conditions of the experiment are as follows: adsorption - 10 °C - 6.54% dry mass, 25 °C - 5.93% dry mass and 40 °C - 5.98% dry mass; desorption - 10 °C - 8.57% dry mass, 25 °C - 7.81% dry mass, and 40 °C - 7.07% dry mass.

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