HYGROSCOPICITY OF FOOD CONCENTRATES ON THE EXAMPLE OF PEA SOUP

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The study was aimed at investigating the hygroscopicity of food concentrates. The sorption phenomenon measurement was made with a static method on the basis of steam adsorption isotherms analysis and with a dynamic method by determination of steam adsorption kinetics and process rate.

Sorption isotherms were determined at water activity range of $a_w=0.07$-0.98. The monomolecular layer capacity V_m and corresponding water activity and the adsorption specific surface were determined after rearrangement of the sorption isotherms BET.

Steam adsorption isotherms of the researched croutons are corresponding to the type II in the Brunauer's classification. While for the researched powders constituting the pea soup concentrate, sorption isotherms were the indirect type between II and III according to the Brunauer's classification. Higher monolayer capacity and the adsorption specific surface characterised croutons and powders of the producer A, which achieved results indicating a better flexibility to the re-hydration process.

INTRODUCTION

Water in food products constitutes one of the factors determining chemical, physical and microbiological changes. A decrease of water content in products can influence the extension of the food storage stability [Lenart, 1991]. Hygroscopic character of food is connected with its ability to absorb water in a humid environment or to release water in a dry environment. [Domian & Lenart, 2000].

Food products sensitiveness to humidity and their ability to absorb water can be determined on the basis of sorption isotherms, presenting the relation between water activity and equilibrium water content in a product. Shape of the sorption isotherms reflects the mechanism of water bonding in the material. Isotherms of the most food products are characterised with a sigmoid shape with insignificant deviations dependent on the type of product and water content [Lenart, 1991]. Water content changes in the investigated material in a time function during the sorption process, presented in the co-ordinate system are called the sorption kinetics. After differentiating the relation of humidity changes with time, we achieve the sorption rate curves [Domian *et al.*, 1996]. The steam sorption kinetics depends on many factors, among others the character of the experimental material, surface diversification, porosity and the relative air humidity and the temperature [Marzec & Lenart, 2004]. In products with complex composition, such as food concentrates of instantized soups with toasts, the humidity sensitiveness is a resultant of powdered food sorption features and additives used.

The aim of the study was to determine isotherms, kinetics and steam sorption rate in the pea soups concentrates.

MATERIAL AND METHODS

The research materials were pea soups concentrates, produced by two producers A and B, present on the Polish market. Croutons and powder constituting the researched pea soups concentrates was the subject to designation.

Water content in researched products was determined with a method of drying at the atmospheric pressure, in the temperature of 105°C [PN-A-79011-3].

Sorption isotherms were determined with a static method. Samples were stored in hygrostats at a temperature of $20°C\pm1°C$, with saturated saline solutions with a water activity from 0.07 to 0.98. Croutons samples were stored in hygrostats for a period of 30 days and powder samples for a period of 90 days. On the basis of initial products mass and its changes in time, equilibrium water contents were calculated and sorption isotherms were determined.

Sorption isotherm was presented in the co-ordinate system $(p/p_o)/a(1-p/p_o)$ and p/p_o. On the basis of data from water activity range of $a_w=0.07$-0.44, the monomolecular layer capacity has been determined with corresponding with it water activity by using the BET (1) equation and the sorption specific surface as a derivative of monomolecular layer, using the equation (2):

$$a = v_m c(p/p_s)\big/\big(1-(p/p_s)[1+(c-1)(p/ps)]\big) \qquad (1)$$

where: a - adsorption (kg/kg); v_m - maximal adsorption size corresponding to total surface coverage with a monomolecular adsorbate layer (kg/kg); c - constant, related in an exponential way with the difference between adsorption heat on

the first and following layers, accepted as stable and equal to the condensation heat; p - steams pressure of adsorbed chemical compound in a gas phase (Pa); and p_s - steams pressure of adsorbed chemical compound, being over the liquid in a state of equilibrium in the adsorption temperature (Pa) [Ościk, 1983; Ocieczek, 2001].

$$PS = V_m \cdot L \cdot N / M \qquad (2)$$

where: PS - sorption specific surface (m²/g); V_m- monolayer capacity (g H_2O/100 g d.m.); M - water molecular mass (18 g/mol); N - Avogadro number (6.023×10^{23} molecules/mol); L - surface covered by water molecule (1.05×10^{-19} m²/molecule).

The steam sorption kinetics in researched samples was designated with a dynamic method, using the measurement stand allowing maintenance of a permanent measurement temperature of 20°C±1°C and constant water activity in the environmental at a level of a_w=0.98. The steam sorption kinetics was determined in time of 48 h.

Interpretation of sorption kinetics were kinetic curves and rate curves. Kinetic curves were the graphical record of adsorbed water amount changes (g/100 g d.m.) in time. While rate curves reflected the steam adsorption rate changes in time (g/(100 g d.m./min)) and were the differential of kinetic curves.

To evaluate sorption of the investigated products a Smirnow–Kołmogorow conformity test has been used. Test statistic had the form of (3).

$$D_{0.05} = 1.36\sqrt{N_1 + N_2 / N_1} \cdot N_2 \qquad (3)$$

where: $D_{0.05}$ – critical value; 1.36 – coefficient for importance level α=0.05; N_1, N_2 – sorption capacity of the examined samples.

RESULTS AND DISCUSSION

On the basis of the performed researches a higher water content has been stated in croutons and in powders of the producer A. Humidity of A croutons reached 3.6 g H_2O/100 g d.m., and the powder humidity reached 6.4 g H_2O/100 g d.m. Water content in croutons B for 3.2 g H_2O/100 g d.m., whereas powder humidity for 4.8 g H_2O/100 g d.m.

The shape of steam sorption isotherms in the examined croutons A and B corresponded to the II type of isotherms according to the classification presented by Brunauer and partners [1940]. In croutons of both producers a similar sigmoid course of isotherms has been stated (Figure 1). Croutons A in an environment with water activity from 0.07 to 0.53, were characterised with a higher sorption in comparison to B croutons. After exceeding the environmental water activity of a_w=0.53, an inverse tendency has been stated and croutons B were characterised with a higher sorption than croutons A. Results of the Smirnow-Kołmogorow conformity test allowed stating that at the significance level of α=0.05 sorption decompositions in both researched croutons A and B were similar. Steam sorption isotherms of the investigated powders constituting pea soup concentrates determined at a temperature of 20°C±1°C could not be precisely qualified to any of the types determined by Brunauer *et al.* [1940]. They have constituted an indirect type between II and III type in the mentioned classification (Figure 1). In conditions of low steam pressure, steam sorption isotherms of the researched pea soup powders A and B, determined at a temperature of 20°C±1°C, were close to the II type, however in higher relative air humidity they have shown an increase of adsorbed water amounts and corresponded with the III type of isotherm [Brunauer *et al.*, 1940].

On the basis of the achieved sorption isotherms it was stated that water content equilibrium in the researched croutons and pea soup powders was dependent on the water activity of the environment and the interaction of water molecules with components of researched products [Mathlouthi, 2001; Ocieczek, 2001; Foster *et al.*, 2005].

In support of sorption isotherms course, BET equation parameters, the monomolecular layer capacity V_m and corresponding water activity and the PS sorption specific surface were defined (Table 1).

The results achieved indicate that pea soup concentrate powders were characterised with a higher monolayer capacity (Table 1). Following water activities 0.23 and 0.24 corresponded with those values. In the researched croutons A and B, a higher monolayer capacity has been stated in croutons A, which corresponded with higher water activity of about 0.20. In croutons B, the monolayer capacity was at a level that corresponded with water activity of 0.18 (Table 1). The observed
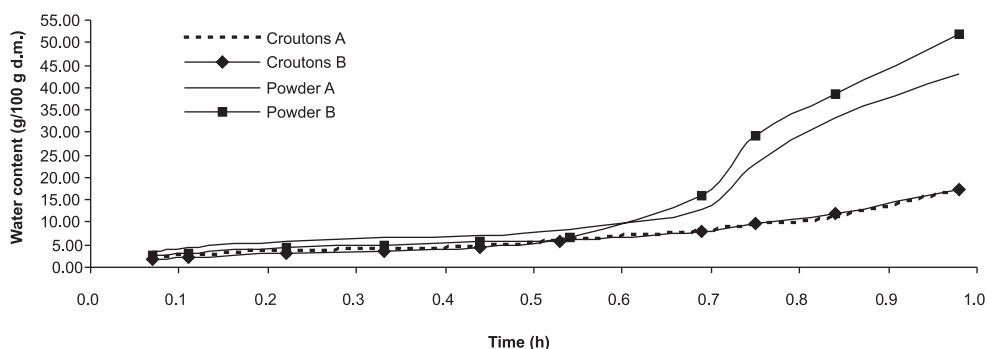

FIGURE 1. Sorption isotherms of croutons and powders of producers A and B, determined at a temperature of 20°C±1°C.

TABLE 1. The BET equation parameters.

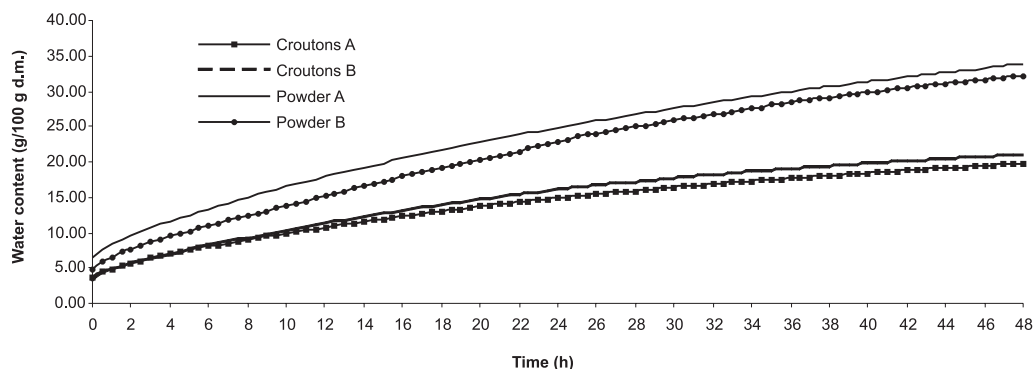| Product	Mean water content (%)	Capacity of monolayer V_m (g H_2O/100 g d.m.)	Water activity a_w (-)	Specific surface of sorption PS (m^2/g)
Croutons A	3.6	2.51	0.20	8.84E+03
Croutons B	3.2	2.45	0.18	8.61E+03
Powder A	6.4	4.29	0.23	1.51E+04
Powder B	4.8	3.43	0.24	1.21E+04

FIGURE 2. Steam sorption kinetics of croutons and powders A and B in an environment with a water activity of a_w=0.98.
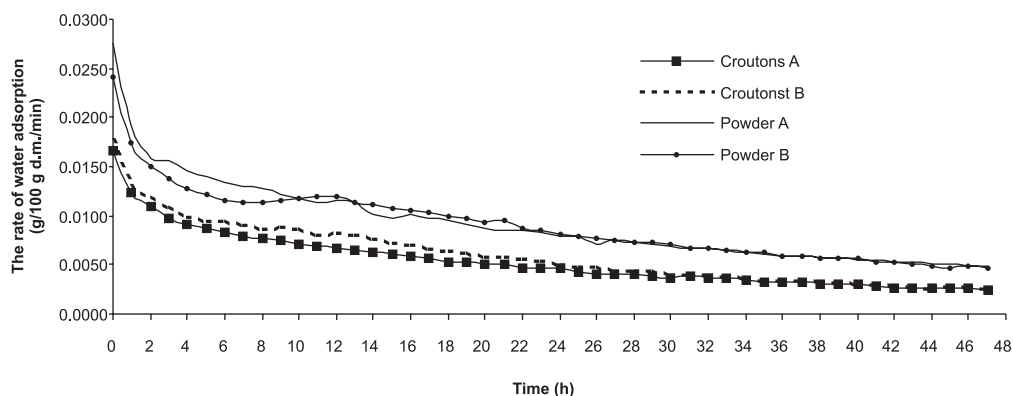

FIGURE 3. Steam process sorption rate of croutons and powders A and B, in an environment with a water activity of a_w=0.98.

differences in croutons A and B could have resulted from differences in state of particular components, determining a lower storage durability due to their higher water activity [Mathlouthi, 2001; Foster *et al.*, 2005].

Sorption specific surface constitutes a derivative of monomolecular layer capacity. It was stated that pea soup powders A and B were characterised with a higher sorption surface, of the order of 10^4, in comparison to the researched toasts A and B. For the pea soup powder A, the sorption surface reached 1.51E+04 m^2/g, while the pea soup powder B achieved a value insignificantly lower, *i.e.* 1.21E+04 m^2/g. In the analysed croutons a higher sorption surface value was achieved for croutons A. Thus it can be assumed that the higher sorption surface values of pea soup powders resulted from the presence of a hydrophobic component, namely fats contained in the inves-

tigated soup powders. Additionally, the formation of colloidal solutions, which are created by the researched pea soups, determines the presence of macromolecules, such as protein or polysaccharides of starch type. Biopolymers are characterized with a significant development of the surface and a significant amount of active site able to absorb water molecules.

Steam sorption kinetics of croutons A and B and powders A and B were presented in Figure 2.

On the basis of the achieved sorption process kinetics curves (Figure 2) it was stated that changes of water content in the researched croutons A and B and in powders of both producers were similar. It was stated that the sorption process rate in the examined croutons A and B, as well in powders A and B, decreased with an increase of water content in the products (Figure 3).

CONCLUSIONS

1. The steam sorption isotherms of the researched croutons A and B were characterised with a course in accordance with the II type according to the classification of Brunauer *et al.* [1940].

2. The sorption isotherms of powders originating from the concentrate A and B were characterised with an indirect shape, between II and III type according to classification of Brunauer *et al.* [1940].

3. A symptom of higher hygroscopicity of croutons A and powder B was a higher monolayer capacity and a higher sorption specific surface.

4. Sorption kinetics curves in croutons A and B and in powders A and B had a similar course.

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HIGROSKOPIJNOŚĆ KONCENTRATÓW SPOŻYWCZYCH NA PRZYKŁADZIE ZUPY GROCHOWEJ

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W pracy badano higroskopijność koncentratów spożywczych. Pomiaru zjawiska sorpcji dokonano metodą statyczną na podstawie analizy izoterm adsorpcji pary wodnej i metodą dynamiczną przez określenie kinetyki adsorpcji pary wodnej i szybkości procesu. Izotermy sorpcji wyznaczono w zakresie aktywności wody a_w=0.07-0.98. Pojemność warstwy monomolekularnej Vm i odpowiadającą jej aktywność wody oraz powierzchnię właściwą adsorpcji obliczono po przekształceniu BET izoterm sorpcji. Izotermy adsorpcji pary wodnej badanych grzanek odpowiadały typowi II w klasyfikacji Brunauera. Natomiast dla badanych proszków tworzących koncentrat zupy grochowej izotermy sorpcji stanowiły typ pośredni pomiędzy II a III według klasyfikacji Brunauera. Wyższą pojemnością monowarstwy i powierzchnią właściwą adsorpcji charakteryzowały się grzanki i proszek producenta A, uzyskane wyniki wskazywały na lepszą podatność tych produktów na proces rehydracji.