Acta Agrophysica, 2008, 12(3), 747-754

CHARACTERISTICS OF SORPTION PROPERTIES OF SELECTED WHEAT CELLULOSE PREPARATIONS

Halina Makała[1], Aneta Ocieczek[2]

[1]Meat and Fat Research Institute, ul. Jubilerska 4, 04-190 Warszawa
[2]Maritime Academy, ul. Morska 83, 81-225 Gdynia
e-mail: halina.makala@ipmt.waw.pl

A b s t r a c t. Sorption capacities of three wheat cellulose preparations were examined. The run of sorption isotherms was determined using the static-desiccator method; BET equation was calculated and the dimensions and volume of capillaries of the examined material were determined from the run of adsorption isotherms in the area of capillary condensation. In the area of monolayer as well as in that of capillary condensation, the preparation of wheat cellulose WF200 was characterised by the highest sorption capacity and specific surface of sorption. In spite of significant differences in the degree of micronisation, the preparations of cellulose: WF 400 and WF 600 were characterised by similar values of sorption capacity in both areas, as well as of specific surface of sorption and volume of capillaries. The studies showed that the technological process, determining the degree of micronisation, had an influence on sorption properties of cellulose preparations and, thereby, on the possibilities of their application.

K e y w o r d s: cellulose preparation, sorption properties, micronisation

INTRODUCTION

Food industry offers diversified cellulose preparations, in production of which parts of cereals, fruits and vegetables, rich in non-assimilable carbohydrates are mainly employed. Due to their differentiated chemical composition, cellulose preparations possess different functional properties and, therefore, different physiological effects. Apart from health-promoting properties and decrease of energetic value, food cellulose – as being added to foodstuffs – affects positively their texture and consistency, facilitates emulsification and water-binding, which prevents too quick drying and inhibits syneresis process (Cludesdale 1997, Anonim 2004, Bacers and Noll 1998).

Market preparations of cellulose are characterised by various water binding abilities that depend, *inter alias*, on the type of raw material from which the preparation is obtained, on technological process and degree of micronisation of its particles, which appears to have a significant effect on their utility properties, especially in the range of shaping the texture (Bacers and Noll 1998, Jimenez-Colmenero *et al.* 2001, Makała 2002, 2003).

THE AIM OF THE WORK

The aim of the study was to characterise and specify the differences in sorption properties of wheat cellulose preparations with different degree of fibre micronisation.

MATERIALS AND METHODS

The research material consisted of the following preparations of wheat cellulose with different degree of micronisation:

- wheat WF 200
- wheat WF 400
- wheat WF 600.

All reagents used in the analyses and preparation of saturated salt solutions were of analytical purity.

Sorption properties of wheat cellulose preparations were evaluated (Atkins 2003). The run of the sorption isotherms of tested flours was outlined by means of the static dessicator method using saturated salt solutions. The scope of research embraced the activity of water in the range of 0.07 to 0.98. The temperature of the tests was 20ºC. The duration of establishing the balance of the arrangement was 30 days.

The BET equation was determined, on the basis of empirical data, with the use of the minimum chi-square method. Fitting the empirical data to the BET equation was characterised on the basis of the average error of estimation (Se), coefficient of determination (R^2) and index of correlation (R) (Makać and Urbanek-Krzysztofiak 2000).

In order to determine the parameters of the process of sorption, such as the capacity of monomolecular layer including the corresponding activity of water and the energy constant, the BET equation was used:

$$a = \frac{\nu_m c \frac{p}{p_s}}{(1-\frac{p}{p_s})[1+(c-1)\frac{p}{p_s}]} \qquad (1)$$

where:
a – adsorption (kg kg^{-1});
v_m – maximum adsorption magnitude corresponding to the complete surface coverage in monolayer of adsorbate (kg kg^{-1});
c – constant, related in the exponential way to the difference between the difference of the heat of adsorption between the first and following layers, accepted to be constant and equal to the heat of condensation;
p – vapour pressure of the adsorbed chemical compound in its gas phase (Pa);
p_s – adsorbed chemical compound vapour pressure over the liquid in balance with the adsorption temperature (Pa) (Ościk 1979, Ocieczek 2008).

Knowing the volume of water vapour adsorbed in the temperature lower than the boiling temperature and the so-called surface of water sitting, the specific surface of the adsorbent was calculated on the basis of the following equation:

$$a_{sp} = \omega \frac{v_m}{M} N \tag{2}$$

where:
a_{sp} – specific surface sorption (m^2 g^{-1});
N – Avogadro number ($6.023 \cdot 10^{23}$ molecules mol^{-1});
M – water molecular mass (18 g mol^{-1});
ω – surface of water sitting ($1.05 \cdot 10^{-19}$ m^2 molecule^{-1}).

The size and capacity of capillaries of tested material were determined on the basis of the run of the isotherms of adsorption in the area of capillary condensation. Calculations were made on the basis of the Kelvin equation:

$$\ln \frac{p}{p_s} = \frac{2\sigma v}{r_k RT} \tag{3}$$

where:
v – molar volume of adsorbed water (kg kg^{-1});
ω – surface tension of liquid at temperature T (Nm^{-1});
r_k – radius of the capillary (m);
R – gas constant (8.314 J·(mol K)$^{-1}$);
T – temperature of the process (K).

The graphic interpretation of the obtained number pairs (*V-r*), called the structural curve, made the basis for the determination of capillary radius (*dV/dr-r*) with the use of the graphic differentiation of the distribution curves method. The maximum values for the distribution curves corresponded to the most frequently occurring pore radius value (Świtka 1992).

RESULTS AND DISCUSSION

Physicochemical characteristics and the possibilities of applying cellulose preparations in meat processing are given in Table 1. Chemical composition of the preparations, i.e. cellulose content and participation of soluble and insoluble fractions, humidity, ash, protein, fats and pH, was identical for all evaluated types of preparations. The assessed preparations were differentiated in respect of physical properties such as bulk density, length of fibres and water binding ability (Anonim 2002, Lander 2004).

Table 1. Characteristics of the examined cellulose preparations

Preparation	Bulk density ($g\ l^{-1}$)	Mean length of fibres (μm)	Water binding capacity, WBC (%)	Oil binding capacity (%)	Application in meat processing
WF 200	75	250	800	690	Scalded sausages, hamburgers, salami
WF 400	40	500	1100	1200	Scalded sausages, hamburgers,
WF 600	210	80	550	370	Scalded smoked meat products

Own elaboration after Lander (2004) and producer's declaration.

Characteristics and comparison of sorption properties of the examined cellulose preparations were based on the evaluation of:

- mutual situation of isotherms of adsorption, being determined at temperature of $20^{o}C$,
- parameters of isotherms of adsorption, being determined from BET model,
- structural characteristics of the examined products, being developed from Kelvin equation.

Sigmoid curves of adsorption as shown in Figure 1 indicate the phenomenon of generating big molecular water layers on the surface of the examined cellulose preparations. Adsorption of water by the tested cellulose preparations increased together with increase of a_w. The phenomenon of absorbing water from the environment was determined by the presence of big molecular substances in the examined preparations which, as being rich in polar sites, enable considerable water adsorption.

The evaluation of sorption areas was conducted by comparison of mutual situation of isotherms in the region of monolayer (0.00-0.20) and capillary condensation (0.80-1.00). In the region of monolayer as well as of capillary condensation, wheat celluloses WF 400 and WF 600 were characterised by the lowest

sorption ability in spite of significant differences in the degree of micronisation. The highest values of sorption capacity in the two regions were revealed by wheat cellulose WF200. The shape and situation of the examined isotherms of water vapour sorption resulted, among other things, from the differences in micronisation of fibres of the evaluated preparations and water binding capacity, being a consequence of abbreviating the length of fibres.

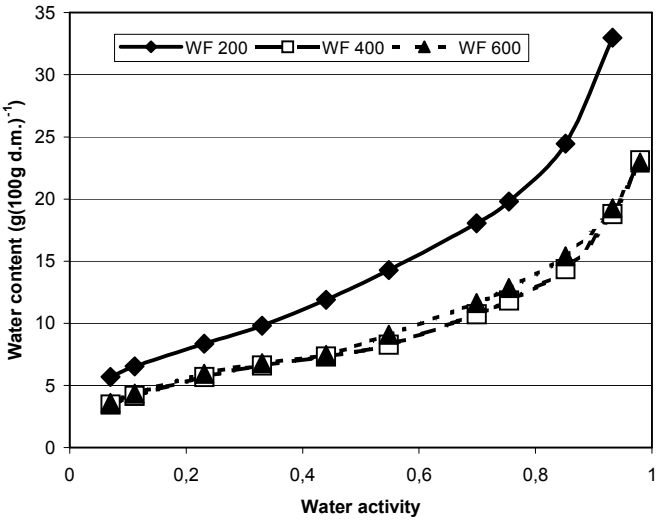

Fig. 1. Characteristics of sorption capacities of market preparations of wheat cellulose

Parameters of the BET equation are given in Table 2. Values of determination coefficient (R^2) showed that more than 99% variability of water content in the examined preparations was determined by water activity. Values of mean error of estimation (Se) informed that empirically determined values of water content, as compared to those obtained from the BET function, differed from 0.0001 for preparation WF 200 to 0.001 g (100 g)$^{-1}$ of DS for preparation WF 600.

The cellulose preparation WF 200 was characterised by the highest volume of monolayer (V_m); the remaining preparations were characterised by a similar level of V_m. The volume of the monolayer of the examined wheat cellulose preparations was differentiated, depending on the degree of its micronisation. Volume V_m was undoubtedly determined by the quantity of the particular components, being rich in polar sites, resulting from the origin of the preparations, and also its physical state, dependent of the degree of micronisation.

Table 2. Parameters of BET equation for the studied cellulose preparations

Preparation	R^2	R	Se	V_m	c	a_w
WF200	0.999	0.999	0.000	6.881	44.219	0.188
WF400	0.999	0.999	0.001	4.797	28.073	0.224
WF600	0.998	0.999	0.001	4.922	29.866	0.216

In the examined cellulose preparations, water activity, corresponding to monolayer, had values from 0.188 (WF 200) to 0.224 (WF 400). The considerable volume of monomolecular layer and corresponding low value of water activity indicates that preparation WF 200 will be characterised by a considerable storage stability. The discussed preparation is able to absorb quite a big amount of water, with its simultaneous immobilisation.

The specific area of sorption was calculated from V_m. The obtained results, as given in Table 3, showed that wheat cellulose WF 200 was characterised by the greatest specific area. Simultaneously, development of the specific area of sorption of the studied preparations allows supposing that meso-capillaries are a dominating form of capillaries in all examined preparations.

Table 3. Structural characteristics of the examined cellulose preparations

Preparation	Specific surface of sorption ($m^2\ g^{-1}$)	General capacity of capillaries (mm^3 (100 g dry matter)$^{-1}$)	Most probable radius of capillaries (nm)
WF200	241.8	115.3	9.050
WF400	168.5	68.1	5.322
WF600	172.9	70.4	5.700

Based on the Kelvin equation, the characteristic parameters of capillaries were determined from the adsorption isotherm, describing the area of capillary condensation (Tab. 3). The discussed equation allows calculating the equivalent weight relative pressures for the corresponding radiuses of capillaries.

The preparations of wheat cellulose WF 600 and WF 400 were characterised by decisively lower general volume of capillaries. Distribution of dimensions of the most probable radius of capillaries in the particular preparations covered the range from 5.322 for type WF 400 to 9.050 for type WF 200. It may be, therefore, supposed that the differences in structure of surface of the examined cellulose preparations, as determined by technological process of their obtaining (micronisation) had an effect on sorption properties, being determined from the run of sorption isotherms.

It is known that the type of raw material as well as parameters of technological process of obtaining the particular types of preparations affect the structure of final product. Sorption features are determined by chemical character as well as physical state of molecule (e.g. amorphous lactose and crystalline lactose). In the analysed case, chemical character of the studied wheat cellulose preparations was identical. The employed technology which allowed obtaining the preparations with the same chemical composition and different physical state, expressed by micronisation of particles (different length of fibres) was a differentiating feature.

The studied wheat cellulose preparations, differing in the degree of micronisation, revealed also differentiated sorption properties. The preparation WF 200, with intermediate degree of micronisation, being expressed by mean length of fibres (250 μm), was characterised by the best sorption features. The preparations WF 400 and WF 600, with the highest (500 μm) and the lowest (80 μm) degree of micronisation, were characterised by decisively weaker sorption qualities.

The obtained results of the studies on sorption properties of wheat cellulose preparations did not confirm the results of the studies of Lander (2004) who stated that cellulose with longer fibres was characterised by higher water binding capacity. According to Lander (2004) there is a precisely determined principle which may be practically employed in the choice of vegetal preparations used in meat products.

CONCLUSIONS

1. In the area of monolayer as well as of capillary condensation the preparation of wheat cellulose WF 200 was characterized by the highest sorption capacity as well as by the specific area of sorption and volume of capillaries.
2. In spite of significant differences in the degree of micronisation, the cellulose preparations WF 400 and WF 600 were characterised by similar values of sorption capacity in both areas as well as specific sorption surface and volume of capillaries.
3. The studies showed that technological process of obtaining the particular types of preparations and their degree of micronisation determined the sorption features of cellulose preparation and the possibilities of its applying.
4. The obtained results of the sorption studies on cellulose preparations have not confirmed, however, the principle formulated by Lander (2004) on the existence of a positive correlation between the length of fibre and water binding capacity by the discussed fibre, affecting thus the texture and structure of meat products.

REFERENCES

Anonim, 2004. Highly soluble wheat fibre. Insoluble ballast substances and benefits of adding them to meat products (in Polish). Mięso i Wędliny, 8, 28-29.

Anonim, 2002. Informational materials of Rettenmaier company.

Atkins P.W., 2003. Physical chemistry (in Polish). PWN, Warsaw.

Bacers T., Noll B., 1998. Ballaststoffe halten Einzug in der Fleischverarbeitung - Fleischwirtsch. 78, 4, 316-320.
Cludesdale F.M., 1997. A proposal for the establishment of scientific criteria for health claims for functional foods. Nutr. Rev. 55, 413-422.
Jimenez-Colmenero F., Carballo J., Cofrades S., 2001. Healthier meat and meat products: their role as functional foods. Meat Science, (59), 5-13.
Lander S., 2004. Hochfuktionelle Weizenfasern. Fleischwirtsch, 7, 45-47.
Makać W., Urbanek-Krzysztofiak D., 2000. Methods of the statistical description (in Polish). Wyd. UG, Gdańsk.
Makała H., 2002. A role of the selected cellulose preparations in shaping the quality of model meat product (in Polish). Rocz. Inst. Przem. Mięsn. i Tł., 39, 147-157.
Makała H., 2003. Effect of potato and wheat cellulose preparations and of inulin on the selected physico-chemical and rheological parameters of model preserved meat product (in Polish). Żywność. Nauka. Technologia. Jakość, 3(36), 21-32.
Ocieczek A., 2008. Evaluation of the usability of sorption isotherms for specification of weight growth factor in noodle products. Acta Agrophysica, 11(1), 147-157.
Ościk J., 1979. Adsorption (in Polish) PWN, Warsaw.
Świtka J., 1992. Impact of chosen technological factors on sorption properties of dried creamary products (in Polish). Scientific WSM work in Gdynia, Gdynia.

CHARAKTERYSTYKA WŁAŚCIWOŚCI SORPCYJNYCH WYBRANYCH PREPARATÓW BŁONNIKA PSZENNEGO

Halina Makała[1], Aneta Ocieczek[2]

[1]Instytut Przemysłu Mięsnego i Tłuszczowego, ul. Jubilerska 4, 04-190 Warszawa
[2]Akademia Morska, ul. Morska 83, 81-225 Gdynia
e-mail: halina.makala@ipmt.waw.pl

S t r e s z c z e n i e . Badano zdolności sorpcyjne trzech pszennych preparatów błonnika. Wyznaczono przebieg izoterm sorpcji metodą statyczno-eksykatorową, równanie BET oraz określono rozmiary i objętość kapilar badanego materiału na podstawie przebiegu izoterm adsorpcji w obszarze kondensacji kapilarnej. Zarówno w obszarze monowarstwy, jak i kondensacji kapilarnej, najwyższą pojemnością sorpcyjną, powierzchnią właściwą sorpcji oraz objętością kapilar charakteryzował się preparat błonnika pszennego WF200. Preparaty błonnika WF400 oraz WF600, pomimo istotnych różnic w stopniu mikronizacji, cechowały się zbliżonymi wartościami pojemności sorpcyjnej w obu obszarach, powierzchnią właściwą sorpcji oraz objętością kapilar. Badania wykazały, że proces technologiczny, warunkujący stopień mikronizacji, wpływa na właściwości sorpcyjne preparatu błonnikowego, a tym samym na możliwości jego zastosowania.

S ł o w a k l u c z o w e : preparat błonnika, właściwości sorpcyjne, mikronizacja