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EFFECT OF TECHNOLOGICAL FACTORS ON WATER ACTIVITY OF EXTRUDED CORN PRODUCT WITH AN ADDITION OF WHEY PROTEINS

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ABSTRACT

Background. The value of water activity in extruded products constitutes a significant indicator of their quality and stability. The state, in which water is found in extruded products, is an indicator of the conducted extrusion process and the used raw material.
Material and methods. The aim of the study was to assess water activity in extruded products made from a mixture of corn grits with 12.5 and 15.0% moisture contents and different level of addition of whey proteins.
Results and discussion. It was shown that the degree of mixture moisture content did not have an effect on the value of a_w in produced puffs. The greatest difference was recorded when introducing 3% proteins in comparison to a_w of puffs produced solely from corn grits, $\Delta a_w = 0.023$. The greater the content of whey proteins, the lower the a_w value. A 3-month storage at a temperature of 18 ±0.5°C influenced a_w of snacks produced from a mixture with a higher moisture content.

Key words: water activity, extrusion, stability, whey proteins, corn puffs

INTRODUCTION

Water contained in food determines the scope and rate of changes between its individual components. Hygroscopic properties of food are connected with the mechanism of water binding in a moist environment or the release of water in a dry medium. All these factors of variation are related with the concept of activity of water contained in the product. Water activity is a measure of its availability to biochemical and microbiological changes. The value of water activity in extruded products constitutes a significant indicator of their quality and stability [Marzec and Lewicki 2006].

Extrusion is a process, in which under the influence of such factors as heat, high pressure and shear forces, readily expandable moist raw materials are mixed, homogenized, condensed and plasticized in one apparatus called an extruder. The apparatus ends with a head, through which cooked mass is pushed and the obtained product receives unique properties. This technique is used to produce highly diverse products, including snacks [Gondek et al. 2006].

The state, in which water is found in extruded products, is an indicator of the conducted extrusion process and the used raw material. Corn grits are the

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most popular raw materials for the production of extrudates. Unfortunately, corn is a raw material of low nutritive value, thus it seems advisable to enrich such products with other ingredients, making it possible to enhance their nutritive or dietary value, and thanks to the above improve their attractiveness for consumers [Altan et al. 2008, Jhoe et al. 2009]. An alternative solution seems to be provided by an addition of whey proteins to corn grits, which may balance the amino acid composition of the product, and thus improve the biological value of proteins. At the same time, combining in a mixture different proteins with a varied water holding capacity may contribute to changes in the quality and stability of the extruded product.

The aim of the study was to assess water activity of extruded products obtained from mixtures with varied moisture contents based on corn grits and different shares of whey proteins.

MATERIAL AND METHODS

Composition

Raw material for analyses comprised puffs produced from corn grits combined with a whey protein preparation. Analyses were conducted on corn grits of 850-1250 μm particle size. The whey protein preparation was obtained from whey proteins left after the production of Dutch-type aging rennet cheeses, which was next subjected to membrane fractionation. Whey proteins were condensed 3-fold applying the nanofiltration process. The retentate, containing 18.64% solids, including 2.08% proteins, 13.98% lactose and 0.91% minerals, was next spray-dried. Moisture content of the preparation was 4.07%. The introduced whey protein preparation contained 10.57% total nitrogen, 2.06% fat and 6.44% minerals.

Corn grits and mixtures produced from this raw material at different proportions and with moisture contents of 12.5 and 15.0% were extruded in these experiments (Table 1). The mixture wetting process was performed 24 h before extrusion. Extrusion was performed in a S-54 single screw extruder by ZMCh Metalchem (Gliwice, Poland) at an L:D ratio of 12:1. The following process parameters were applied: temperature at individual zones of 135/175/135°C, screw rotations at 90 $rpm \cdot min^{-1}$ and nozzle diameter $Ø$ = 3.5 mm.

Produced puffs were stored for 3 months at 18 ±0.5°C in a container with high barrier properties in relation to water vapor. Six production cycles were applied and each measurement was taken in three replications.

Water activity

Water activity was measured using an AquaLab 4TE series apparatus by Decagon Devices Inc. (Pullman, USA), equipped with a thermostat measurement chamber using Peltier thermoelectric elements. Samples of v = 15 cm^3 were placed in a DE 501 measurement vessel by Decagon Devices Inc. (Pullman, USA) and tested at a temperature of 20°C [ISO 21807].

Statistical analysis

Statistical calculations were performed using a data analysis software system STATISTICA (version 9.1) by StatSoft, Inc. (2010).

Table 1. Composition of extruded mixtures with moisture contents of 12.5 and 15.0%

Moisture content 12.5%		Moisture content 15.0%	
corn grits, % d.m.	whey protein preparation, % d.m.	corn grits, % d.m.	whey protein preparation, % d.m.
100	0	100	0
99	1	99	1
98	2	98	2
97	3	97	3
95	5	95	5
90	10	90	10

RESULTS

Based on the conducted analyses it was stated that water activity (a_w) of produced corn puffs with an addition of whey proteins ranged from 0.2775 to 0.2140.

It was shown that with an increase in the wetting rate in the extruded mixture, irrespective of the proportions of corn grits and whey protein preparation, the value of a_w in the produced puffs was greater by over 2%, which corresponds to 0.0055 units of a_w (Fig. 1). However, the measured difference was not statistically significant ($p = 0.051$, Test-$t = -2.191$).

The lowest a_w values of puffs produced from a mixture with the highest wetting rate (15%) in the conducted experiment was 0.2219, while the highest was 0.2775. The observed range of a_w values in puffs resulted from the amount of introduced whey proteins (Fig. 2).

It was found that a 1% and a 2% share of the whey protein preparation in the mixture with corn grits did not cause statistically significant changes in a_w values of ready-to-eat puffs. Only a 3% share of whey protein preparation contributed to a significant reduction (by 8.7%) of a_w in puffs. The mean value of a_w in puffs with a 3% share of these proteins was 0.2401. The conducted statistical analysis showed that the greater share of whey proteins exceeding 3%, the lower the a_w value in produced puffs. A 10% addition of the whey protein preparation, applied in this experiment, contributed to a reduction of a_w in puffs by 16.6% in comparison to a_w of puffs produced with no addition of whey proteins. The mean a_w value of produced puffs was 0.2194. However, it needs to be stressed that an increase in the share of proteins from 5 to 10% in the puff formulation did not contribute to the formation of such considerable differences in a_w, as at an increase in their share from 3 to 5%. At the increase in the amount of added whey proteins from 3 to 5% the difference in a_w of produced puffs was 0.0140 units. In turn, at an increase in the amount of whey proteins from 5 to 10% the difference in a_w of puffs was 2 times smaller, amounting to only 0.0067 units. Such a trend was observed, irrespective of the wetting rate of the initial mixture and storage time of the product after extrusion.

The experiment showed no effect of storage time of puffs on their a_w only when they were produced from a mixture with a lower moisture content, i.e. 12.5% (Table 2).

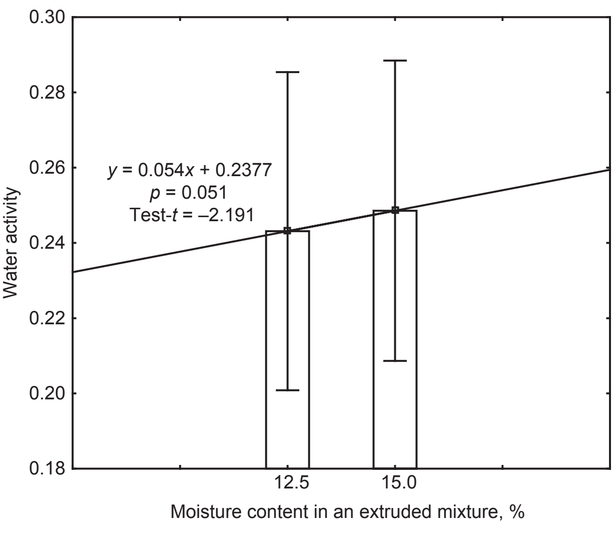

Fig. 1. Effect of moisture content in an extruded mixture of corn grits and whey protein preparation on a_w of produced puffs, irrespective of their storage time, $df = 6$

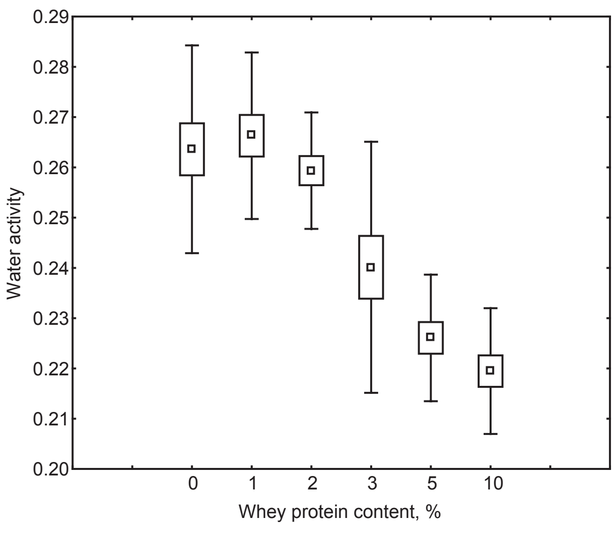

Fig. 2. Effect of the proportion of whey proteins in the extruded mixture on a_w of produced puffs, irrespective of their storage time, $df = 6$

Table 2. Effect of storage time on water activity of corn puffs with a share of whey proteins depending on the wetting rate of the extruded mixture, $p = 0.005$, $df = 5$

Raw material moisture content %	Storage time, month		Test-*t*	*p*
	0	3		
12.5	0.2488 ±0.0236	0.2374 ±0.0186	2.567	0.051
15.0	0.2529 ±0.0216	0.2442 ±0.0191	4.481	0.006

It was shown that a difference of 2.5% in the wetting rate of the initial raw material, such as a mixture of corn grits and whey protein preparation, caused significant differences in a_w of ready-to-eat puffs, but only after 3 months of their storage. Stored puffs produced from grits with a 15% wetting rate were characterized by a_w by 0.007 units greater than that of puffs produced from grits with a lower moisture content. Such differences were not detected when puffs were tested immediately after production ($p = 0.426$; Test-*t* –0.864).

With an increase in the wetting rate of the mixture subjected later to extrusion the a_w value of puffs depended significantly on their storage time. Puffs produced from a mixture with a 15% moisture content and stored for 3 months had a_w values ranging from 0.2219 to 0.2641 at mean a_w of 0.2442. They were significantly lower than those measured directly after puff production.

DISCUSSION

Elimination of the water phase from the product during extrusion provided the product with different mechanical and biochemical characteristics, but also with marked changes in stability [Harris and Peleg 1996, Chaunier et al. 2005]. The technological process based on the action of high temperatures contributes to a reduction of microbial counts, protein denaturation and a loss of the capacity for selective permeability of microbial cell walls. High temperature causes vibrations in water molecules, leading to the destruction of hydrogen and disulfide bonds in the spatial structure of proteins in microbial cells. The lower the water content in the processed raw material (such as corn grits or whey protein preparation), the slower the process.

It may be assumed that during extrusion microbial cells are destroyed not only by the influence of high temperature, but also as a result of intensive friction forces and a rapid reduction of pressure, after the protein mass leaves the outlet nozzle of the extruder [Fichtali and Voort 1995]. Experiments conducted by Baca et al. [1995] showed that in the extrusion process of acid casein the microbial counts dropped from 1.1 million to 320 cfu·g^{-1}. A study by Queguiner et al. [1989] showed that extrusion may be applied to reduce the counts of *Streptococcus thermophilus* in the concentrate of whey proteins obtained using ultrafiltration. Extrusion run at 133°C caused a drop in the counts of *Streptococcus thermophilus* from $1 \cdot 10^5$ to approx. 10 cfu·g^{-1}.

The low and constant water activity of extruded products contributes to a limitation in the rate of chemical changes, mainly fat oxidation and non-enzymatic browning [Fitzpatrick et al. 2004]. It is assumed that the optimal range of water activity for products based on powdered milk is 0.11-0.23. This range results e.g. from the state of lactose contained in the whey protein preparation. It was shown that the metastable amorphous lactose crystallizes as a consequence of the action of the driving force, resulting from an increase in particle mobility in the visco-elastic state [Bronlund and Paterson 2004]. This phenomenon causes the release of water, dissolving newly formed crystals and leading to powder caking. This process is intensified at an elevated relative humidity during further storage [Jouppila et al. 1997]. Thus, not only technological procedures, but also further storage conditions may significantly alter quality attributes of the extruded product [Duizer 2001]. Water adsorbed by the material and found at a specific stage of interaction with the adsorbent influences food stability through changes in color, taste and aroma, as well as texture and acoustic properties [Scanlon and Zghal 2001, Castro-Prada et al. 2007].

CONCLUSIONS

1. The wetting rate (12.5 and 15.0%) of a mixture of corn grits and whey protein preparation does not have a statistically significant effect on a_w in produced puffs.

2. Introduction of whey proteins to the extruded mixture at min. 3% contributes to a significant reduction of a_w in the produced puffs. The greatest difference was found when introducing 3% proteins in comparison to a_w of puffs produced solely from corn grits, $\Delta a_w = 0.023$.

3. The greater the amount of whey proteins, the lower the a_w value, but the differences did not increase further. From the technological point of view a further introduction of whey proteins exceeding their 5% share in order to enhance puff stability needs to be seriously considered.

4. The effect of a 3-month storage of puffs at a temperature of 18 ±0.5°C in a packaging with high barrier properties in relation to water vapor was significant only at a higher initial moisture content of the extruded mixture.

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