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Forecasting the qualitative indices of albumin-vegetable mixtures during storage

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Mathematical models were received using the Rosenbrock's function to forecast the qualitative indices of albumin-vegetable mixtures with apple pectin fiber (APF). The APF consists of extruded wheat mill run (60 %) and apple powder (40 %). Dietary fiber concentrates with polyfunctional properties were used to create albumin-vegetable mixtures (AVM). The efficient use of resources and combined nutritive elements was taken into consideration. The optimal quantity of apple pectin fiber in albumin mass constitutes 4 to 6 %. This quantity was determined organoleptically. The received samples had a homogenous, plastic consistency with APF fractions. The taste and smell were characteristic of albumin mass with a slight flavor of apple pectin fiber.

Functional dependence of albumin-vegetable mixtures on their qualitative indices during storage was determined using the least squares method. The qualitative indices of polynomial regression equations of albumin-vegetable mixtures are adequate and correspond to the actual process. The equations are appropriate and correspond to the actual process.

The experimental and statistical modeling with the STATISTIKA program was used for mathematical description of the moisture retaining capacity, active acidity and changes in the moisture content of the albumin-vegetable mixtures. The controlling factors are albumin mass quantity and moisture content as well as APF: whey ratio. It was proved that 4.6 to 5.1 % APF content ensures minimum changes during storage.

Practical application of the obtained mathematical models is forecasting changes of the indices of albumin-vegetable mixtures with time. The study findings can be used for the manufacture of combined foods from vegetable components and by-products obtained during milk processing. It is a current trend in the dairy processing industry.

Keywords*:* albumin mass, apple pectin fiber, albumin-vegetable mixtures, experimental and statistical modeling method.

Introduction

Whey processing is a current trend. Combined foods are manufactured from milk processing by-products and vegetable components [1–3]. The efficient use of resources and combined nutritive elements are taken into consideration. It is necessary to use dietary fiber concentrates (DF) in maximum quantities compatible with dairy products to enrich and regulate the qualitative indices of dairy products [4]. There is a number of publications on the use of dietary fiber concentrates in dairy products [5–9]. No information regarding albumin mass mixtures with DF is available.

Albumin mass is received from whey protein consisting of lactalbumin (α i β), albumin, immunoglobulin, proteose-peptone, and β-lactoglobulin (50 %) fractions, including 162 amino acid residues, 2 intramolecular disulfide bonds, and 1 sulfhydryl (thiol) group of cysteine residue [10, 11]. The above mentioned whey protein components determine a high biological value of albumin mass. The mass can be used for developing products of both special and prophylactic purpose, making it possible to broaden the existing assortment of wholesome food [7, 8].

The addition of polyfunctional dietary fiber (DF) concentrates is necessary for regulating the qualitative indices of albumin mixtures used as the basis for manufacturing of dairy desserts.

In the gastrointestinal tract DF interact with proteins, ferments, hormones, carbohydrates breakdown products, peptides and amino acids, fatty acids, etc. The character of these transformations depends on the composition, structure, density of dietary fibers and correlation of amorphous and crystalline fiber parts [12–14].

New principles of dietary non-traditional (for dairy industry) use of fiber concentrates are implemented in albumin-vegetable mixtures (AVM).

Dietary fiber concentrates have polyfunctional properties.

Objective – elaboration of mathematical models for forecasting the qualitative indices of albumin-vegetable mixtures with dietary fiber concentrates during storage.

Materials and methods

Optimization criteria (controlled factors) such as moisture retaining capacity, active acidity and moisture content were chosen to achieve the objective. Based on a priori information (prior studies or literature data) zero levels of controlling factors are the best values. A variability interval was also established. The study was repeated three times.

Albumin mass (78 to 83 % moisture content, (95±5) °T titratable acidity) was produced in a laboratory setting by the thermal acid coagulation of cheese whey (pH 4.4–4.6). Conditions were as follows: duration (90±2) minutes, temperature (95±2) °C.

Apple pectin fiber (APF) (Technical Specification of Ukraine (TU U) 30335750.001-2000) was chosen as a dietary fiber concentrate. It consists of an extruded wheat bran (60 %) and apple powder (40 %). The APF chemical composition comprises moisture (6.0 %), sugars (48.7 %), organic acids (5.0 %); fiber (13.4 %), pectin substances (12.4 %) (including water-soluble – 5.1; non-water-soluble – 7.3), proteins (6.7 %), fats (6.8 %), and mineral substances (0.713 %) [15].

Owing to the organoleptic evaluation it was established that the optimal quantity of APF in albumin mass constitutes 4 to 6 %. The received samples had a homogenous, plastic consistency with APF fractions. The taste and smell were characteristic of albumin mass with a slight DF flavor. The addition of APF of less than 3 % is unreasonable and that of more than 6 % leads to deterioration of the organoleptic properties of the mixtures. The mixture (AVM) becomes coarse and heavy with a significant DF flavor. APF swelling (5-10 min) is required to adjust the moisture content in pasteurized (74±2°C), 15–20sec, whey (W) (pH – 5.3, dry matter – 6.5 %; lactose – 4.6 %; protein – 1.3 %; ash – 0.6 %).

The following qualitative indices were determined in AVM samples: the content of moisture, by complete desiccation (102±2) °C, active acidity (pH) and moisture retaining capacity (MRC), by determining moisture content which escaped AVM subjected to pressing and was absorbed by a filter paper.

The stages of preparatory and the main experimental studies are shown in Fig. 1.

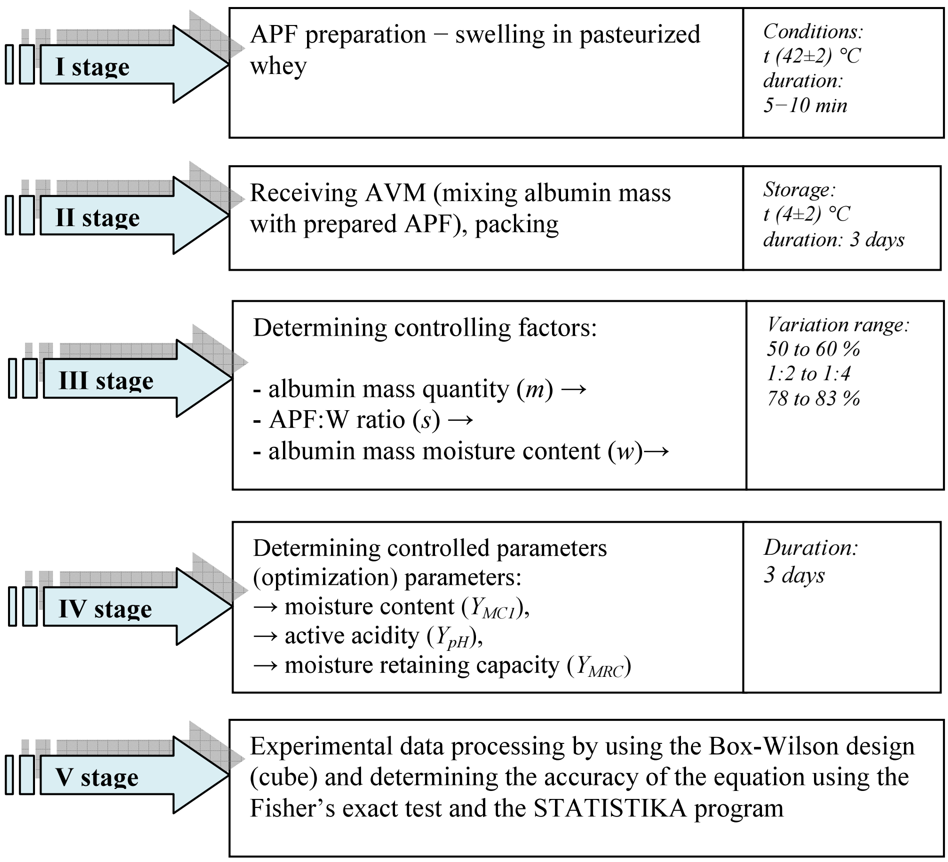

Fig. 1. Stages of experimental and statistical studies

The least square analysis was used to determine the functional dependence of albumin-vegetable mixtures on the qualitative indices [16].

Beta coefficient was calculated. The general form of the equation is as follows:

$$Y=b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_{12} \cdot x_1 \cdot x_2 + b_{23} \cdot x_2 \cdot x_3 + b_{13} \cdot x_1 \cdot x_3 + b_{123} \cdot x_1 \cdot x_2 \cdot x_3 \qquad (1)$$

The significance of the coefficients and the adequacy of the equation were determined by the Fisher's exact test.

Possible functions were considered, such as linear, degree, quadratic, exponential, hyperbolic and polynomial. Functional relationships were determined, which most accurately describe changes in the AVM qualitative indices. The correlation coefficients (R^2) of each function were calculated and the optimal ones were determined [17].

Results and discussion

The experimental data of the mathematical and statistical analysis was processed/carried out. The polynomial regression equations of the qualitative indices of albumin-vegetable mixtures were received:

- (a freshly made AVM) at the beginning of the storage

$$Y_{1(MC1)}=74.406+0.150x_1+1.350x_2+1.850x_3+0.438x_1x_2+0.313x_1x_3 \qquad (2)$$

$$Y_{2(pH1)}=4.982+0.006x_1+0.011x_2-0.011x_3 \qquad (3)$$

$$Y_{3(MRC1)}=55.035+6.064x_1+2.484x_2-5.355x_3-0.340x_1x_3-0.385x_2x_3+0.630x_3^2 \qquad (4)$$

- on the 3rd day of storage

$$Y_{1(MC2)}=64.381+1.090x_1+2.54x_2+3.01x_3-0.881x_1^2+0.869x_2^2+0.619x_3^2 \qquad (5)$$

$$Y_{2(pH2)}=4.645+0.01x_1+0.02x_2 \qquad (6)$$

$$Y_{3(MRC2)}=67.691-0.481x_1-2.217x_2-2.074x_3+0.54x_1x_2+0.338x_1x_3+0.74x_2x_3+0.489x_3^2 \qquad (7)$$

The received equations are adequate and correspond to the actual process, conforming to both the degree of separate factors and their interaction effects.

Additionally, mathematical models were received using the Rosenbrock's function. The mathematical models are empirical formulas for approximation of the experimental data:

- (a freshly made AVM) at the beginning of storage

$$Y_{1(MC1)} = 52.586 \cdot \frac{w^{0.1}}{m^{0.313} \cdot s^{0.059}}, \ R^2=0.9620\ \% \qquad (8)$$

$$Y_{2(pH1)} = 5.22 \cdot \frac{1}{w^{0.013} \cdot s^{0.018}}, \ R^2=0.95148\ \% \qquad (9)$$

$$Y_{3(MRC1)} = 53.027 \cdot \frac{w^{0.017} \cdot s^{0.04}}{m^{0.198}} \ R^2=0.96096\ \% \qquad (10)$$

- on the 3rd day:

$$Y_{1(MC2)} = 26.295 \cdot \frac{s^{0.04}}{m^{0.141} \cdot w^{1.899}}, \ R^2=0.9940\ \% \qquad (11)$$

$$Y_{2(pH2)} = 5.144 \cdot \frac{m^{0.002}}{w^{0.013} \cdot s^{0.002}}, \ R^2=0.975\ \% \qquad (12)$$

$$Y_{3(MRC2)} = 69.569 \cdot \frac{w^{0.178}}{m^{0.112} \cdot s^{0.043}}, \ R^2=0.95806\ \% \qquad (13)$$

Graphical interpretation of the changes in moisture retaining capacity of the albumin-vegetable mixtures during 3 days of storage, depending on the quantity (*m*) and moisture content of albumin (w) and APF:W ratio (s) is presented in Fig. 2.

According to the obtained regression equations (equations 2, 8) and mathematical models (equations 5, 11) it was established that the albumin mass moisture content has a greater influence on the changes of the AVM qualitative indices during storage than APF:W ratio. Maximum values of AVM moisture content can be achieved with 83 % albumin mass moisture content and 1:4 ratio. In absolute values it corresponds to 4.62 % of APF in AVM. It was proved, that with APF:W ratio change from 1:4 to 1:2, the quantity of free moisture in AVM decreases by 9.02 %. Such a positive effect allows to reduce the duration of self-pressing operation and to increase the output of albumin mass.

APF influence on the active acidity of AVM was established (equations 3, 9, 6, 12). The average value of this index first of all depends on the changes of pH. pH value (within (1.0±0.1) %) in albumin mass during storage, which doesn't exceed limit deviations of studies.

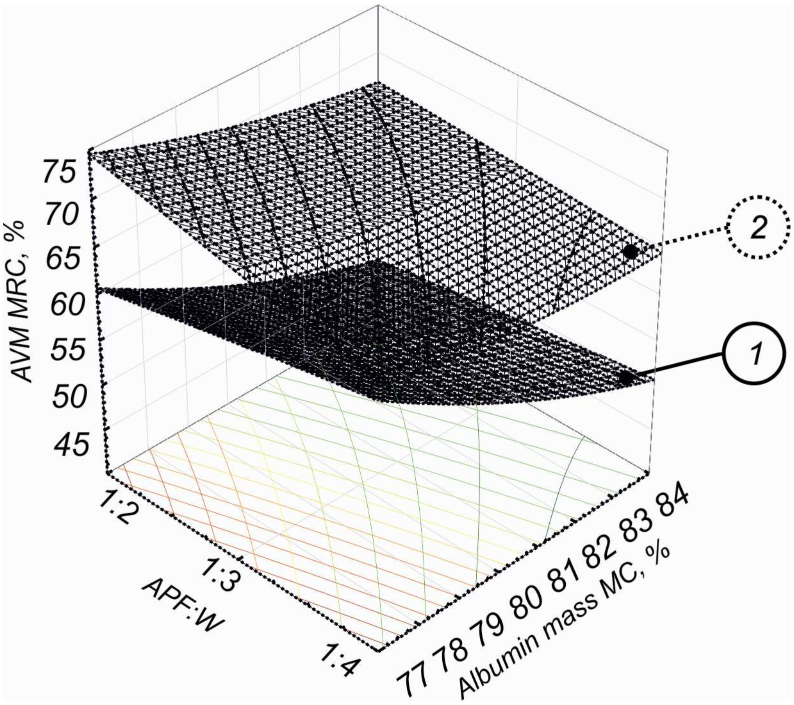

Fig. 2. Response surfaces of AVM changes in moisture retaining capacity: at the beginning (1) and on the third day of storage (2)

The analysis of the equations and mathematical models (4, 10, 7, 13) and change of the respond surfaces of the AVM moisture retaining capacity (Fig. 2) during the whole storage period shows that this index is in inverse proportion to the APF:W ratio. A decrease in the albumin mass moisture content and an increase in the APF:W ratio (1:4) favors the increase of moisture retaining capacity in the albumin-vegetable mixtures at the beginning of storage. An average increase by 1.25 times compared with the above mentioned samples is observed. It reaches peak values with the lowest possible moisture content (78 %) and the APF:W ratio (1:2), which corresponds to 5.08 % DF content in AVM. This can be probably explained by the APF multicomponent composition: complex biopolymers of linear and divergent structure with hydroxyl (cellulose, hemicellulose), phenolic (lignin), carboxyl groups (hemicellulose, pectin substances), which increase with time an intermolecular interaction (hydrogen bonds), the ability to sorb water and other polar molecules and ions, resulting in the increase of moisture retaining capacity.

Conclusion

According to the regression equations and mathematical models, the albumin mass moisture content has a greater influence on the changes in the AVM qualitative indices during storage than the APF:W ratio. It was proved that with the APF:W ratio change from 1:4 to 1:2, the quantity of free moisture in AVM decreases by 9.02 %.

The pH value in albumin-vegetable mixtures changes within (1.0±0.1) % during storage, which does not exceed limit deviations of studies. It was experimentally determined that the quantity of apple pectin fiber in albumin mass should constitute 4.6 to 5.1 %.

Elaborated mathematical models can be used for the development of a manufacturing technology for albumin mass based dairy desserts with dietary fibers.

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ALBUMINO-AUGALINIŲ MIŠINIŲ KOKYBĖS RODIKLIŲ PROGNOZAVIMAS LAIKYMO METU

Santrauka

Besisukančių koordinačių (Rozenbroko) metodu gauti matematiniai modeliai albumino mišinių su obuolių pektinu ląstelienoje (OPL) kokybės rodikliams prognozuoti. Į OPL įeina ekstruduotos kviečių sėlenos (60 %) ir obuolių milteliai (40 %). Albumino-augaliniams mišiniams (AAM) gauti buvo naudoti maistinių skaidulų koncentratai, turintys polifunkcionalių savybių. Atsižvelgta į išteklių taupymo ir maistinės kombinatorikos principus. Obuolių pektino ląstelienoje kiekis, maksimaliai suderintas su albumininiu pagrindu, yra 4−6 %. Optimalus įdėto į albumininę masę OPL kiekis nustatytas jusliniu būdu. Gautų mėginių konsistencija buvo vientisa, plastiška su OPL intarpais. Skonis ir kvapas − būdingi albuminui su vos juntamu obuolių pektino ląstelienoje prieskoniu.

Mažiausių kvadratų metodu buvo nustatytos albumino-augalinių mišinių kokybės rodiklių kitimo laikymo metu funkcinės priklausomybės. Regresinių rodiklių, apibūdinančių albumino- augalinius mišinius, polinominalinės lygtys yra adekvačios.

Siekiant matematiškai aprašyti albumino-augalinių mišinių drėgmės sugėrimo gebos, aktyviojo rūgštingumo ir drėgmės masės dalies pakitimus, taikytas eksperimentinio statistinio modeliavimo metodas ir programa STATISTIKA. Valdantieji veiksniai yra albumino masės kiekis ir drėgnis, komponentų OPL-PI santykis. Įrodyta, kad 4,6−5 % įdėto į mišinį OPL užtikrina mažiausius šio mišinio pokyčius laikymo metu.

Parengti matematiniai modeliai leidžia prognozuoti albumino-augalinių mišinių rodiklių kitimus laikymo metu. Gauti rezultatai taikytini kombinuotiems produktams iš antrinių pieno žaliavų ir augalinių ingredientų. Tai aktuali tema pieno perdirbimo pramonėje.

Raktažodžiai: albumino masė, obuolių pektinas ląstelienoje, albumino-augaliniai mišiniai, eksperimentinio statistinio modeliavimo metodas.