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Production Technology of Extrusive Poly-Cereal Food of High Degree of Readiness

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Abstract: As a result of the performed researches a method for manufacturing of a extruded poly-cereal product was developed which firstly, reduces irrational power consumptions, ensures food products expansion and improves nutritive quality by combining several types of coarse whole meals of grain crops; secondly, supports starch modification and gelatinization, lowers the ratio of unassimilable compounds and content of microorganisms in poly-cereal mixtures; thirdly, raises the degree of preparation of poly-cereal based food products which significantly improves marketable and organoleptical properties of the quality.

Key words: Poly-cereal mixtures, extrusion technology, blending, mixing, extrusion, coarse whole meal

INTRODUCTION

Lack of macro and micro-nutrients leads to reduction of nutritive and biological value of food products and thus to the depletion of adaptive capacities of an organism and onset of a wide range of alimentary diseases. Therefore, one of the key priorities of the modern food industry is to develop technologies and to expand a line of functional food products which decrease risks of developing chronic diseases and maintain health. Therefore, the most prospective area in solving the problem is to eliminate the lack of macro and micro-elements, i.e., enrich food products with natural biologically active substances which will enable correction of diet for a wider population.

Therefore, it appears to be appropriate to develop technologies for manufacturing of cereal-based products of high degree of preparation, i.e., new-generation cereal products with high concentration of the most important natural minerals and biological nutrients.

One of the methods to improve nutritive quality of food products is to manufacture a wide range of cereals as well as to compose poly-cereal mixtures with a balanced amino-acid, mineral and vitamin composition. It is also worth mentioning the necessity in application of new approaches in grain processing which will improve the degree of preparation of food products by using extrusion technologies of finished poly-cereal mixtures (Giles *et al*., 2005; Ospanov *et al*., 2013; Ostrikov *et al*., 2009).

We have performed experimental researches in order to determine optimal parameters for scheme of manufacturing of poly-cereal food products of high degree of preparation with further assessment of nutritional properties and marketable advantages of new food products.

The results given in study are received during performance of research works on subjects: "developing the technology of production of highly prepared products from domestic poly-cereal feedstock" (# the state registration 0112PK01528) and "development of technology of production of extruded poly-cereal convenience foods with fruit and berry as well as with meat and dairy filling" (# the state registration 0115PK00719) on grant financing of scientific researches of committee of science of the ministry of education and science of RK.

MATERIALS AND METHODS

As an object for the research we have determined two poly-cereal mixtures (Table 1-2), composed using

Table 1: Formula for "fitness" poly-cereal product of high degree of preparation

Components	Contents
Whole barley meal (%)	6.36
Whole corn meal (%)	42.75
Whole oat meal (%)	20.00
Whole buckwheat meal (%)	24.54
Whole millet meal (%)	6.35
Rated value of nutritive and biological value	
Content of proteins in the mixture (%)	14.28
Content of starch in the mixture (%)	62.32
Content of cellulose in the mixture (%)	7.46
Calorific content in the mixture (kcal)	318.87
Caloric value of the mixture (kJ)	1334.15

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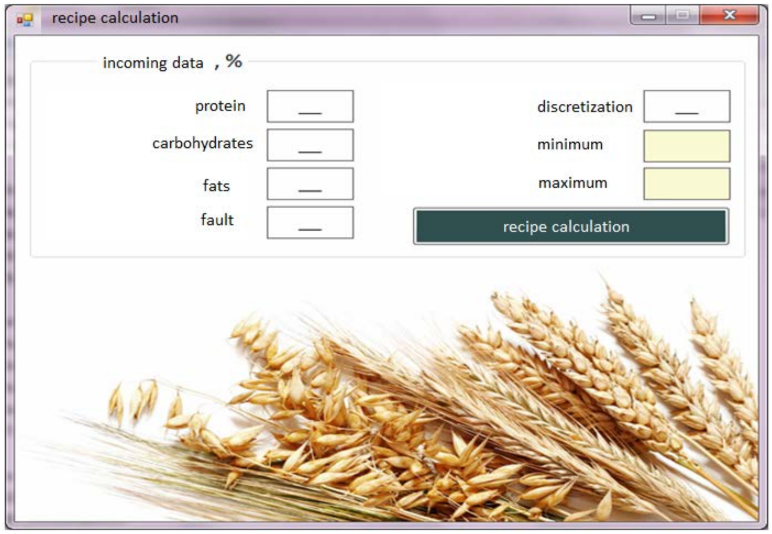

Fig. 1: Software windows-interface

Table 2: Formula for "Zdorovye" poly-cereal product of high degree of preparation

Components	Contents
Whole corn meal (%)	16.660
Whole oat meal (%)	26.200
Whole buckwheat meal (%)	50.000
Whole millet meal (%)	7.140
Rated value of nutritive and biological value	
Content of proteins in the mixture (%)	14.040
Content of starch in the mixture (%)	59.753
Content of cellulose in the mixture (%)	10.281
Caloric content of the mixture (kcal)	318.780
Caloric value of the mixture (kJ)	1333.770

the computer software "calculation of a formula for poly-cereal mixture for manufacturing of products of high degree of preparation" (Fig. 1) (Ospanov *et al*., 2014).

RESULTS AND DISCUSSION

Hereafter we studied processes of production of poly-cereal products of high degree of preparation. The major production processes which define quality and marketable advantages of products of high degree of preparation are process for refining of raw grain; process for mixing free-running components until a homogenous mixture is obtained; process for extruding poly-cereal mixture.

Experimental researches for defining optimal states for refining of grain of cereals were performed on the experimental disk mill LM-3600 type. Operational efficiency of the disk mill was assessed according to the following indications: specific power consumption and fineness of milled particles (Fig. 2) (Ospanov *et al*., 2014).

The analysis of the graph has shown that specific power consumption for milling depends solely on linear

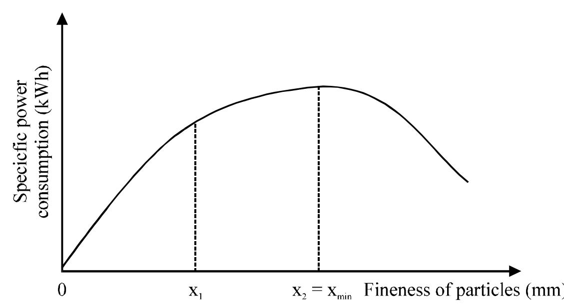

Fig. 2: Dependence of operational efficiency of mill unit

dimensions of milled products. Therefore, it appears the most appropriate to calculate specific power, depending on deviations in linear dimensions (x_1 and x_2) from their minimal (x_{min}) values.

At the same time, experience shows that unlimited increase in linear dimensions of milled products requires unrestricted increase in value of specific power consumption for milling up to $x_2 = x_{min}$.

Therefore, A.A. Ospanov upon some adjustments of Rittinger's and Kicks laws proposed a formula which expresses a rational dependence of specific power on x_1 and x_2 dimensions (Ospanov *et al*., 2014). Further, we studied mixing process and influence of mixing time (t) on caloric value of poly-cereal mixture at different rotation rates of the working member of the mixer.

We loaded different components of a poly-cereal mixture into the mixing container of the experimental plant and mixed them; each 10 sec we took samples to assess the caloric value of the result mixture. Based on experiment data we constructed a diagram of dependence of a caloric value of the poly-cereal flour mixture (C_v, kcal)

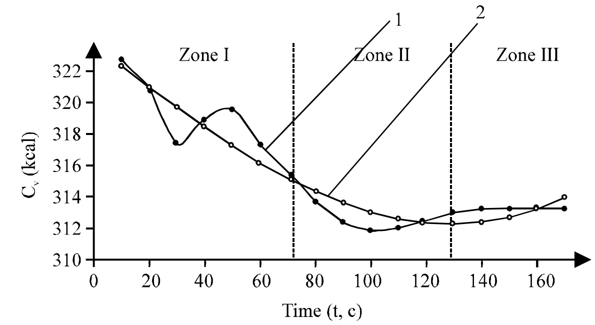

Fig. 3: Influence of mixing time on caloric value of poly-cereal mixture at the rate of rotation of the working member of the mixer 2800 $\min^{-1}$; 1: experimental data; 2: data, obtained by calculation (regression equation)

on mixing time (t, c) of free-running components at the rotation rate (2800 $\min^{-1}$) of the working member of the experimental mixer (Fig. 3). Optimization of the results achieved was performed using the method of least square approximation of experimental data of cubic functions.

Analysis of the resulted dependence shown in Fig. 3, demonstrates presence of three clear zones where mechanical process of mixing takes place. Zone I is a zone of shear mixing, resulting in random distribution of poly-cereal mixture particles, characterized by sharp decrease in values of C_v from 322.78-315.35 kcal at fixed time values t = 70 sec and the rate of rotation of the working member = 2800 $\min^{-1}$. Zone II is a zone of slow decrease in C_v values where C_v changed from 317.28-312.95 kcal at the values: t = 130 sec and n = 2800 $\min^{-1}$. Zone III is a zone where target values of caloric content of poly-cereal flour mixture are achieved and mixture segregation occurs. At the same time caloric value of the mixture made up 313.2 kcal per 100 g at the value of t = 140 sec.

Therefore, the rate of rotation of the working member n = 2800 $\min^{-1}$ at t = 140 sec shall be considered as an optimal mixing time for a poly-cereal mixture; further increment of values for processing of poly-cereal flour mixture will lead to irrational electric power consumption.

Further, we studied a process of extrusion of the poly-cereal mixture in manufacturing of products of high degree of preparation. Experimental researches were performed on commercial extruder. We have studied dependence of power consumed by electric drive of the extruder (N, kW) on variable values of humidity of poly-cereal flour mixture and the rotation rate of the working member of the experimental plant (Fig. 4).

$$ECH = 323.73-0.1421t+1.34.10^{-4}t^2-2.13.10^{-6}t^3, R = 0.951$$

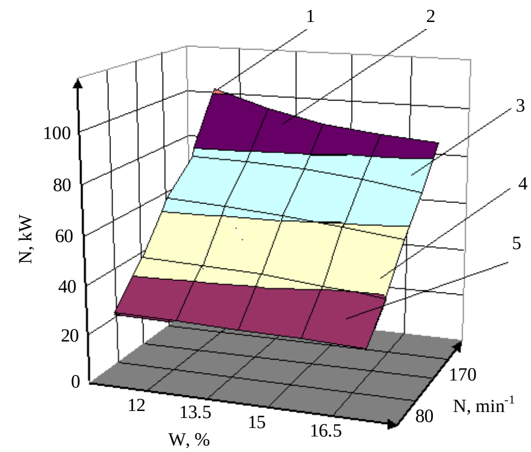

Fig. 4: Dependence of power consumption of the electric drive of the extruder (N, kW) on humidity (W, %) and the rotation rate of the working member (n, $\min^{-1}$)

Analysis of the behavior of the three-dimensional surface showed that increase in rotation rate of the working member (screw) n from 80-250 $\min^{-1}$ leads to increase in consumption of power by electric drive of the extruder (N, kW). At the same time humidity of the processed poly-cereal flour mixture reduces N values during the extrusion.

Thus, for instance, at 12% humidity of the poly-cereal flour mixture and the rotation rate of the screw = 80 $\min^{-1}$, the N value made up 29.5 kW. At W = 13.5% and n = 80 $\min^{-1}$, N value made up 29.0 kW. Increase in humidity up to 15% led to reduction in N down to 28.8 kW. Further, increase in humidity up to 18% at n = 80 $\min^{-1}$ reduced consumption of power by the electric drive of the device down to 27.0 kW. Sobtained when changing values of rotation rate of the working member from 120-250 $\min^{-1}$. At n = 120 $\min^{-1}$ and W = 12%, the consumption of power by the electric drive of the plant made up 45.5 kW. Increase in n value up to 170 $\min^{-1}$ resulted in increase of N values up to 64.5 kW. Further, increase in n values up to 250 $\min^{-1}$ led to increase in N up to 102 kW. Maximum power consumption of the electric drive made up 102.0 kW at the rotation rate of the working member n = 250 $\min^{-1}$ and 12% humidity of the processed material.

Obtained dependence of the power consumption by electric drive of the extruder (N, kW) on humidity (W, %) and the rotation rate of the working member (n, $\min^{-1}$) provides adequate accuracy for disclosure of extrusion process in the investigated ranges of factor values which have impact on efficiency of technological process

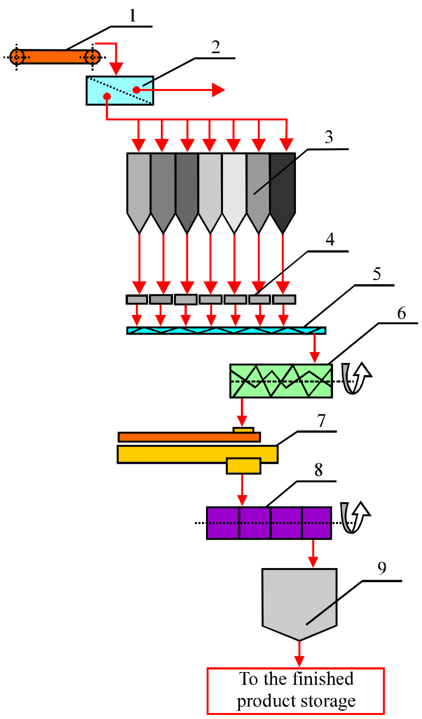

Fig. 5: Method of production of extruded poly-cereal products

management. The data obtained were taken as a basis for process for manufacturing of products of high degree of preparation (Fig. 5).

The proposed scheme for manufacturing of poly-cereal products of high degree of preparation using the new method (Ospanov *et al*., 2013) comprises the following technological machines and equipment: transfer mechanisms 1, flour sieving machine 2, processing bins 3, dosing machines 4, chain (or screw) conveyor 5, mixer 6, extruder 7, cylinder dryer 8 and the bin for finished products 9.

Raw flour stock in accordance with science-based formula (Table 1) is supplied by conveying unit 1 to the flour sieving machine 2. In the course of sieving coarse impurities are removed (packed flour lumps and foreign particles). At the same time operation mode of the sieving machine shall maintain highest possible separation of coarse impurities (packed flour lumps) and exclude transfer of flour to the waste >1%. Woven-wire-cloth sieve plates with dimensions of 056 shall be installed in the sieving machines.

Woven-wire nets with square meshes shall be taken according to GOST 3826-66, GOST 12184-66 and GOST 3924-74. Presence of foreign particles in fine flour as well as metal foreign matter (traces) is not allowed.

Then, flour material is supplied to the processing bins 3 in order to accumulate raw stock on the processing line. Thereafter, an even flow of the free-running flour material according to the specified formula is forwarded to the automatic dosing machines 4. Chain (or screw) conveyor 5 supplies weighed portions of flour material to paddle-type mixer 6 in order to obtain homogenous poly-cereal mixture. Finished mixture is loaded into the food extruder 7. After the extruder the obtained granules are cooled in the cylinder dryer 8 under the steady operation which maintains temperature of emergent granules not exceeding the ambient temperature by 10°C.

After cooling the product is supplied to the bin for finished products 9, equipped with release slides and then to the finished product storage.

CONCLUSION

As a result of the performed researches a method for manufacturing of a extruded poly-cereal product was develope which:

- Reduces irrational power consumptions, ensures food products expansion and improves nutritive quality by combining several types of coarse whole meals of grain crops
- Supports starch modification and gelatinization, lowers the ratio of unassimilable compounds and content of microorganisms in poly-cereal mixtures
- Sraises the degree of preparation of poly-cereal based food products which significantly improves marketable and organoleptical properties of the quality

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