

Analysis and synthesis of the process of fondant formation in the production of sweets with fondant cases containing amaranth seed processing products

Svetlana Khasanova^{1*}, Zinaida Skobelskaya¹, and Murat Gins²

¹ AS Intersurgical, Moscow, Derbenevskaya emb., 11, of. 904, 115114, Russia

² RUDN University, Moscow. Miklucho-Maklaya str., 6, 117198, Russia

Abstract. Sweets with fondant cases make up a significant part of the assortment of sugary confectionery products produced in our country. The solution of "narrow" issues of technology is possible by changing the chemical composition of sweets due to the introduction of powder semi-finished products into the formulation. Amaranth meal powder is a product of meal processing - sanitary and benign waste in the production of seed oil, which is formed in significant quantities. To introduce a new component into the lipstick formulation, the meal was thermally treated in the IR spectrum and ground to a powder with an average particle size of no more than 20-25 microns with a dispersion of at least 92%. Specially prepared amaranth meal powder, having a high specific surface area, causes instant supersaturation in the syrup and a reduction in the latent period of sucrose crystallization, which in turn leads to rapid structure formation and compression of the technological flow in time. Embedding in the technological flow of the stages of preparation of amaranth meal powder and introduction into syrup involves an advanced processor approach to management. The processor approach in flow management should ensure not only a high-quality exchange of information between subsystems, but also eliminate the isolation of all sections and components of the technological line. An important part of process management and their improvement is the calculation of the integrity of the flow through the experimental determination of the stability of individual subsystems. The purpose of this work was to evaluate the effect of a new component of the formulation of amaranth meal powder on: the leading process of the flow - fondant formation; the integrity of the technological flow.

1 Introduction

An important theoretical and practical task in the intensification of the production of sweets with fondant cases is to control the process of crystallization of sucrose. Crystallization ultimately determines the appearance, shape, consistency, taste of sweets, the growth rate of sucrose crystals and the stability of all other processes occurring during storage [1-10].

* Corresponding author: sh@intersurgicalrus.ru

Fondant candies are systems in which sucrose is in two aggregate states, liquid and solid. In the finished lipstick, the processes of sucrose phase transition from a liquid state to a solid state, the migration of moisture from the candy shells into the environment, the change in the degree of supersaturation continuously occur. These processes are both the driving force behind the formation of quality and the very concept of "lipstick", and determine the rate of loss of consumer properties of products based on lipstick. That is why the management of the processes of preserving the high consumer properties of sweets remains the subject of research by many scientists. A deep and comprehensive study of aspects of theory and practice in improving technological systems for the production of fondant is contained in the works of representatives of various scientific schools of the Russian Federation: Moscow — G. A. Marshalkin, L. N. Aksenova, Z. G. Skobelskaya, N. V. Karusheva; Voronezh — A.V. Zubchenko, G. O. Magomedov, A. Ya. Oleinikov; Tambov — E. I. Muratova, P. M. Smolikhina. The work of scientists makes it possible to better understand the issues considered in this article and to isolate one of the most promising methodologies for optimizing and intensifying the technology of sweets with fondant cases - changing the chemical composition by introducing seed components into the formulation, allowing for rapid mass crystallization of sucrose in the entire volume of syrup or plant-based moisture-retaining components that cause instant supersaturation. The use of specially prepared amaranth meal powder in candy technology can combine both of these properties. The production of oil from amaranth seeds accumulates significant amounts of sanitary and benign waste - meal. Amaranth meal has a rich chemical composition and the use of modern approaches to its modernization with the use of infrared and photocatalytic technologies will both rationally solve the issues of stabilization of physico-chemical processes in the production and storage of sweets with fondant cases, and expand the raw material base of the food industry within the framework of the closed cycle concept [10,11,12]. The aim of the work was to identify the patterns of influence of a new component of lipstick amaranth meal powder on the crystallization processes; analysis of the center of the technological flow – the subsystem of fondant formation, in which the most complex processes are carried out, and which is most sensitive to external factors of influence; assessment of the stability of the developed technology; determination of the expediency and validity of the use of amaranth meal powder in the production of sweets. The work was performed at the Moscow State University of Food Production and the Peoples' Friendship University of Russia.

2 Materials and methods

The research was carried out at the Moscow State University of Food Production and the Peoples' Friendship University of Russia. The objects of the study were: the product of processing amaranth seeds – sanitary and benign meal, amaranth meal powder and sweets with fondant cases of various chemical composition, prepared according to traditional recipes and with powder.

Amaranth meal was subjected to IR treatment, crushed to a given fraction and introduced into the formulation of sugar, fruit, milk lipstick, replacing an equivalent amount of sucrose.

Morphological and granulometric analysis of amaranth meal and powder was carried out on the device GIU-1 (granulometric measuring device). The granulometer consists of a microscope with a built-in video camera; a personal computer connected to a video camera; a power source. Amaranth meal powder was sprayed with a thin layer on a slide and installed in the socket of a mobile microscope table. The video camera transmitted the image of the test sample to the screen of a personal computer. To reduce the error, at least 15,000 particles of amaranth meal powder were examined. In the program, the experimental data "Particle size distribution (as a percentage of the number of particles)" and "Particle size distribution (as a percentage of volume)" were isolated and copied, transferred to the table. Using a

special program, the average particle size was determined. To do this, the number of particles in each fraction was first calculated using the formula:

$$n = \% \text{ of the total number of particles} * N / 100\%, \quad (1)$$

where n is the number of particles in each fraction, pcs.; N is the number of analyzed particles, pcs

Then the volume of each fraction was found by the formula:

$$V = n * 1/6 * \pi * d^2, \quad (2)$$

where V is the volume of the fraction, mm³; π is the number of pi; d is the average diameter of the particles.

The candies were stored at a temperature of 18 ± 2 °C, relative humidity of $70 \pm 2\%$.

The granulometric composition of the lipstick is carried out by electronic microscop with subsequent processing of the results using the program "Granulometer-1". It should be noted that this method of studying the granulometric and morphological properties of food raw materials has not lost its relevance to this day.

Morphological analysis of lipstick was carried out by electron scanning microscopy on the equipment of SEM LEO-1430 VP, Carl Zeiss, Germany with a four-square electron backscattering detector with accelerating ultrahigh voltage. The choice of the method is due to the depth of field ten orders of magnitude higher than a light microscope; high resolution; relatively low preparation costs, easy interpretation of three-dimensional data.

The methodology for constructing an operator model and analyzing the stability of the lipstick subsystem is based on the provisions of the "Theory of technological flow" and the scientific direction "Systemology of food and processing Industries", founded by Academician of the Russian Academy of Sciences, Doctor of Technical Sciences, Professor. Panfilov.

3 Results and discussion

Amaranth meal was processed at the UTZ-4 grain raw material heat treatment plant in the short-wave infrared spectrum. The method of heat treatment provided uniform heating of raw materials and controlled change of its technological characteristics. IR-processing of amaranth meal made it possible to achieve sufficient fragility of the part for further processing into a powdered semi-finished product. Fractions of amaranth powder with a given particle size of 20-25 microns were obtained by grinding heat-treated meal on impact-pin mills (disintegrator plants). After heat treatment, the meal particles become brittle and are crushed to the required size without much effort. The meal was crushed on impact-pin disintegrators MAP-800 to a given dispersion. Prepared amaranth meal was injected into boiled sugar-treacle syrup. The operator model of the technological flow of the production of sweets with fondant cases containing amaranth meal powder has a hierarchical structure, where subsystems consist of two or more technological operations. Secondary steam, waste and intermediate products are discharged outside the system for storage (Figure 1).

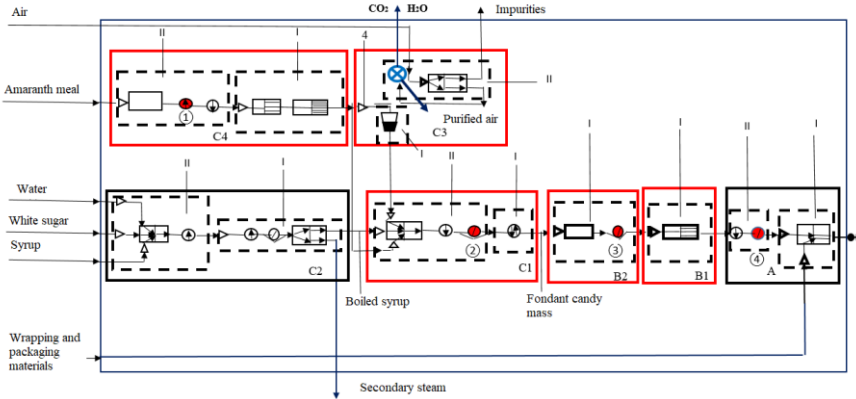


Fig. 1. Operator model of the technological system for the production of sweets with fondant cases containing amaranth meal powder

This operator model makes it possible to evaluate the system as an integral structure with the sequential allocation of each element, to reveal the interaction of parts (elements) and solve the problems of ensuring the functioning of systems, where A is a subsystem of product formation with quality indicators corresponding to the standard, containing the operators: I wrapping and packaging of sweets, II the formation of candy cases; B1 is a subsystem formation of candies in the form of individual objects with specified quality indicators, containing the operators: I molding of candy cases; B2 is a subsystem for the formation of a layer of fondant candy mass, containing the operators: I smearing candy mass into the formation; C1 is a subsystem for the formation of fondant candy mass with specified quality indicators, containing the operators: I obtaining lipstick, II fondant formation; C2 is a subsystem for the formation of syrup with specified quality indicators, containing the operators: I obtaining boiled syrup, II preparation of a prescription mixture; C3 – storage subsystem of amaranth meal powder, containing operators: I mechanical and photocatalytic air purification, II storage of amaranth meal powder; C4 is a subsystem for the formation of amaranth meal powder, containing the following operators: I formation of amaranth meal powder with a given granulometric composition, II IR processing of amaranth meal. Formation of: ④ – appearance, ③ – structure, ② – taste, ① – aroma.

The calculation of the stability of individual subsystems of the technological flow after the introduction of amaranth meal powder of the technological flow is presented in Table 1, where P1, P2 are probabilistic measures; H is the information entropy characterizing the degree of randomness of the system and corresponding to this distribution of the values of the quality indicator of the intermediate product or product; n is the stability of the binary (i.e., a subsystem with two possible states process by a parameter that is significant for the state of the subsequent subsystem) of the subsystem of the technological system [13,14]. In the production of sweets with fondant cases, all technological systems are binary, i.e. when it is possible to produce only suitable or unusable products. In calculating the stability of the system, four subsystems were considered together: C1 - a subsystem for the formation of a fondant candy mass with specified quality indicators, containing operators; B2 - a subsystem for the formation of a layer of fondant candy mass; B1 - a subsystem for the formation of sweets in the form of individual items with specified quality indicators; A - a subsystem for the formation of a product with quality indicators corresponding to the standard. I.e. for the analysis, systems were selected that are affected by the introduction of a new prescription

component – amaranth meal powder. All subsystems selected for analysis are statistically dependent on each other. All subsystems selected for analysis are statistically dependent on each other. The integrity level of the system of five statistically dependent systems for experimental lipstick with amaranth meal powder is calculated by the formula:

$$\Theta C3C1BA = \eta C3 + \eta C1 + \eta B/C3C1 + \eta A/BC3C1 - 3 \tag{3}$$

where Θ is the entropy of the C3C1B system, η is the stability of the subsystem.

For the control group, where there is no subsystem for the introduction of amaranth meal powder:

$$\Theta CBA = \eta C + \eta B/C + \eta A/CB - 2 \tag{4}$$

The level of integrity of all the considered subsystems was determined experimentally when an intermediate product was obtained within a minute, an hour, a shift: for the experimental group (candies with fondant cases. Containing amaranth meal powder): Θ min = 1.0; Θ hour = 0.85; Θ shift=0.95. For the control group (candies with fondant cases prepared according to the traditional recipe), the level of subsystem integrity: Θ min = 1.0; Θ hour = 0.87; Θ shift=0.90.

Table 1. Stability of individual subsystems of the technological flow of candy production with fondant cases (control)

Subsystem	Period of work	Sample size	Number of samples and products		P1	P2	-P1log2P1	-P2log2P2	H	η
			valid	invalid						
C	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		99	1	0.990	0.010	0.014	0.066	0.080	0.920
	shift		98	2	0.980	0.020	0.028	0.110	0.140	0.860
B	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		98	2	0.980	0.020	0.028	0.110	0.140	0.860
	shift		97	3	0.970	0.030	0.043	0.150	0.190	0.810
A	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		97	1	0.970	0.030	0.043	0.150	0.190	0.810
	shift		96	2	0.960	0.040	0.058	0.180	0.240	0.760

Table 2. Stability of individual subsystems of the technological flow of candy production with fondant cases containing amaranth meal powder (experiment)

Subsystem	Period of work	Sample size	Number of samples and products		P1	P2	-P1log2P1	-P2log2P2	H	η
			valid	invalid						
C3	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		100	0	1.0	0	0	0	0	1.0
	shift		99	1	0.990	0.010	0.014	0.066	0.080	0.920
C1	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		100	0	1.0	0	0	0	0	1.0
	shift		99	1	0.990	0.010	0.014	0.066	0.080	0.920
B	minute	100	100	0	1.0	0	0	0	0	1.0
	hour		99	1	0.990	0.010	0.014	0.066	0.080	0.920
	shift		98	2	0.980	0.020	0.028	0.110	0.140	0.860
A	minute	70	100	0	1.0	0	0	0	0	1.0
	hour		98	1	0.980	0.020	0.028	0.110	0.140	0.860
	shift		98	2	0.980	0.020	0.028	0.110	0.140	0.860

The obtained data on the diagnostics of individual subsystems of technological flows of the control and experimental groups indicate that the introduction of amaranth meal powder into the formulation of sweets with fondant cases did not reduce the level of integrity of the system and its stability is assessed as high. On the model of the technological system

development process (Figure 2), where the average stability of subsystems η_i is postponed along the abscissa axis, the number of outputs of systems L is on the ordinate axis, with respect to equidistant curves, the control model area is marked in red, lies right on the border of the regions of highly organized systems (shaded) and summative with tolerances for the parameters of the output of subsystems and beyond the diagnostic period of the system per shift [15].

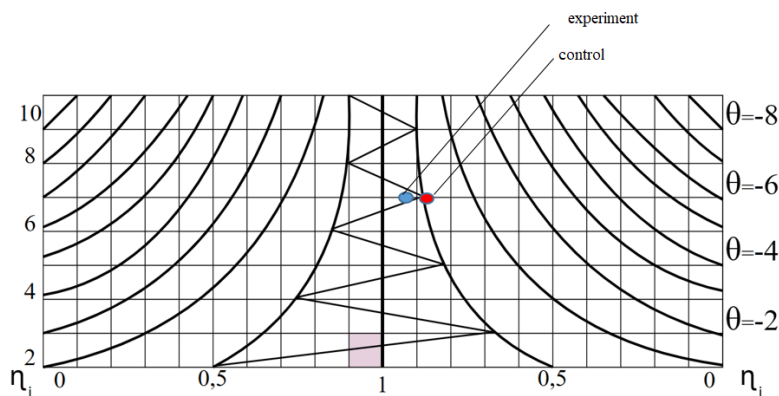


Fig. 2. Diagram of the process of development of the technological system for the production of sweets with fondant cases

The field of the experimental model lies within highly organized systems, although it is not yet close enough to the spiral of technology development that is degenerating into a straight line.

4 Conclusion

The research carried out is aimed at studying the technological flow of the production of sweets with fondant cases containing amaranth meal powder. The study of the technological flow requires not only system analysis, but also system synthesis. This is expressed in the development of end-to-end subsystems of the technological flow that affect the self-organization of the entire system. The technological flow of the production of sweets with fondant cases has all the signs of a stable, sufficiently organized system. The introduction of amaranth meal powder into the technological flow requires the creation of a new subsystem and complication of the process at the initial stage. However, in the future we observe a simplification of the functioning of the object of study. The results of the study suggest that a real technological system has prerequisites for evolution into a deserted technological stream.

References

1. Skobelskaya Z.G. Technology of sugar confectionery production : a textbook for SPO / Z.G. Skobelskaya, G.N. Goryacheva.– St. Petersburg: Lan, 2023. – 423 s
2. Klimovtseva Z.G. Investigation of the production process of crystalline iris : dis. ... Candidate of Technical Sciences: 05.18.01 / Klimovtseva Zinaida Grigorievna. – M., 1972. – 250 p.
3. Marshalkin G.A. Technology of confectionery products / G.A. Marshalkin – M.: Food industry, 1978. – 447 p.

4. Hartel RW, Joachim H, Hofberger R (2017) Confectionery science and technology. Berlin: Springer; 2017.
5. Skobelskaya Z.G. Modification of the properties of amaranth meal for the confectionery industry / A.Y. Lebezova, S.D. Khasanova, Z.G. Skobelskaya // in the book: Development of the food and processing industry of Russia: personnel and science – Moscow: 2017 - pp. 27-31
6. Kochetkova A. Specialized hypocholesterolemic foods: ingredients, technology, effects / V. Vorobyeva, I. Vorobyeva, A. Kochetkova, V. Mazo, S. Zorin, K. Sharafetdinov // Foods and Raw Materials – 2020. - № 1. - C. 20-29.
7. Bakumenko O.E. Technology of fortified foods for target groups. Scientific foundations and technology : monograph / O.E. Bakumenko. – Moscow : Delhi Plus, 2013. – 287 p.
8. Alekseenko E.V. Possibilities of using sublimated vegetable powders in the production of grain extruded products / O.E. Bakumenko, E.V. Alekseenko // Storage and processing of agricultural raw materials. – 2019. – No. 1. – pp. 116-129.
9. Krasina I.B. The use of amaranth seed processing products in the production of fondant candies / I.B. Berestova, Yu.F. Roslyakov, N.A. Shmalko, V.V. Mozgovaya V.V., T.V. Miroshnichenko // News of Universities. Food technology. - 2006. – No. 2. – pp. 62-64.
10. Kirdyashkin V.V. Influence of high-temperature IR radiation on the content of oligosaccharides of bean seeds / A.A. Andreeva, D.S. Bakhtina, V.V. Kirdyashkin, R.H. Kandrov // Bread products. - 2020. - No. 11. - pp. 42-44.
11. Skvirya M.A. Herbal supplements in the production of fondant sweets / M.A. Skvirya, I.B. Krasina, A.V. Temnikov // Mater. VIII scientific and practical conference with international participation "Modern problems of technology and technology of food production". – Barnaul, 2006. – pp. 13-16
12. Shmalko N.A. Influence of amaranth seed processing products on the quality of fondant candies / N.A. Shmalko, I.B. Krasina, Yu.F. Roslyakov, V.V. Mozgovaya, T.V. Miroshnichenko // News of universities. Food technology. - 2008. – No. 1. – pp. 32-34.
13. Panfilov V.A. Theory of technological flow: textbook / V.A. Panfilov. - 3rd ed., stereotype. – M.: INFRA-M, 2019. – 320 p.
14. Maitakov, A. L. Synergetics of technologies for the production of multicomponent products / A. L. Maitakov, A.M. Popov / News of higher educational institutions. Food technology. – 2018. – Vol. 362-363, No. 2-3. – pp. 112-116.
15. V.A. Panfilov Synergetic approach to the creation of agro-industrial complex technologies of the future. Equipment and technology of food production. 2020. No. 4, T50, pp. 642-649. <https://doi.org/10.21603/2074-9414-2020-4-642-649>