OPTIMIZATION OF THE COMPOSITION OF FILLINGS WITH HEAT-STABLE PROPERTIES

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Summary: The studies belong to a food industry and apply for the determination of composition, parameters quantitative and functional technological of the composition for the heat-stable fillings, which are used in fabrication of bakery and confectionery products. Criterion of heat-stability will be represented by BI (bakery index), which should be in interval 90-100 units for the heat-stable fillings, 80-90 units for the fillings with average heat-stability and under 80 units for heat-unstable fillings. Food fibers like a pectin, starch, gums and other may give heat-stable properties to fillings.

Key words: fruit filling, heat-stable, gellan gum, starch

It is known a composition of filling heat-stable which included raw materials from fruits and vegetables, sugar, starch, gellan gum and citric acid [1]. Difficulty of this invention there is impossibility in determination the optimal amounts of the ingredients introduced and necessity to establish these amounts by numerous experimental pulping. Missing of a theoretical version to establish the optimal amounts of raw materials for the production of fillings heat-stable can lead to economical losses of the producer due to the excess of the number of stabilizing introduced, as well as the deterioration of the quality of the final product.

The objective of the invention consists in the possibility of choosing the optimal quantity of ingredients stipulated in recipe for heat-stable fillings to the achieve the heat-stable and rheological properties necessary to obtain the finished product of high quality.

Utilization of mathematical models will solve two problems: first of all, from the wide range of raw materials to determine the optimal quantities of stabilizers for proposed heat-stable fillings, as well as to check the possibility of obtaining heat-stable filling for concrete values of stabilizers.

The heat-stable filling can be used in the baking process at high temperatures in the products of bakery and confectionery closed, as well as in the open products.

Through to the mathematical models developed, it will be possible to select the mass fraction of the required dry substance of the filling ready for the use, to choose the optimal quantity of stabilizers in the predeterminated range, ensuring heat-stable, rheological characteristics and high quality of the finished product.

Creation of the heat-stable filling in the wide range of dry substances with predetermined properties according to the invention provides establishing of the composition according to the optimal quantity of ingredients introduced. Not only the quality of the finished product will be controlled, taking into account the rheological parameters of the filling, but also will be supervising all technological processes of the produce of the fillings with the desired qualities.

The proposed objective is solved by using mathematical models applied to optimize composition of heat-stable fillings containing raw materials like a fruits, berries or vegetables, sugar, starch, gellan gum and citric acid.

For the elaboration of the technology of heat-stable fillings of fruits, berries and vegetables was used the planned experiment 2^3 [2]. The realization of this experiment allowed to obtain mathematical models with the presentation of the variables in natural values, for the search for the optimal solution that would ensure minimal material expenses for the production of heat-stable fillings.

The initial matrix of the mathematical form of the connection between the response functions Y (BI - the bakery index, V - viscosity) and the inputs investigated X (SU - dry substance content, G - gellan gum content and A – starch content) is given by the following formula:

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i \neq j} b_{ij} x_i x_j + \sum_{i=1}^{k} b_{ii} x_i^2 + \ldots.. \qquad (1),$$

where:
Y – response function;
x_i – inputs investigated;
b_0, b_i, b_{ij} – coefficients of the equation.

For the determination of the possibility of selecting the optimized filling composition with established properties are investigated the following response functions - the heat-stable and the viscosity of the filling as response functions that depend on three input factors: the dry substance content of filling, the starch content and gellan gum content introduced into the filling composition:

$$BI = f\ (A, G, SU);$$
$$V = f\ (G, A, SU).$$

Based on the planned experiment on developing the technology of heat-stable fillings from fruits, berries and vegetables, in order to search for the optimal solution that would ensure minimal material consumption, adequate regression models with 5% significance were obtained, subsequently transformed into interpolation formulas with the presentation of the variables in natural values, which are presented by the following mathematical formulas 2 and 3:

$$BI = 59,65 - 4,76 \cdot A - 85,26 \cdot G + 0,33 \cdot SU + 49,19 \cdot A \cdot G + 0,12 \cdot A \cdot SU + 0,22 \cdot G \cdot SU - 0,82 \cdot A^2 \cdot G \cdot SU + 290,87 \cdot G^2 - 189,69 \cdot G^3 - 0,0087 \cdot SU^2 \qquad (2)$$

$$V = -86,43 - 39,5 \cdot A + 774,62 \cdot G + 1,40 \cdot SU + 422,96 \cdot A \cdot G + 0,65 \cdot A \cdot SU - 8,26 \cdot G \cdot SU - 6,96 \cdot A \cdot G \cdot SU \qquad (3)$$

where
BI – bakery index, units;
G – gellan gum content, kg, in the interval 0,1…1,0;
A – starch content, kg, in the interval 0,5…1,0;
SU – dry substance content, %, in the interval 30...65;
V – dinamic viscosity of filling, Pa·s (at shear speed s^{-1}).

At the following ratio per 100 kg of finished product,% by weight: raw material of fruits, berries or vegetables from 45.0 to 50.0; sugar from 20.2 to 57.1; starch from 0.5 to 1.0; gellan gum from 0.1 to 1.0 and citric acid from 0.1 to 0.3.

In the filling proposed like an agglutinant, gelling and stabilizing agent are used gelan gum (E 418) and starches (E1400-E1405, E1411-E1414) which are approved for use in the world and native practices for production of food, including jams, jellies, fillings, etc.

The recipe of the composition allows to create heat-stable fillings over a wide range of soluble dry substances - from 30% to 65%.

The developed mathematical model allows to determine the mass fractions of the components, which ensure their established value in the recipe for the production of heat-stable fillings, as well as determination the heat-stable of the fillings knowing values of the initial components of the recipe in the proposed ranges.

Additionally, the fillings may also contain ascorbic acid, which will allow to raise the nutritional value of the finished product.

The result of the invention is the creation of a mechanism for optimizing the composition of fillings with guaranteed heat-stable properties due to the mathematical models elaborated on the calculation of the bakery index, taking into account the interactions of the ingredients as well as the dynamic viscosity of the finished product. Mathematical models have a graphical interface of user that allows the initial data to be entered within the declared range to obtain the optimal result.

The criterion of heat-stable is the BI index, which is determined by known methods which involve measuring the increase in relative dimensions of the filling sample after baking in open form on a dough or dense filter paper.

Knowing the value of viscosity is a very important thing for food industry specialists in solving technical tasks in the production of fillings and choosing the optimal variant of technological equipment.

The significance of the correlation coefficients of the developed models is verified according to the standard criterion t -Student. The adequancy of the models is confirmed by the criterion Fisher.

Table 1 presents the results of comparative determinations of the heat-stable of the fillings obtained experimental, as well as their values calculated according to the developed models BI = f (A, G, SU) in the wide range of technological parameters investigated.

Table 1 *Results of comparative determinations of heat-stable fillings*

Nr. exp.	Content		SU (dry substance), %	BI (bakery index), units		Deviation of the values calculated by the experimental ones	
	gellan gum, %	starch, %		calculated	experi-mentally	absolut error, units	relativ error, %
1.	0,67	0,3	30	90,59	90,60	0,01	0,01
2.	0,1	0,5	40	55,66	55,56	0,1	0,18
3.	0,1	1	40	55,68	55,56	0,12	0,22
4.	1	0,5	40	100	100	0	0
5.	1	1	40	100	100	0	0
6.	0,44	1	60	59,01	58,82	0,19	0,32
7.	0,9	0,5	65	89,46	89,66	0,20	0,22
8.	0,1	0,5	70	38,7	38,46	0,24	0,62
9.	0,1	1	70	38,67	38,46	0,21	0,54
10.	0,45	1	70	50,24	50	0,24	0,48
11.	0	1	70	43,76	43,48	0,28	0,64
12.	1	0,5	70	83,51	83,33	0,18	0,22
13.	1	1	70	66,87	66,67	0,2	0,3

The obtained data denotes a high degree of correlation of the experimental data with those calculated using the developed regression equation, which allows to establish the necessary quantities for the true range of the technological parameters regarding the production of fillings with guaranteed thermostable properties.

Table 2 presents the experimental and theoretical results regarding determination of viscosity of fillings V = *f* (G, A, SU) with heat-stable properties established in the wide range of technological parameters studied.

Table 2. *The experimental and theoretical results regarding determination of viscosity of fillings*

Nr. exp	Content gellan gum, %	Content starch, %	SU, %	Dinamic viscosity of filling, Pa·s (at shear speed s^{-1})		Error, %	
				experimental	calculated	absolut, units	relativ %
1.	1	1	40	545,0	544,9	0,15	0,02
2.	1	0,5	40	479,4	479,3	0,08	0,02
3.	0,1	1	40	15,3	15,0	0,35	1,96
4.	0,1	0,5	40	14,7	14,5	0,2	1,36
5.	1	1	70	150	149,8	0,2	0,12
6.	1	0,5	70	179	178,9	0,1	0,06
7.	0,1	1	70	31,4	30,8	0,6	1,91
8.	0,1	0,5	70	31,4	31,0	0,4	1,27

Absolute errors are in the range of 0.08 ... 0.6 units and the relative errors do not exceed 2%, but the higher the viscosity - the error margin of the results is less.

The results show the coincidence of the obtained values, which indicates the adequacy of the model received and the possibility of using it to optimize the composition of the fillings.

Examples for determining the composition and technological parameters of heat-stable fillings:

Example 1

Initial data: heat-stable apple filling with bakery index BI = 90 units, starch content A = 0.6% and content of dry substance SU = 30%.

It is necessary to determine the concentration of gellan gum G,%.

According with formula 2 we determine the content of gellan gum G,%:

when BI = 90 ⇨ G = 0.6%.

Respectively, when the starch content is 0.6% and the content of gellan gum 0.6% - the heat-stable of the filling with the mass fraction of dry substance 30% will be 90 units.

The viscosity of the prepared filling is determined according to formula 3:

$$V(G=0.6) = -86{,}43 - 39{,}5\cdot 0{,}6 + 774{,}62\cdot 0{,}6 + 1{,}40\cdot 30 + 422{,}96\cdot 0{,}6\cdot 0{,}6 + 0{,}65\cdot 0{,}6\cdot 30 - 8{,}26\cdot 0{,}6\cdot 30 - 6{,}96\cdot 0{,}6\cdot 0{,}6\cdot 30 = 336{,}8\ (Pa\cdot s).$$

Therefore, when the starch content is 0.6% and the content of gellan gum 0.6%, the viscosity of the filling with the content of dry substance 30% will be 337 Pa·s.

Example 2

Initial data: heat-stable apricot filling with bakery index BI = 90÷100 units, starch content A = 1.0% and content of dry substance SU = 40%.

It is necessary to determine the concentration of gellan gum G, %.

According with formula 2 we determine the content of gellan gum G, %:

- when BI = 90 ⇨ G = 0.64%.
- when BI = 100 ⇨ G = 0.80%.

Respectively, when the starch content is 1.0% and the content of gellan gum 0.64% - 0.80% the heat-stable of the filling with the content of dry substance 40% will be in interval 90...100 units.

The viscosity of the prepared filling is determined according to formula 3:

$V_{(SU\ 40\%)} = 332{,}9\ (Pa\cdot s)$.

$V_{(A=0{,}65)} = 427{,}1\ (Pa\cdot s)$.

Therefore, when the starch content is 1.0% and the content of gellan gum from 0.64% to 0.80%, the viscosity of the filling with the content of dry substance 40% will be in the limits 337...427 Pa·s.

Example 3

Initial data: heat-stable plum filling with content of dry substance SU = 65.0%, content of gellan gum G = 0,9 and starch content A = 0.5%

It is necessary to determine the heat-stable of filling by determining of bakery index BI.

According to formula 2 we determine the index BI: BI = 90

Respectively, when the content of gellan gum is 0.9% and the starch content of 0.5% - the filling with the content of dry substance 65.0% will have heat-stable properties.

The viscosity of the prepared filling is determined according to formula 3:

$V_{(A=0,5)} = 206,6\ (Pa \cdot s)$.

Therefore, when the content og gellan gum is 0.9% and the starch content will be 0.5% the viscosity of the filling with the content of dry substance 65% will be 207 Pa s.

The mathematical models obtained allow to quickly and accurately select the optimal option from a wide range of options to determine optimal values of the ingredients in the composition of fillings, which ensures the economy in fabrication of finished product with declared established properties.

The developed methodology of determination the optimal composition of heat-stable fillings received a patent - MD 821 Z 2015.05.31. The authors of the patent were awarded with a Diploma and the Gold Medal in recognition of high scientific contribution and loyalty to the XXII –th International Salon of Research, Innovation and Technological Transfer INVENTICA 2018, Iasi, Romania, 27-29 June 2018

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