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DEVELOPMENT OF HEAT-STABLE FRUIT FILLINGS USING GELLAN GUM AS STABILIZER

Janna CROPOTOVA, Svetlana POPEL, Lidia PARSHAKOVA

Practical Scientific Institute of Horticulture and Food Technology, 59 Vierul 59, MD 2070, Chisinau, Republic of Moldova

Corresponding author email: janna_cr@mail.ru

Abstract

This research was designed in aim to determine the optimum percentage of gellan gum for the development of heat-stable fruit fillings with a wide range of soluble solids – from 40 to 70°Brix, which maintain its sensory and textural characteristics before, during and after baking on the basis of Response Surface Methodology. The low acyl gellan gum Kelcogel F was selected to be used in heat-stable fruit filling′s development due to its excellent thermal and freeze-thaw stability. This high-viscosity hydrocolloid possesses curative properties for sufferers of hypercholesterolemia, high blood pressure, and diabetes and forms a firm gel in as little as two hours, delivering full strength in less than 5 hours.
The fruit fillings′ samples with the same pH and different soluble solids content were prepared locally from fruit pulp, sugar, low acyl gellan gum Kelcogel F and citric acid. The produced fruit fillings were put through standard bakery test to evaluate their heat-stability by determining bakery index (BI) through measuring the diameter of a fruit filling′s sample before and after baking process performed under exactly fixed conditions: at a temperature of 220°C for 20 minutes. The rheological behavior of the fruit fillings prepared on the basis of gellan gum has been investigated by performing experimental measurements at the rotational rheometer Rheotest RV2.
There were obtained the final equations in terms of actual factors in order to describe the influence of soluble solids and gellan gum on fruit filling's heat-stable, sensory and rheological properties. The adequacy of the regression equations was evaluated by the F-test for analysis of variance (ANOVA) using statistical package STATISTICA v.6 and has shown that the models were statistically significant.

Key words: *heat-stable, gellan gum, filling.*

INTRODUCTION

Nowadays extended demand for palatable, cheap and ready on-the-go snacks and meals containing eco-friendly fruit-based foodstuffs has resulted in development of various confectionery and bakery products with fruit fillings. Each fruit filling has different designations and requirements, depending on the customer′s demands, product type, technological process of preparation and the manufacturer′s capabilities. For example, a fruit pie filling baked with the dough, which can further be stored, frozen and then thawed or even rebaked, certainly needs not only high oven and freeze/thaw-stability, but also texture control. The high thermo-stability of fruit filling insures that after baking the pastry remains intact when cut and the filling retains ″fresh-made″ characteristics. There are three main types of bakery fillings: heat-stable, limited bake-stable and non heat-stable fillings (*Herbstreith & Fox KG)* . The melting behavior of fruit fillings depends on the duration and temperature of the baking process. Fruit compositions start melting and flow if they are exposed for a short time to a temperature much higher than their melting point or if they undergo high temperatures in the range of melting point in a long time. However, some bakery products, such as doughnuts that are filled after frying, stored for a few days at room temperature and then consumed, don't require fillings with high heat-or freeze/thaw stability. Fruit fillings for cookie bars require a solid consistency to hold their shape and volume in the finished product, and low aw to ensure long-term shelf life and decrease moisture migration. These mostly need to be formulated with dehydrated fruit, such as low-moisture apples, apricots or prunes or concentrated fruit-stuffs with high soluble solids content and stabilizing agents, to achieve a low finished-product moisture level. Stabilizers and dehydrated fruit can highly increase the viscosity and prevents ″boil out″ during baking.

One of the restrictive factors in the utilization of natural fruit fillings for bakery products is their tendency not only to become softer but also to degrade thermally at high oven temperatures. Unfortunately at the moment fruit jams and jellies rich with pectin are mostly used as bakery fillings. But they also do not behave well at high temperatures during baking, being not heat-stable. Food manufacturers can currently buy ready-to-use fruit bakery fillings from canning or ingredient suppliers, but the percent of fruit part there is very low, because formulations for heat-stable fruit filling with high sensory characteristics face technological difficulties that impose some constraints. Fruit – whether it's fresh, frozen or dehydrated – adds flavor, texture and natural nutrients to the finished fruit fillings. However, it can vary in size and quality as a natural ingredient. Thus, in order to create a smooth and consistent product, manufacturers have to make adjustments during production. They may include the following manipulations: blending the fruit or fruit concentrate, adding sugars, acids or buffers, using stabilizing agents to adjust the product's stability and texture, within legal guidelines. Generally, the requirement for using high percentage of fruit-based raw materials can't be matched with heat-stability and low water activity and thus, manufacturers have to resort to imitation or application of high amounts of various food additives.

Therefore, in this research we decided to experiment with adding gellan gum to fruit fillings' compositions, seeking for the heat-stable fillings which will not drip out of the cake during baking.

Our objectives were to study the correlation among heat-stability, sensory and rheological properties of the fruit fillings prepared with different ratio of gellan gum within a wide range of soluble solids – from 40 to 70°Brix on the basis of experimental design technique.

There are a lot of advantages gained from the use of gellan gum in heat-stable fruit fillings preparation, such as:

- no 'boil-out' of filling;
- good volume fill throughout shelf life;
- excellent flavor release;
- decrease of moisture transfer into the dough;
- fluidity control of the filling if consumed hot;
- perspective to create new bakery products, such as mini-turnovers, which would be extremely difficult using a more conventional filling thickener.

The removal of "boil-out" and "tailing" of fruit fillings keeps the processing lines free from burned on deposits, and thus maintains the standard of hygiene of the line high, without a requirement for extra labor.

Further, since the heat-stable fruit fillings don't melt, the addition of hot custard beyond fruit filling's sheet in a multilayer desserts' preparation, for example, can also be accepted. These properties permit energy savings and more rapid processing of ready-to-eat layered desserts prepared with fruit fillings.

The application of Response Surface Methodology (RSM) as one of the most commonly used techniques of experimental design allows predicting the heat-stable and rheological properties of the fruit fillings prepared with gellan gum as stabilizer.

MATERIALS AND METHODS

Raw materials

Apple aseptic puree was produced at the canning plant 'Conserv-E' (Chisinau, Republic of Moldova). Sugar was acquired from a local supermarket (Chisinau, Republic of Moldova). Citric acid solution (50%) was prepared locally in the Laboratory of Functional Foods of the Practical Scientific Institute of Horticulture and Food Industry (PSIHFT) of the Republic of Moldova. Low acyl gellan gum (KELCOGEL F) was purchased at the Moscow International Exhibition for Food Ingredients, Additives and Flavorings – "Ingredients Russia" (Moscow, Russian Federation).

Sample preparation

The fruit fillings samples were prepared locally in the Laboratory of Functional Foods of the PSIHFT from apple puree (12°Brix), sugar, low acyl gellan gum powder (KELCOGEL F) and citric acid (50% concentration).

The whole amount of the sugar was shared out in two parts, and the first one was introduced to the smooth apple puree, and heated till the sucrose has dissolved. This prior apple-sugar mix served as the basis for four different fruit fillings' formulations presented in the study. The amount of added sugar was calculated on the basis of the final required soluble solids for each fruit filling sample, in order to prepare fruit fillings within a wide range of soluble solids − from 40 to 70°Brix. After that, the gellan gum was dissolved with the rest of the sugar in the ratio 1:10 in hot water using a high speed stirrer. This dispersion was heated from 90 to 98°C and the temperature maintained for 1 min to give a clear solution. The resulted gellan gum solution was added to the apple blend by taking in account four different formulations and followed by intensive mixing at a temperature of more than 80°C. After obtaining a homogeneous mixture, citric acid was introduced to the final apple filling′s composition, leading to lowering pH. With the initiation of gelling, mixing time became critical, and mixing was only continuing for one to two minutes after adding citric acid.

The prepared fruit fillings were preserved in glass jars after sterilization for 2 days before testing.

Physicochemical, rheological and sensory analysis

The physicochemical, rheological and sensory analysis of the fruit fillings samples were carried out at the Laboratory of Functional Foods of the PSIHFT.

The soluble solids of the fruit fillings were determined using benchtop refractometer ABBE and expressed in°Brix. The pH was measured by a potentiometric method, introducing the electrode directly into the fruit fillings.

The fruit fillings′ viscosity before baking was investigated through experimental measurements at the rotational rheometer Rheotest RV2.

Sensory analysis of the fruit fillings' samples after baking was conducted by 10 randomly selected members of the panel. Each of the key sensory characteristics (color, taste, flavor, general appearance and texture) was evaluated by a numerical estimation, ranging between 1 (for extremely bad parameters) and 5 (excellent parameters). Average value based on estimates of each parameter was calculated to receive overall evaluation of the sample.

Determination of heat-stability

Standard bakery test was used to determine the heat-stable properties of the fruit fillings′ samples in the following way: a certain amount of prepared fruit filling was given into a base of the filter paper type 'Blue ribbon' with a diameter of 120 mm by a metal ring with defined geometry (50 mm diameter and 10 mm height) and then baked under exactly fixed conditions: at a temperature of and 220°C for 10 minutes (*Herbstreith & Fox KG)*. During and after this baking process all changes in physicochemical, textural and sensory attributes of the tested fruit filling were estimated. The bakery index was determined by measuring the sample diameter before and after baking by placing a line across the sample and calculating via the following formula:

$$BI = 100 - \frac{D_2 - \bar{D}_1}{D_2} \cdot 100$$

(1)

where

BI − bakery index, %;

D_1 − average diameter of sample before baking, mm;

D_2 − average diameter of sample after baking, mm.

Diameter of a fruit filling sample before baking as a diameter of the metal ring is 50 mm. For measuring the sample diameter depending on its shape, from two to four lines were drawn, and the average was calculated.

For validation experiments we used not only the filter paper type 'Blue ribbon', but also pastry samples with a diameter of 60 mm. For the pastry samples we selected another metal ring with the following dimensions: 30 mm diameter and 10 mm height.

Statistical analysis

In order to establish the optimal percentage of gellan gum introduced into fruit filling's composition for attributing high thermo-stable properties, Response Surface Methodology (RSM) was applied. It was revealed that mostly percentage of stabilizer and soluble solids influence fruit fillings′ thermal stability and rheological behavior (at the same high temperature and for the same baking duration). Thus, only gellan gum content and soluble solids were used as independent variables in two-level factorial design. The levels of these variables were set at: 0.1 and 1.0 for percentage of gellan gum and 40 and 70 for soluble solids,°Brix. The heat-stability of fruit fillings as one of the response variables was expressed through the bakery index (BI, units). All experiments adjusted by the design planned in coded and encoded form of process variables, were conducted randomly. The results obtained through application of RSM were verified by conducting the validation experiments under the optimized conditions of all factors. Statistical package STATISTICA v.6 and MATCAD v.15 was used to evaluate the adequacy of the regression equations through analysis of variance (ANOVA) and to visualize the influence of all factors on response variables by drawing 3D surface plots.

RESULTS AND DISCUSSIONS

Physicochemical and sensory characteristics of the fruit fillings analyzed before baking under laboratory conditions have revealed that they meet the international food standard CODEX STAN 296-2009 FOR JAMS, JELLIES AND MARMALADES.

All fruit fillings prepared with different soluble solids and gellan gum content had the same low pH – 3.1.

The fruit fillings baked along with pastry samples at a temperature of 220°C for 20 minutes were evaluated for sensory quality. The main organoleptic parameters of the fruit fillings with gellan gum after baking are shown in Table 1.

Table 1. Organoleptic parameters of the fruit fillings with gellan gum after baking

Product name	Average sensory scores			
	color	taste	flavor	texture
Fruit filling with 40 ºBrix and 1% gellan gum	5	5	5	4
Fruit filling with 70 ºBrix and 0.1% gellan gum	4	4	4	3
Fruit filling with 40 ºBrix and 0.1% gellan gum	4	4	4	3
Fruit filling with 70 ºBrix and 1% gellan gum	4	4	4	4

The statistical analysis of sensory scores demonstrated that no significant difference was found ($p > 0.05$) for the color, taste, flavor and texture of the fruit fillings with low soluble solids (40°Brix) and 1% gellan gum before and after baking. However, sensory score of listed characteristics for the fruit fillings with low content of gellan gum (0.1%) for both low and high soluble solids was significantly different from initial values after baking process. Mean values ranged from 4.0 to 5.0, 4.0 to 5.0, 4.0 to 5.0, and 3.0 to 5.0 for color, taste, flavor and texture respectively indicating moderate acceptability of the product after baking.

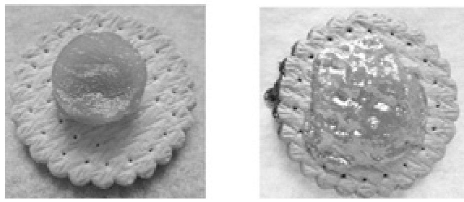

Figure 1. Fruit filling′s appearance after baking at 200ºC for 20 minutes: 40 ºBrix sample prepared with 1% gellan gum (a) and with 0.1% gellan gum (b)

According to the Figure 1, it is clear that the fruit filling sample prepared with 1% gellan gum didn′t become runny or caramelized and stayed well on its place, maintaining its original color, shape and volume. It also didn′t make the biscuit sample under and around it wet or burnt (such as fruit filling sample prepared with 0.1% gellan gum) during baking. The consistency of the fruit filling after baking is nice, smooth but not sticky or gooey. The fresh apple taste and aroma was also well preserved for both of the fruit filling samples shown in the figure above.

Table 2. 2k design matrix for fruit fillings development on the basis of gellan gum

No	X_1 gellan gum content,%		X_2 soluble solids,°Brix		Y_1 bakery index expressing thermal stability	Y_2 viscosity before baking Pa·s	Y_3 overall acceptability after baking, scores
	Code value	Encode value	Code value	Encode value			
1	1	1	-1	40	96.15	521.7	4.75
2	1	1	1	70	40.0	88.2	4.00
3	-1	0.1	-1	40	50.0	14.5	3.75
4	-1	0.1	1	70	30.0	30.5	3.75

The elaboration of heat-stable fruit fillings was conducted through application of the design expert software package STATISTICA v.6 and MATCAD v.15. The experimental design with different independent variables in coded and encoded form i.e. soluble solids and gellan gum content and bakery index, viscosity and overall acceptability of the fruit fillings after baking as responses are presented in Table 2 above.

After processing the experimental data, the following regression equations (2, 3 and 4) describing fruit fillings′ heat-stability, viscosity and overall acceptability in terms of actual values were derived:

$$BI = 66.18 + 104.83 \cdot G - 0.53 \cdot SS - 1.34 \cdot SS \cdot G \quad (2)$$

$$V = -129.78 + 1229.48 \cdot G + 2.19 \cdot SS - 16.65 \cdot G \cdot SS \quad (3)$$

$$A = 3.5277 + 2.2222 \cdot G + 0.0003 \cdot SS - 0.0253 \cdot G^2 \cdot SS \quad (4)$$

where
BI – bakery index, units;
V – viscosity, Pa·s;
A – overall acceptability, scores;
G – gellan gum content,%;
SS – soluble solids,%.

The obtained models were statistically significant according to the data of the F-test for analysis of variance. The validation experiments′ data closely agreed to the predicted values of the developed models with acceptable percentage errors.

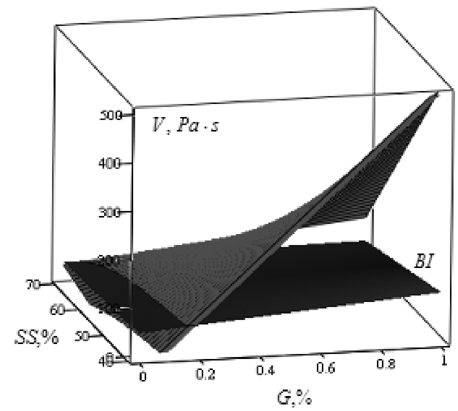

Figure 2. The influence of soluble solids and gellan gum content on bakery index (blue plot) and viscosity of fruit fillings (red plot)

The response surface plots of the polynomial equations represented above have been plotted using MATCAD v.15 as a function of two variables i.e. soluble solids and gellan gum content (Figure 2) in order to visualize their common effect on bakery index that expresses heat-stable properties (blue plot) and viscosity of fruit fillings.

CONCLUSIONS

There were derived three statistically adequate regression equations in terms of actual factors describing the common effect of soluble solids and gellan gum content on fruit filling's heat-stable, rheological and organoleptic parameters.

Judging from the present study, it is obvious that low acyl gellan gum can be definitely used in the development of heat-stable fruit fillings with low soluble solids because of the two major benefits of this hydrocolloid. The first advantage is that gellan gum reduces heat transfer, by forming gelled phase, thereby keeping the temperature of fruit fillings′ compositions lower during the baking time. This also decreases moisture loss and eliminates boil-out. The second main advantage is a reduction in the rate of moisture loss for an increase in shelf life of the finished product. During the investigation it was also revealed that gellan gum would be more advantageous try to use in combination with other hydrocolloids (by finding their common synergetic effect) for the development of heat-stable fruit fillings with high soluble solids, while reducing the standard doses of adding gellan gum as stabilizer.

REFERENCES

Goupy J, Creighton L., 2007. Mixture Designs. In: Goupy J, Creighton L, eds. Introduction to Design of Experiments. Cary, NC: Sas Institute Inc., p. 287-306

Szczesniak A.S., 2002. Texture is a sensory property. Food Quality and Preference, 13, p. 215–225

Tang J., Tung M. A., Zeng, Y., 1998. Characterization of gellan gels using stress relaxation. Journal of Food Engineering, 38, p. 279 – 295.

Codex Stan 296-2009 for jams, jellies and marmalades.

Herbstreith & Fox KG. Recipe. Product. Pectins in Fruit Preparations for Bakery Products. http://www.herbstreith-fox.de