AN EXPERIMENTAL STUDY REGARDING THE INFLUENCE OF THE RELATIONSHIP BETWEEN RECIPE INGREDIENTS ON THERMAL STABILITY OF FRUIT FILLINGS

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Abstract: Our research was designed in aim to elaborate a thermo-stable fruit filling for bakery products.
In order to test the heat-stability of prepared fruit fillings with a minimal number of experiments while reducing time, materials and energy we investigated and determined the optimal ratio of recipe components through experimental design technique.
This paper deals with a practical study of thermo-stable properties of fruit fillings through experimental design method that allows to describe the main interactions between the response variable expressed through bakery index which defines fruit filling's heat-stability and two critical factors that affect it.
Key words: pectin, fruit filling, experimental design

Introduction

Nowadays one of the most significant challenges concerning the use of fruit fillings from natural raw materials for bakery products is their thermal stability, because formulations for heat-stable fruit filling with high sensory characteristics face technological difficulties that impose some constraints. Generally, the requirement for high quality fruit fillings' ingredients 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.

High baking stability of a fruit filling ensures that the final filled bakery product will be aesthetically agreeable, with fresh fruit taste and aroma, good texture, without dough cracks and filling leaks not only after baking but also during the whole storage period.

There are three major types of bakery fillings: bake-stable (or heat-stable), limited bake-stable (or with medium stability) and non bake-stable (or non heat-stable) fillings. 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. In order to manufacture heat-stable fruit fillings with attractive appearance, natural fruit flavor and aroma, the melting temperature of fruit half-stuff composition has to be higher than the temperature in the oven. If a fruit filling is bake-stable it won't change its original shape under applied heat: it won't start boiling or melting with intensive bubble formation and won't also show any tendency to syneresis [1].

One of the limiting factors in the application of natural fruit fillings for bakery products is their tendency to not only becomes softer but also to thermally degrade at high oven temperatures.

Thermal degradation of a polycomponent system such as fruit filling represents generally molecular deterioration as a result of overheating. At high temperatures the components of the long chain backbone of the food polymer system can begin to separate (molecular scission) and react with one another to change the properties of the whole composition. It is a part of a larger group of degradation mechanisms for fruit-based composition that can occur from a variety of causes such as:

- heat (thermal degradation and thermal oxidative degradation in the presence of oxygen);
- light (photo-degradation);
- oxygen (oxidative degradation);
- weathering (generally UV degradation), etc.

General speaking, the ability of a food composition to resist these degradation causes is called the "heat stability" or "thermal stability" of the foodstuff and in this article we will concentrate on the process of thermal degradation with particular emphasis on heat stabilizers used to prevent this unfavorable process.

Almost each foodstuff can be protected from thermal degradation by incorporating special stabilizers into them. The stabilizers are used to keep the polymer chains and the original molecular structure of food compositions intact and therefore their main physicochemical properties can be retained over a longer period.

The special food composition stabilizers can work in a variety of ways but in most cases they act by interrupting the thermal degradation cycle to slow down or prevent the cycle from completing.

When producing fruit-filled bakery foods, high-volume manufacturers can either purchase ready-to-use fruit fillings from a canning supplier or create their own fillings using fruits, water, stabilizers and other required ingredients. Moldovan high, low and medium-volume bakery and confectionary companies basically purchase ready-to-use heat-stable fruit fillings or stabilizing systems from foreign ingredient suppliers. But, unfortunately, these fillings aren't readily adaptable to modern requirements for bakery technology, because they can't resist high oven temperature retaining their initial color, flavor, aroma and structure.

The aim of this research work is to create a natural heat-stable fruit filling composition for bakery products which maintains its sensory and physicochemical characteristics (texture, form, viscosity, etc.) before, during and after baking by using a special heat stabilizer – low-methoxyl pectin on the basis of experimental design technique.

New food product development is a sophisticated, expensive and risky multistage process and special requirements should be considered during all its steps such as consumer demands, quality of the ingredients, quantity, price, properties, technical conditions and legislation background. In order to formulate and test ingredients that would be used, many food scientists or engineers use statistical approaches such as experimental design in their research. It is very important to use experimental design to save chemicals, to reduce volume of experiments and ingredients, time, total financial input and energy for new food product development.

Mathematical modeling for new food product development is widely used to solve the problem where several independent variables (or factors) x_1, x_2,…x_k influence the response variable value y. Thus, mathematical modeling is used in order to determine the effect of one by one factor and the most important their interactions [2, 3].

Experimental design of multi-component foods such as heat-stable fruit filling for bakery products is of growing interest for food technology and industry, because all used ingredients and their variation range can be tested with a minimal number of experiments while reducing time, materials and energy.

Today, pectin is a very important nutrient in the human diet as it is the major component of dietary fiber and has been reported to bind heavy metals, to lower serum cholesterol levels and to have immune-stimulating and anti-ulcer activities. Due to its anion character, pectin can be also used as a cation exchanger for the removal of metal cations from aqueous solutions [4].

Considerable evidence suggests that dietary supplementation with pectin may reduce levels of serum total cholesterol, decrease low density lipoprotein cholesterol, and moderate the glucose response and may also have anti-cancer activities and many bioactive properties [5].

There are also some commercial available pectins that can be easy used as heat stabilizers for fruit filling's compositions.

Materials and methods

In our research we selected the two main factors – *soluble solids content* and *percentage of stabilizer* (pectin) that mainly influence the heat-stability of fruit fillings. Therefore, we only used two-level factorial design in order to visualize the effect of different factor combinations on the selected response variable and to determine the range of values (levels) of these factors. Briefly, two-level factorial design consists of k variables or factors, set at two different levels, indicated as "-1" (the minimum) and "+1" (the maximum). The levels of these variables were set at: 0.5 (-1) and 1.2 (+1) for percentage of stabilizer (pectin), %, and 45 (-1) and 72 (+1) for soluble solids content, °Brix. Our response variable is a thermo-stability of fruit filling expressed through the bakery index (BI).

The fruit fillings samples were produced locally from fruit pulp, sugar, stabilizer pectin type 580 SF Danisco, citric acid, and ascorbic acid. Differences in consistence and texture were achieved by using of different percentage of stabilizer pectin type 580 SF, Danisco and by concentrating up to various soluble solids content.

It should be particularly noted that bakery test was carried out under the following constant conditions: at a temperature of 200°C for 10 minutes (baking duration). Four samples of prepared fruit fillings with the same dimensions (50 mm diameter and 10 mm height) were placed in a single oven at the same time. After 10 minutes these fillings were removed from the oven and were used to determine bakery index that expresses heat-stability.

Results and discussions

Four samples of fruit fillings were prepared with pH 3.35 and different ratio between soluble solids content and stabilizer pectin type 580 SF Danisco.

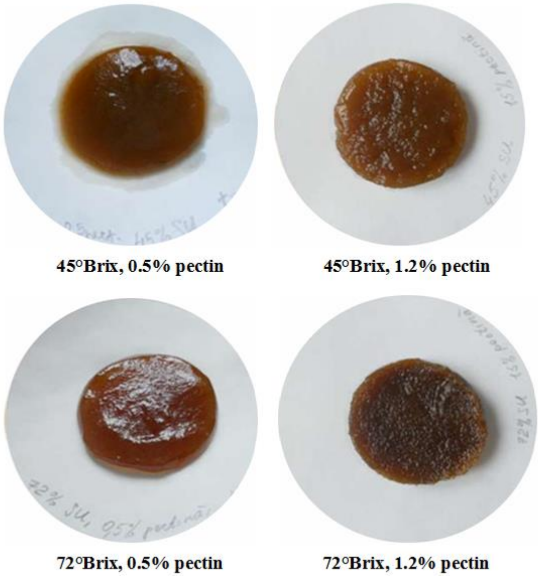

Fig. 1 Fruit fillings appearance before baking

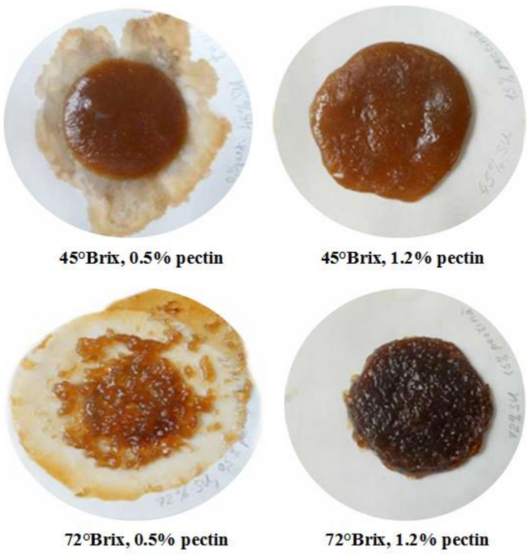

Fig. 2 Fruit fillings appearance after baking at 200ºC for 10 minutes

Sensory characteristics of prepared fruit fillings determined under laboratory conditions have demonstrated that they meet the international food standard CODEX STAN 296-2009 FOR JAMS, JELLIES AND MARMALADES.

In order to obtain optimum conditions for heat-stable fruit fillings production we had to use experimental design and to determine a mathematical relationship between the response variable Y – bakery index and associated control variables denoted by X_1 – percentage of stabilizer and X_2 – soluble solids content.

The table 1 below reports the bakery index of the tested fruit fillings according to soluble solids content and percentage of stabilizer pectin type 580 SF Danisco.

Table 1. 2k design for heat-stable fruit filling production

№ exp.	X_1 percentage of stabilizer (pectin), %	X_2 soluble solids content, °Brix	Y bakery index that expresses heat-stability
1	0,5	45	80
2	1,2	45	63
3	0,5	72	2
4	1,2	72	81
Σ	3,4	234	226
Medium	0,85	58,5	56,5

The final equation in coded variables for this 2^k design of heat-stable fruit filling production has the following form:

$$Y = 56{,}5 + 15{,}5 \cdot X_1 + 13{,}5 \cdot X_2 \qquad (1)$$

This equation is adequate; however it doesn't not accurately describe the process of heat-stable fruit filling production. Our factors are simultaneously varied, with a minimum number of assays, according to the design methodology. The major disadvantage of this model is that it does not include interactive effects among the variables and, eventually, it does not depict the complete effects of the parameters on the process. Therefore, we propose a more complex model in order to take into consideration the plane curvature formed by the factors and the response variable. In this case we use the following procedure: $X_3 = X_1 * X_2$.

After some mathematical transformations our equation took take the following form (with natural variables):

$$336{,}43 - 252{,}86 \cdot P - 5{,}43 \cdot SU + 5{,}08 \cdot P \cdot SU = BI \qquad (2)$$

where

P – percentage of pectin, %;

SU – soluble solids content,°Brix;

BI – bakery index.

The highest achievable index is 100 when the sample is completely stable and no spreading of the fruit filling is observed. Fruit fillings are considered heat-stable if their bakery index is in the range 90 – 100.

Now, when we have already obtained an equation for the heat-stable fruit fillings production based on pectin type 580 SF Danisco, it is relatively easy to find the optimum quantity of stabilizer for any soluble solids content in order to get the high output of the process expressed through bakery index.

On the basis of the formula above for the same high bakery index (from 90 to 100), the least amount of pectin type 580 SF Danisco is required for the production of heat-stable fruit fillings with 30 and 40 °Brix.

Conclusions

Nowadays bakery and confectionery manufacturers demand high-quality fruit fillings with heat-stable characteristics in various innovative forms at competitive prices, because one of the main problems related with the preparation of filled bakery products consists in the filling's thermal instability.

According to the present investigation it's established that selected stabilizer pectin type 580 SF Danisco would be more advantageous to use for manufacturing thermo-stable fruit fillings with 30 and 40 °Brix. The results were checked by carrying out a confirmatory experiment.

References

1. *Herbstreith & Fox KG*. Recipe. Product. Pectins in *Fruit Preparations for Bakery Products*. http://www.herbstreith-fox.de
2. Goupy J, Creighton L. Mixture Designs. In: Goupy J, Creighton L, eds. Introduction to Design of Experiments. Cary, NC: Sas Institute Inc; 2007: 287-306
3. Box GEP, Hunter JS, Hunter WG. Factorial designs at two levels. In: Box GEP, Hunter JS, Hunter WG, eds. Statistics for Experimenters. Design, Innovation, and Discovery. 2nd edition. Hoboken, NJ: John Wiley & Sons, Inc.; 2005; 173-234
4. Kohn, R. (1982). Binding of toxic cations to pectin, its oligomeric fragment and plant tissues. *Carbohydrate Polymers,* 2, pp. 273-275.
5. Yamada, H., Kiyohara, H., & Matsumoto, T. (2003). Recent studies on possible functions of bioactive pectins and pectic polysaccharides from medicinal herbs. In F. Voragen, H. Schols, & R. Visser (Eds.), Advances in pectin and pectinase research (pp. 481–490). Dordrecht: Kluwer Academic Publishers.