Mathematical model of liquid activization while making breads in domestic breadmaker

Vitaliy Borodin, Ganna Tsygankova

National University of Food Technologies, Kyiv, Ukraine

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Corresponding author:

Ganna Tsygankova
E-mail:
tsgk.anna@gmail.com

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Abstract

Introduction. When preparing ingredients for bread baking cooking books say that beating eggs up improves quality of bread. The basis of this fact is given in this paper.

Materials and methods. Maked in domestic breadmaker bread brioche is studied. Methods of mathematical modeling are applied to consideration of a problem of a liquid activization during breads making in domestic breadmaker.

Results and discussion. We understand liquid as any substance which can spread. If we receive a positive changes in results of application of certain technology (which can be fixed measurements) in some characteristics of a ready product we can speak about liquid activization. Examples of liquid activization are given.

The mathematical model, which shows, that intensity of contact of firm and liquid fractions while transformation liquid into foam must increase is developed. They considere, that foam consists of set of spherical segments of spheres with any radius R and different height h. Natural restriction is put on heights of segments h to distribute them uniformly on an interval $[0, R]$. For the characteristic of the contact area of firm and liquid fractions the concept of dome coefficient is considered. The mathematical expectation of dome coefficient of spherical segments defines average dome coefficient. It is proved, that the average dome coefficient is equal 1,5 for the offered model of foam.

Conclusion. The offered mathematical model of foam shows possibility of intensification of firm and a liquid fractions contact in 1,5 times during transformation a liquid into foam.

Introduction

A domestic breadmaker is a household electromechanical device whose main function is automatical baking of shaped bread, starting with a dough kneading and ending with baking the end-product. The principal of breadmaker's functioning is simple. The device consists of a non-stick bowl with a blade-agitator inside. There is a control panel with buttons on the outside of the breadmaker(Figure 1).

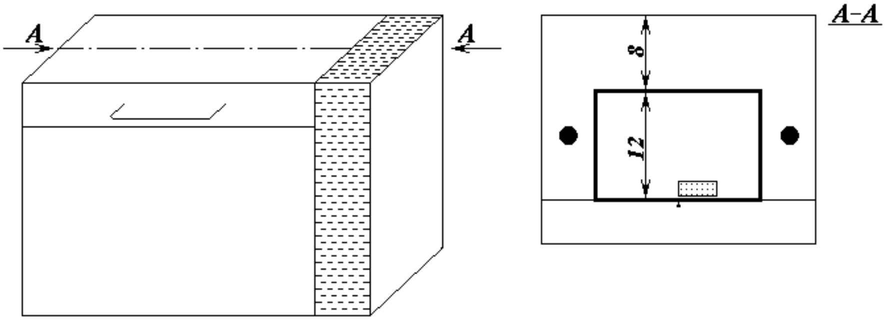

Figure 1

A baking dish is filled with all the necessary ingredients then a button is pushed and after a specified time bread is done.

It is known, that whisking eggs until the appearance of foam while preparing the ingredients for baking bread can improve the quality of bread [5]. The ways of increasing the area of contact of firm and liquid fractions are studied in this work. There is a theoretical assumption that a transformation of liquid into foam can increase the area of contact of fractions what leads to the activization of the liquid. The experiments have shown that there really was the activization of the liquid and the volume of bread increased.

Materials and methods

The problem of the liquid activization during making bread via domestic breadmaker is studied [3,6]. We are going to apply the methods of mathematical modeling.

The technology and the mode of breadmaking. The traditional ingredients for making bread-brioche: milk 200ml, 2 eggs, 140 grams of melted butter, 500 grams of unbleached rye flour, 1 teaspoon of salt, 60 grams of sugar, 2 teaspoons of dry yeast. All the ingredients are added in the baking dish in the sequence mentioned above. After that the breadmaker is turned on. We used another way of adding the ingredients for making bread by domestic breadmaker in our experiment. All the ingredients are separated into liquid fraction and firm fraction. The liquid fraction consists of milk, eggs, and melted butter. The other ingredients belong to the firm fraction. When preparing the liquid for the dough we transform the liquid fraction into foam. It leads to the improvement of bread's quality [2]. Then we continue baking.

Liquid activization. The liquid is turned into foam via the V-technology of whisking [1]. According to this technology the axis of whisks is situated parallel to the surface of liquid while whisking. An overtime taken to whisk liquid by the V-technology is not more than a minute. We transform liquid into foam according to the next rules:

1. All the steps of whisking must be done by V-technology.
2. The first step – whisking eggs 20 sec.
3. The second step – add milk and whisk 20 sec.
4. The third step – add melted butter and whisk 20 sec.

Mathematical modeling of foaming. The process of foaming is considered. We accept that foam itself is a complex of spherical segments with the arbitrary radius. We find the dome coefficient of the spherical segment. It depends on the parameters of fragments of the foam (radius and height of the spherical segment). An average dome coefficient is a constant measurement which shows increasing of the area of the surface of contact between firm and liquid fractions while transforming the liquid into the foam, what leads to the increasing of bread's volume.

Results and discussion

Water, steam, humidity in capillaries, mix of water and flour, dough and everything that can flow is considered as a liquid. If the application of certain technology brings changes (which can be fixed by measurements) in some characteristics of an end-product a liquid activization may be discussed. For example in various cookbooks it is said that bread tastes much better if eggs are replaced by eggs whisked into foam while preparing the dough [5]. This characteristic is not considered as the activization. But if the bread made with whisked eggs is sold at least 5 percent more expensive than we can talk about the activization of the liquid the bread made of. Another example. We shall whisk eggwhite or we can call it "liquid" until foaming. According to the traditional technology of whisking and the instruction of a blender this process takes 5 minutes. At the same time using the V-technology allows to get the foam for 1 minute. We can say that the V-technology of whisking activates the liquid no matter what the aim of using the whisked eggwhite.

In some cases the term "activization" is used incorrectly. Let's look at the example. Conduction and convection are the main ways of heating the liquid. We can see the conduction while heating one end of a metal rod with insulated lateral surface and watch the changing of the temperature at the other end of the rod. While heating atmosphere we can see the almost pure convection. Firstly, the sun's rays pass through the air and heat the ground. The air gets warm from the ground, becomes lighter, and goes up. After that colder layers of air go down replacing the warm air described above. There are convective flows going up and the more intensive the are the more effective and convective the heat transfer. Thus all the manuals are suggesting to create a forced vortical circulation to get more effective convective heat transfer. We have to admit that this statement (about the effectiveness of the vortical circulation for the convective heat transfer) is correct for water, however it is unjust for the complex liquids like milk, for instance. We shall let the milk boil in the pan. A simple mixing can help to save the situation at the moment when the milk is going to leak out of the pan. It means that a forced vortical circulation weakens the convective heat transfer rather than increases. It means that the qualitative general characteristics of the esteem of the effectiveness can not be accepted without numerical estimations.

Let's look at the example of the incorrect usage of the term "liquid activization" while the circulation of the convective heat transfer is forced. According to one of the cookbooks there are two ways of cooking of the semolina. As the result the semolina will be either "disgusting" or "royal". It is noticed, that using the way "A" the semolina is made by continuous non-stop stirring (a circulational swelling of the liquid), and there is no stirring while using the way "B". If we want the semolina to boil equally in both ways, we ought to put the regulation of the electric stove in position "3" for the way "A" and choose position "2" for the way "B". It means, that mixing does not activise the heat transfer, but decreases it 1,5 times.

If we want to make a mathematical model we have to admit that the contact between liquid and firm fractions is cyclical in the way described below. Firstly a part of the area (П) is covered by the layer of liquid, and then the wet area is strewed by the firm fraction. There was a contact between firm and liquid fractions and a mixture of the liquid and the firm fraction was formed. The mixture is removed from the area (П). The process is repeating creating new portions of the liquid. It means that the area (П) is covered by the new layer of the liquid, then it is strewed by the firm fraction and after that a mixture removed from the area (П) is created. Hence, there is a question: How shall the area of the contact between liquid and firm fractions increase per cycle if the liquid is replaced by foam?

Firstly, let's consider more simple case. The foam on the area (П) consists of hemispheres of different radius, which completely covered the area. A hemisphere of a radius R is based on the circle with a big diameter and with the area $S_2 = \pi R^2$ and it has curve surface area $S_3 = 2\pi R^2$ (the half of the area of the sphere's surface) (Figure 2).

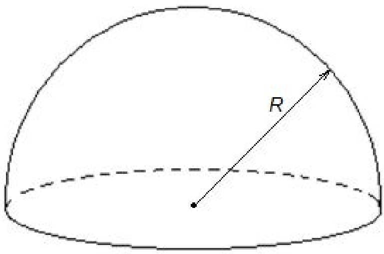

Figure 2

We use the dome coefficient to characterize the area of the foam's surface.

The dome coefficient is the ratio of the surface area S_1 to the area of the base S_2, which is located over the surface:

$$k = \frac{S_1}{S_2}.$$

In other words, S_1 is the area of dome's surface, and S_2 is the area of area covered by the dome.

The dome coefficient of the hemisphere is $k = \frac{S_3}{S_2} = \frac{2\pi R^2}{\pi R^2} = 2$.

The dome coefficient of the hemisphere does not depend on the radius of the hemisphere. Thus, we have k=2 for the foam, which consists of the hemispheres with arbitrary radius R. Henceforth, the area of the foam's surface which consists of the hemispheres is twice bigger than the area where the foam is based.

Let's make the mathematical model more realistic. We shall presume, that the foam consists of the complex of spherical segments of the sphere with the same radius R and a different height $h, 0 < h \le R$, which completely cover the plane (П) (Figure 3).

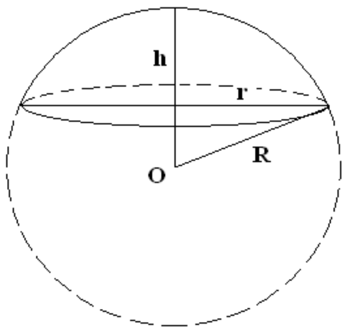

Figure 3

A spherical (ballpoint) segment is the part of the sphere with the radius R, which is cut off from the sphere by any plane. The base of the spherical segment is a circle with the radius r, and the area $S_2 = \pi r^2$. The height of the spherical segment is the part of the circle's radius which is perpendicular to the cutting plane from the plane to the sphere. The length of the height h. The area of the curved surface (the lateral surface) of the spherical segment

$$S_3 = 2\pi Rh = \pi(r^2 + h^2)$$

The dome coefficient of the spherical segment is the ratio of the lateral surface's area to the area of the base.

$$k = \frac{S_3}{S_2} = \frac{Rh}{r^2} = 1 + \left(\frac{h}{r}\right)^2 .$$

The dome coefficient of the spherical segment is variable and it depends on the height of the segment h and the radius of the base r.

After some transformations the formula of the dome coefficient of the spherical segment is

$$k(h) = \frac{2R}{2R - h} .$$

The dome coefficient of the segment grows from 1 to 2 when $h \in [0, R]$, it is easily seen from the formula above. For example, $k\left(\frac{R}{2}\right) = \frac{4}{3}$, $k\left(\frac{2}{3}R\right) = \frac{3}{2}$.

A dome coefficient of the foam is a mathematical expectation of the dome coefficients of the spherical segments or an average value of the dome coefficients of the spherical segments.

Let's make an assumption that the spherical segments with the height $h, 0 \le h \le R$, are equally possible. According to this hypothesis the dome coefficients $k(h) = \frac{2R}{2R-h}$ are divided with a density

$$f(h) = \begin{cases} \frac{3}{2R^3} h(2R-h), h \in [0, R], \\ 0, \qquad h \notin [0, R]. \end{cases}$$

The mathematical expectation of the dome coefficients

$$k_{cp} = \int_{-\infty}^{\infty} f(h)k(h)dh \ .$$

Substituting the functions' value and calculating the integral, we get $k_{cp} = \frac{3}{2}$.

As the k_{cp} does not depend on the radius of the big sphere, our assumption that all the spherical segment are created from the sphere of the same radius *R* is unnecessary. We can put the result we have got on the more realistic mathematical model.

Conclusion

If a segment height division is even for each of the *R*, the average dome coefficient of the foam is $k_{cp} = \frac{3}{2}$ for the foam which consists of the spherical segments with the arbitrary radius.

The mathematical model which is made, shows that the surface area of the interaction of the firm and liquid fractions, while transforming the liquid into the foam, grows 1,5 times bigger. This implies that using the foam instead of the liquid intensifies a technological process of kneading dough.

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