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WATER IN STALING PROCESS AND METHODS OF MEASUREMENT IN FROZEN YEAST CAKES

Magdalena Skotnicka, Piotr Palich

Department of Organization of Tourist and Hotel Services, Maritime Academy
ul. Morska 83, 81-225 Gdynia
e-mail: skotitka@wp.pl

A b s t r a c t. In the performed research the authors evaluated methods of confectionary products staling in yeast cakes. In the elaboration a designation of staling rate is proposed, based on the value of blue quantity and cake stress changes determined by means of the INSTRON 5543 apparatus. Mutual relations between researched parameters were determined. Additionally, a comparison of two staling rate designation methods was made.

K e y w o r d s: blue quantity, staling, starch retrogradation, water content in product, Instron

INTRODUCTION

Water is the basic component of food and significantly influences the quality and storage durability of food products. It appears in food in different forms, as gravitational water or bound water, and its proportion in processing and storage of food changes within a broad range under the influence of different factors. However, independent of the range of content changes, water is the main factor influencing the intensity of physical-chemical processes forming quality features. In food products during storage there is a continuously proceeding series of changes with a physical, chemical, biochemical and microbiological character. One of the methods of limiting the dynamics of proceeding changes is lowering of water content or transformation of gravitational water into bound water, inaccessible for changes impairing food quality. Depending on the type of product, its destination, storage time, different techniques of decreasing the water content are used, such as drying, dehydration, or freezing (Barcenas and Rosell 2006).

In comparison with other methods of food storage, freezing and frozen storage is the best method of long-lasting maintenance of high food product quality, mainly for the reason of insignificant loss of valuable nutritious components and sensory features (Betlińska and Bońca 2000, Cybulska and Doe 1997).

However, durability of frozen products has a limited time character, because it does not cause inactivation of enzymes, nor does it fully protect from the impact of microbes. Freezing does not eliminate chemical changes, it only strongly slows down the rate of those processes during the storage time at constant low temperatures.

Quality changes in frozen food are the resultant of residual biochemical and chemical changes, such as proteins denaturation, starch retrogradation, fats oxidation, and specific physical processes: mass loss, ice recrystallisation and structural changes proceeding under the influence of low temperatures, mainly on the product surface.

Despite the many changes which food products undergo during the freezing storage, at an industrial scale as well as in the everyday life, this way of food storage is one of the basic processes with multidirectional and permanently expanding usage (Kluza and Góral 1993). Almost all food products undergo freezing, including also bakery and confectionary products. Assortment of frozen confectionary products is quite wide, however frozen yeast cakes only recently appeared on our market. Taking into account that such products are very popular in Western Europe and in USA, it can be assumed that within a short period of time also in Poland different types of yeast cakes produced at industrial scale will appear. (Hombach 2002). Freezing is a method which should mainly prevent or minimise the staling process. Bakery products ageing is the main problem that producers of bakery products have to struggle with.

The mechanism of bakery products ageing is very complicated and not completely known. This process is related with changes in starch-protein complexes. During self-cooling and storage of bakery products there occurs the phenomenon of starch retrogradation, whereby starch transforms from the amorphous state to an ordered form, creating a crystalline net (Szajewska *et al.* 2004, Ambroziak 2004, Skotnicka 2006, Palich 2007). Monitoring of the retrogradation process in time is the basis for determination of storage conditions and bakery and yeast cakes products durability and quality.

The aim of the elaboration was to evaluate the methods used for research of confectionary products staling during storage time.

The scope of the elaboration included:

- Determination of water content changes during storage time, under various temperature conditions,

- Determination of staling rate changes on the basis of statistical tests for compression determined with the aid of Instron apparatus during storage time, under various temperature conditions,
- Determination of staling rate changes on the basis of blue quantity during storage time, under various temperature conditions,
- Determination of the correlation between stress changes determined with the aid of Instron apparatus and the blue quantity in yeast cakes.

MATERIALS AND METHODS

The research material were yeast cakes composed of wheat flour, plant fat, sugar, eggs, yeasts, powdered milk, vanilla sugar, salt, aroma identical with the natural one, and beta-carotene, packed into cellophane, frozen with the contact method, and stored for the period of six months in three different storage chambers:

- In variable temperature conditions (–12ºC; –22ºC), which was initiated per 72 hours,
- At a constant temperature of –12ºC,
- At a constant temperature of –22ºC

Table 1. Chemical composition of yeast cake

No.	Chemical composition of yeast cake	Unit of measure	Value
1	Albumen	(g)	6.5
2	Carbohydrates	(g)	53.6
3	Lipids	(g)	12.3
4	Salt, NaCl	(%)	0.052
5	Water content	(%)	27.42

Most of the frozen yeast cakes available on the market have a period of consumption usability from four to six months, which is why the study was performed for 180 days. In this period every 30 days the water content was determined with the drying method in accordance with the norm PN-84/A-88027 (Krełowska-Kułas 1993) and the staling rate was determined by two methods: on the basis of statistical tests for compression with the aid of INSTRON 5543 apparatus and by determination of starch ageing rate by specifying the blue quantity with the method proposed by (Neukom, Rutz 1981). All the tests were performed in 7 replications.

The method of staling rate evaluation using the INSTRON 5543 apparatus consisted in realization of statistical tests for compression of defrosted cake pieces.

The frozen yeast cakes were fully defrosted at room temperature, pieces of cake with size of 250 mm x 250 mm were cut out and subjected to a compression

test by applying a force until 65% deformation was achieved, which was considered as a limit, because after its exceeding part of samples decomposed or fully deformed. A head with a maximal loading of 1 kN, with an installed attachment, was used in the compression tests.

The second method consisted in determination of blue quantity, which is a measure of starch content soluble in water. The absorbance measurement was made in a spectrophotometer at the wavelength of 580 nm in a prepared extract with Carezza I and II reagents and water with an addition of 0.004% potassium iodide as the indicator. The blue quantity was expressed as a value of absorbance read directly on the spectrophotometer (Neukom and Rutz 1981, Fik and Surówka 2001).

Obtained results allowed to determine the relation between the studied parameters of frozen yeast cake products, i.e. the blue quantity and cake stress changes. The relation measure was the Person line correlation coefficient which was calculated according to the formula (1) (Makać 2001, Łomnicki 1999):

$$r(x,y) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{n \cdot s(x) \cdot s(y)} \tag{1}$$

where: s(x) – standard deviation of feature x, s(y) – standard deviation of feature y, n – sample size, $\bar{x}, \bar{y}$ – arithmetic averages.

In order to determine statistical significance of correlation coefficients, the value of (t_{obl}) was calculated and compared with (t_{tab}) read from tables, at (n-2) freedom rates and $\alpha = 0.05$

Using the formula (2):

$$t = \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}} \tag{2}$$

where: n – sample size, r – standard deviation.

RESULTS AND DISCUSSION

Next to drying and loss of aroma in bakery products during the storage, there is also a staling process. Ageing of bakery products involves a series of unfavourable sensory changes decreasing the product quality. The cake surface becomes tender and matt, and the crumb becomes hard, dry and crumbling, which is mainly related with redistribution of water during the storage time (Chung *et al.* 2003, Słowik 2002). The bakery products staling rate depends on many factors resulting from the technological process and storage conditions.

In the course of storage, the water content in the studied products underwent a systematic decrease. This phenomenon was a result of the products tending to achieve a state of humidity equilibrium with the environment. According to the literature, the higher the environment temperature, the higher humidity capacity it has and the more humidity it can take over from products.

Distribution of research results (Fig. 1) indicates that water content changes in time were dependent on the environment temperature. Storage temperatures adopted in the experiment and their variations could decide about the amount of water in the product, and they could influence the durability and quality of yeast cakes.

Systematic loss of water led to the retrogradation of starch, consisting in increasing the rate of starch molecules cross-linking, which was characterized by ordered and compact structure resulting from cake staling, manifested with hardening and crumbling of the crumb.

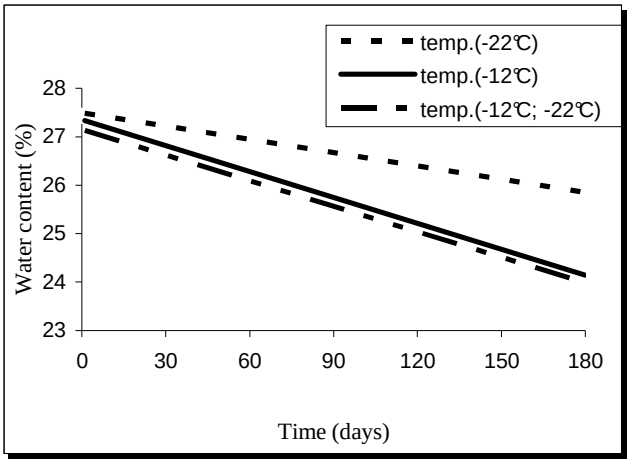

Fig. 1. Dependence of water content changes in time during storage in different conditions

When cakes are removed from the furnace and start to cool down, the water evaporation process begins, at first from the cake surface and then from deeper layers of the pulp. During freezing storage, next to drying there is a constant migration of water from the inside of the cake towards the cake surface, which is intensified by partial evaporation; it favours changes in the starch structure (Ceglińska *et al.* 2003).

Determination of the same water content and monitoring of the dynamics of its changes in storage time does not give a possibility to identify the rate of cake ageing. Determination of the staling rate is, however, really important as it is a kind of starting

point for the evaluation of confectionary products quality. The literature gives many determination methods for bakery and confectionary products staling rate.

In the elaboration, staling rate changes are presented on the example of two methods: instrumental and physicochemical.

The INSTRON 5543 apparatus was employed in the instrumental method. The research allowed to determined changes of stress of cake crumb. Results were obtained in statistical tests for compression with final deformation of 65% of original cake piece volume. The value of 65% was assumed as critical for tested cakes because in some cases any higher deformation conducted to destruction of cake piece.

Distribution of the results (Fig. 2) indicated that with extending storage time the measured stress values increased, and additionally the dynamics of those changes was closely related with temperature conditions during the storage. Increase of stress of cake crumb during storage in temperature of –22ºC was the lowest between results for all other storage temperatures and was estimated at 0.0125 MPa in the yeast cake. In the conditions of variable and constant temperature of –12ºC changes of the stress rate were significant and estimated at 0.0265 MPa. Fluctuation of temperature during the storage tended to accelerate the process of cake staling, which was reflected in high values of cake piece stress after six months of storage. Proceeding process of cake ageing caused that starch retrogradation appeared in the product. This phenomenon was accompanied by release of water which migrated towards gluten, and crosswise bonds were formed in the starch molecule.

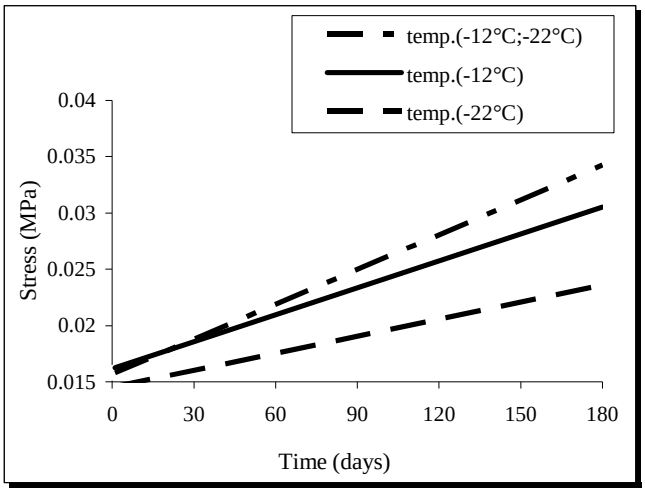

Fig. 2. Cake stress changes with time function

Next to the instrumental method of staling rate measurement, in the elaboration a physicochemical method is presented, based on the determination of the blue quantity with the aid of absorbance measurement. The blue quantity is a measure of the content of starch soluble in water. As the staling proceeded, processes of starch forms ordering caused that crystallizing starch became insoluble in water. Additionally, water bonded earlier in free spaces as a result of retrogradation systematically evaporated and was available for starch in a lower rate.

In the case of the studied cakes, the absorbance value decreased in time (Fig. 3). The most visible changes were observed in cakes stored under conditions of temperature fluctuations (–12º; –22ºC) and at the temperature of –12ºC. Achieved results allowed stating that such low absorbance values after six months were a result of a complete product staling. Cakes characterized by such values were not suitable for consumption. The crumb was hard and crumbling.

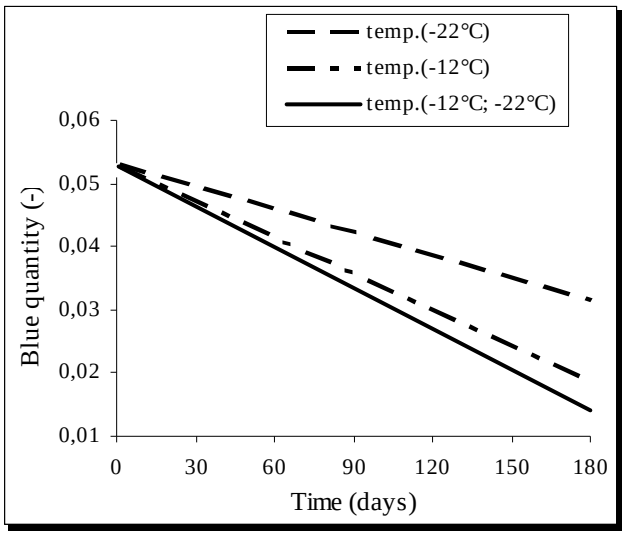

Fig. 3. Changes of blue quantity in cake in a time function

Calculated Person line r(x,y) correlation coefficients confirmed the strong relation between researched parameters. The determination coefficient $r^2(x,y)$ in all cases exceeded 0.96, which means that over 96% of variation of each researched feature was conditioned by variations of the other one, and the indetermination coefficient $\varphi^2(x,y) = 0.025$ informs that 2.5% of variations of each researched parameter resulted from the action of other factors.

In all experimental variants, the statistics of t_{obl} was higher than the t_{tab}, which means that calculated correlation coefficients were statistically significant. Yeast

cakes are products in which structural changes have a decisive effect on forming the quality, which is why it is important to monitor changes related with the product rheology (Skotnicka and Palich 2006).

On the basis of performed research it can be stated that monitoring of water content changes in yeast cakes in time alone does not give a full and clear picture of the ageing process.

Table. 2. Calculated statistical coefficients for research results

Dependence of parameters	a	b	R	R^2	φ^2	t_{obl}
Water content/ Changes in stress	0.013	0.002	0.985	0.969	0.030	24.58
Water content/ Changes in blue quantity	0.058	–0.005	0.982	0.991	0.009	31.92
Changes in stress/ Changes in quantity	0.058	–0.005	0.982	0.991	0.009	24.57

a (y) – line regression coefficient, b (y) – line regression coefficient, r – standard deviation, r^2 – determination coefficient, φ^2 – indetermination coefficient, t_{obl} – calculated t-student test.

The distribution of the studied parameters indicates that water content changes in time were closely related with the cake staling rate. Proposed methods of staling rate measurement confirmed the dependence between the water content and the starch retrogradation. Additionally, the distribution of results of determination of the blue quantity and stress changes gives a possibility to use them alternately.

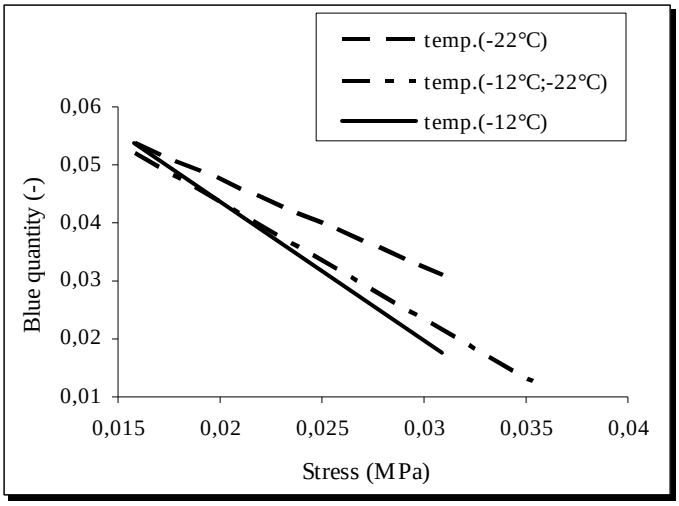

Fig. 4. Dependence of blue quantity changes from cake stress changes in a time function

The method based on the use of the INSTRON 5543 apparatus involves high financial resources, while the determination of the blue quantity is much cheaper, though labour-consuming. However, learning the staling process mechanisms and monitoring the staling rate in time is a basic criterion in the evaluation of confectionary products quality and durability.

CONCLUSIONS

1. The temperature and its constancy during storage time are factors determining the quality of frozen yeast cakes.
2. The staling phenomenon is closely related with the amount of water and its migration in the product during the storage time.
3. Proposed methods of staling rate determination describe well the process of confectionary products ageing and can be used alternately.

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WODA W PROCESIE CZERSTWIENIA W MROŻONYCH WYROBACH Z CIASTA DROŻDŻOWEGO

Magdalena Skotnicka, Piotr Palich

Katedra Organizacji Usług Turystyczno-Hotelarskich, Akademia Morska
ul. Morska 83, 81-225 Gdynia
e-mail: skotitka@wp.pl

S t r e s z c z e n i e. W podjętych badaniach dokonano oceny metod czerstwienia wyrobów ciastkarskich w mrożonych wyrobach z ciasta drożdżowego W pracy zaproponowano oznaczenie stopnia czerstwienia na podstawie liczby niebieskiej i zmian naprężenia miękiszu wyznaczonego za pomocą urządzenia INSTRON 5543. Określono wzajemne związki pomiędzy badanymi parametrami. Dokonano ponadto porównania dwóch metod oznaczania stopnia czerstwienia,

S ł o w a k l u c z o w e: liczba niebieska, czerstwienie, retrogradacja skrobi, zawartość wody w produkcie, Instron