A METHOD TO INCREASE THE NUTRITIONAL VALUE OF AERATED CONFECTIONERY

A. D. Toshev[a,]*, A. S. Salomatov[a,], and A. S. Salomatova[b]**

[a]South Ural State University (National Research University),
pr. Lenina 76, Chelyabinsk, 454080 Russia,
*phone: +7 (351) 267-99-53, e-mail: a.d.toshev@mail.ru
**phone: +7 (351) 267-97-33, e-mail: SalomatovAS@mail.ru
[b]Chelyabinsk State Academy of Agricultural Engineering,
pr. Lenina 75, Chelyabinsk, 454080 Russia,
phone: +7 (351) 267-96-28, e-mail: SalomatovaAS@yandex.ru

(Received February 07, 2014; Accepted in revised form February 17, 2014)

Abstract: A technology and a formulation for the production of meringue of increased nutritional value have been developed. Stepwise introduction of components of a complex additive including puffed barley (6%) and eggshell powder (2%) has been implemented in the new technology. The effect of the above named additive on heat treatment of meringues has been investigated; for this, test samples of pastry were baked at a temperature of 100°C until the content of solids reached 96%. Changes of temperature in the surface layer, central part, and bottom of the sample were monitored during baking. The process of baking of the samples can be arbitrarily divided into three stages, namely, warming, baking, and drying. Dynamics of changes in the surface temperature of the test sample was comparable to that registered for the control sample; the surface was thoroughly heated and moisture evaporated almost completely during 12–15 minutes after the beginning of treatment. The duration of warming for the center of the test samples decreased by 15.4%, and the duration of baking decreased by 6.8%.The additive also had a marked effect on the dynamics of temperature distribution in the bottom of the samples during baking; however, the duration of warming for the test sample was comparable to that for the control sample due to additional heating of the system upon contact with the metallic baking sheet. Introduction of the additive resulted in a decrease of baking time due to the increase of heat conductance of the foam mass containing the additive. Introduction of a complex additive combining components of plant and animal origin to the technology of meringue production contributes to increased production intensity and decreased energy consumption.

Key words: meringue, complex additives, puffed cereals, eggshell, heat treatment

UDC 664.1:664.7
DOI 10.12737/4135

INTRODUCTION

The problem of preservation and promotion of health and increasing life expectancy has received considerable attention worldwide since the mid-20th century. Therefore, the significance of dietary fiber that can have a beneficial effect on health as a component of functional food has increased. Cell walls of barley endosperm contain large quantities of β-glucan, a dietary fiber that has received special attention due to its ability to reduce the level of cholesterol in the blood and thereby diminish the risk of cardiovascular diseases. Moreover, recent reports show that this fiber prevents a sharp increase in blood glucose levels after food consumption [1, 2, 3]. There is scientific evidence showing that diets characterized by low glycemic index may reduce insulin resistance and prevent the development of diabetes. Research involving long-term observations of 90000 women and 45000 men showed that insulin-independent diabetes mellitus was 30% less likely to develop in people who regularly consumed cereal-based foods. The high capacity for reducing the glycemic index of foods characteristic of β-glucan is related to its ability to form viscous solutions decelerating starch hydrolysis and cholesterol absorption. The daily dose of β-glucan recommended by the U.S. Department of Food and Drug Administration is 3 g or at least 0.75 g per serving [1, 2, 4, 5].

A trend of using barley flour containing β-glucan as an alternative to wheat flour in the production of pasta, bread, and ethnic foods, has been growing during the recent years. The use of barley flour is justified from the standpoint of health benefits, but its negative effect on the structure and consumer characteristics of the products hinders its widespread use in the food industry. Therefore, current research on β-glucan-enriched foods is focused on finding ways of introducing it into the formulation so that the consumer characteristics of the final product remain similar to those of the conventional analog [2, 6, 7].

The wide prevalence of diseases caused by excess body weight, which is, in its turn, usually caused by consumption of food containing large amounts of easily digestible carbohydrates, requires changing the existing technologies in order to reduce the glycemic index of foods. The use of complex additives obtained by combining materials of plant and animal origin, for instance, puffed barley combined with eggshell powder, is one of the approaches to increasing the nutritional value of food while reducing the glycemic index. Components of the complex additive were selected using the concepts of food combinatorics which takes the mutual effects of the ingredients into account. For example, puffed barley contains the polysaccharide β-glucan capable of lowering the glycemic index of foods [2, 8, 9], and eggshell contains large amounts of calcium (more than 3 %), which requires the presence of B-vitamins [10, 11] for absorption; the content of the above named vitamins in barley may amount to 7.0 mg %. Thus, the components of the complex additive complement each other. The use of the additive described above contributes to complex enrichment of foods and the reduction of their glycemic index.

Meringue with a sugar content of at least 95±1% was chosen as the object of investigation. Part of the sugar required by the formula (8%) was replaced by a complex additive, namely, 6% of sugar was replaced by puffed barley (PB) and 2%—by eggshell powder (ESP). The ratio of components in the complex additive and the parameters of its introduction were determined using experimental assessment of the rheological, structural, and mechanical properties of the foam mass; these experiments are beyond the scope of the present article.

The aim of the present study was to characterize the effect of the complex additive on the duration of meringue baking.

OBJECTS AND METHODS OF RESEARCH

The effect of the complex additive on heat treatment of meringue was investigated. Samples of aerated mass in which 8% of sugar was replaced with the additive described above were prepared. The samples were baked at 100ºC until the content of solids reached 96%. Temperature distribution in the surface layer, central part, and bottom of the samples under investigation was monitored during baking using a probe inserted into the samples at various depths. The temperature displayed by the device was recorded every 5 minutes. The samples weighed 50 ± 2 g.

RESULTS AND DISCUSSION

The effect of a complex additive on the process of meringue baking was investigated. The temperature at which the meringues were baked was not higher than 100ºC, because otherwise surface cracking and sugar caramelization resulting in a dark discoloration of the pastries would occur. Preliminary experiments showed that baking at a temperature above 100ºC resulted in drying of the product crust, while a considerable amount of moisture was still retained in the center of the pastries. Evaporation and release of moisture from the center of the pastries resulted in cracking of the meringue surface, which is an unacceptable defect of the product. Notably, the duration of meringue baking largely depended on the thickness of the layer of the aerated mass deposited onto the baking sheets. The aerated mass has a low thermal conductivity due to a foamy structure, and therefore the baking process takes a considerable amount of time. The additive introduced into the aerated mass affected the thermal conductivity of the system, and hence the duration of baking changed.

Baking is one of the principal production stages determining the quality and consumer appeal of the meringue. Moisture contained in the aerated egg mass evaporates during meringue baking, this resulting in the formation of a brittle airy structure.

The heat treatment process was investigated in order to determine the duration of baking of the meringue containing a complex additive. Cake-shaped samples weighing 50 ± 2 g were deposited on parchment-lined baking sheets using a pastry bag. A probe was inserted into the test samples in order to follow the temperature changes during baking. The probe was inserted to different depths in order to monitor the temperature changes in the surface layer, center, and bottom of the product. The temperature displayed by the device was recorded every 5 min. The meringues were baked in a steam convection oven at 100ºC. The effect of the complex additive on the temperature distribution in the bulk of the meringue is illustrated by Figs. 1, 2, and 3.

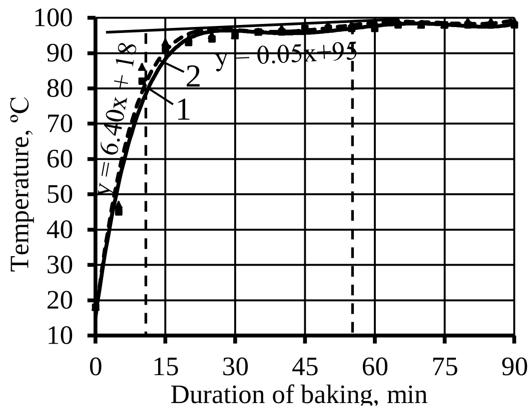

Fig. 1. Temperature change in the surface layer of the meringue during baking:
1 – control;
2 – meringue containing a complex additive.

As shown in Fig. 1, the process of baking of the control semi-finished product (curve 1) can be divided into three phases, namely, warming, baking and drying. The process of meringue crust warming takes 11–12 min and is characterized by a rapid temperature increase to 80ºC. Formation of the meringue structure and redistribution of moisture occur at the baking step, during which the temperature in the surface layer increases by 15ºC at most. The formation of the structure of the surface layer of the meringue is completed after 55 ± 1 min of baking. The drying step resulting in the setting of structure follows the process of baking and is accompanied by a slight temperature change (1–2 ºC). The temperature curve characterizing the process of baking of a meringue containing the complex additive follows a similar pattern (curve 2).

The meringue surface was heated evenly, the additive having no significant effect on temperature distribution in the surface layer. Therefore, the effects of additives on temperature distribution in the deeper layers were investigated (Figs. 2, 3).

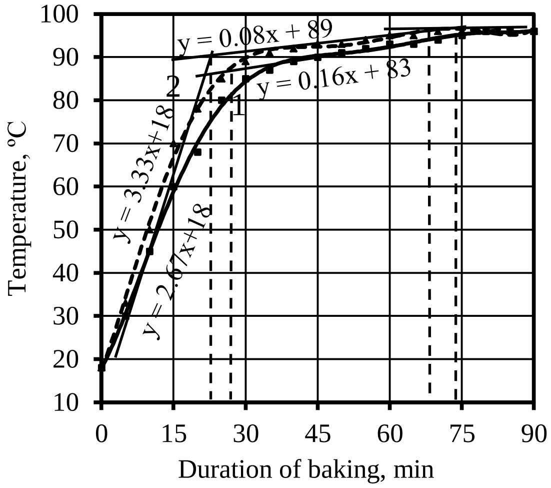

Fig. 2. Temperature changes in the center of the meringue during baking:
1 – control;
2 – meringue containing a complex additive.

As shown in Fig. 2, warming of the central part of the control meringue sample (curve 1) is characterized by a temperature increase to 80ºC and takes 25 ± 1 min, twice as long as the process of crust warming (Fig. 1). Baking of the semi-finished product is characterized by formation of a porous structure and a gradual increase in temperature of the mass. The baking process is completed at 74 ± 1 min when a temperature of 95 ± 1 ºC is reached. Baking is followed by setting of the structure of the meringue, during which the temperature increases by 1—2 ºC at most. Drying takes 5±1 min and is accompanied by setting of the porous structure and formation of a brittle meringue. Changes occurring in the deep layers of meringue containing a complex additive differ from those occurring in the control sample with regard to the duration of several processes. Notably, the warming process for curve 2 is shorter, taking only 22 ± 1 min, and the baking process is completed at 68 ± 1 min. Drying time is also reduced to 3 ± 1 min. Reduction of the baking time due to the effect of the additive was especially pronounced for deep layers of the meringue. Temperature changes in the meringue bottom were investigated to obtain a complete characteristic of the effect of the additive on the baking process (Fig. 3).

As shown in Fig. 3, warming of the bottom of a control meringue takes 22 ± 1 min and results in a temperature increase to 60ºC (curve 1). The process of bottom warming is more intensive than the warming of the center of the meringue (Fig. 2). This is probably due to additional heating of the aerated mass caused by contact with the metal baking tray. The baking process, during which the temperature increases to 95ºC, starts after the warming and is completed at 71 ± 1 min. The drying step is characterized by a slight increase in temperature resulting in setting of the structure. The course of temperature change in the bottom of a meringue containing a complex additive (curve 2) is similar to that recorded for the control sample, with the additive having no effect on the duration of the process of warming. However, the stage of actual baking for curve 2 is completed at 67 ± 1 min. Therefore, the additive has a higher thermal conductivity than the bulk of the foam mass and provides for a faster increase of temperature and a decrease of the baking time from 80 to 70 minutes, that is, by 12.5 %.

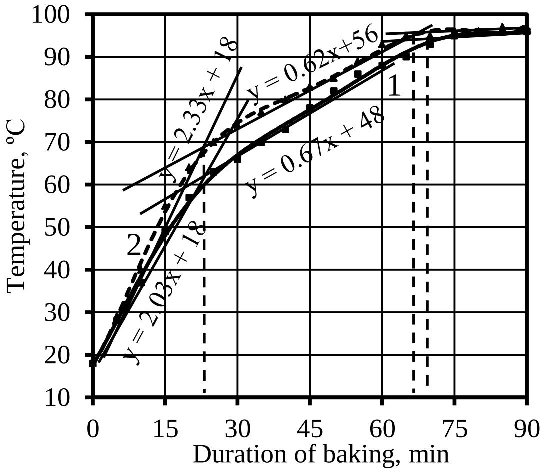

Fig. 3. Temperature change in the meringue bottom during baking:
1 – control;
2 – meringue containing a complex additive.

Microscopic analysis of meringue samples containing the complex additive was conducted using scanning electron microscopy (microscope JEOL JSM-6460LV). The method is based on irradiation of the sample site under investigation by a finely focused electron beam and registration of the signals of the secondary backscattered electrons forming upon the interaction of the electron beam with the sample surface. Secondary electron emission occurred in an area close to the beam incidence site and this allowed for the formation of an image characterized by a relatively high resolution. The resulting signal was amplified and processed, and the images obtained were displayed on a computer screen. A procedure for the microscopic study of the structure was devised and a magnification of 5000 x was shown to be optimal. Results of the experiment are shown in Fig. 4.

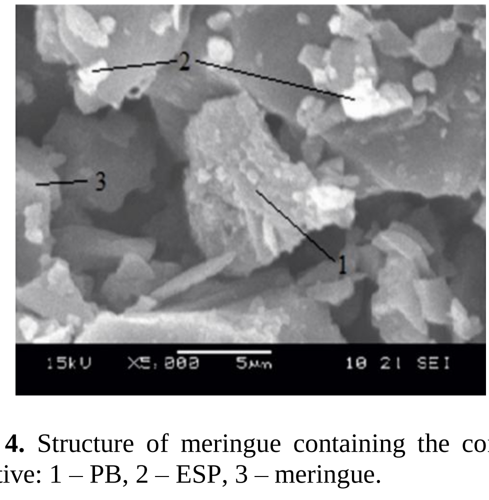

Fig. 4. Structure of meringue containing the complex additive: 1 – PB, 2 – ESP, 3 – meringue.

A microscopic study of sample structure (Fig. 4) revealed a uniform distribution of the additive in the bulk of meringue. Puffed barley particles characterized by a layered structure (1) could be seen in the photographs. Smaller eggshell particles were visible as well (2). Images of meringue layers constituted most of the photograph (3).

Investigation of the cooling process of meringue containing the complex additive showed that the semi-finished baked product requires gentle cooling by convection for 35÷40 minutes at a temperature of 20÷25 ºC and air flow rate of 1.5÷2.0 m/s.

The work performed allowed for a 12.5% reduction of meringue baking time due to the replacement of 8% sugar by a complex additive including puffed barley (particle size 1.5–2.0($\cdot 10^{-3}$) m) and ground eggshell (particle size $40 \cdot 10^{-6}$ m) in a 3:1 ratio.

REFERENCES

1. Lee, S., Inglett, G.E., Palmquist, D., and Warner K., Flavor and texture attributes of foods containing β-glucan-rich hydrocolloids from oats, Food Science and Technology, 2009, vol. 42, no. 1, pp. 350-357.
2. Cavallero, A., Empilli, S., Brighenti, F., and Stanca, A.M., High (1→3,1→4)-β-Glucan Barley Fractions in Bread Making and their Effects on Human Glycemic Response, Journal of Cereal Science, 2002, vol. 36, no. 1, pp. 59–66.
3. Volikakis, P., Biliaderis, C.G., Vamvakas, C., and Zerfiridis, G.K., Effects of a commercial oat-β-glucan concentrate on the chemical, physico-chemical and sensory attributes of a low-fat white-brined cheese product, Food Research International, 2004, vol. 37, no. 1, pp. 83–94.
4. Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K., and Lähteenmäki, L., The sensory characteristics and rheological properties of soups containing oat and barley β-glucan before and after freezing, Food Science and Technology, 2004, vol. 37, no. 7, pp. 749–761.
5. Xu, J., Chang, T., Inglett, G.E., Kim, S., Tseng, I., and Wirtz, D., Micro-heterogeneity and micro-rheological properties of high-viscosity oat β-glucan solutions, Food Chemistry, 2007, vol. 103, no. 4, pp. 1192–1198.
6. Oliveira, R.J., Matuo, R., da Silva, A.F., Matiazi, H.J., Mantovani, M.S., and Ribeiro, L.R., Protective effect of β-glucan extracted from Saccharomyces cerevisiae against DNA damage and cytotoxicity in wild-type (k1) and repair-deficient (xrs5) CHO cells, Toxicology in Vitro, 2007, vol. 21, no. 1, pp. 41–52.
7. Lazaridou, A. and Biliaderis, C.G., Molecular aspects of cereal β-glucan functionality: Physical properties, technological applications and physiological effects, Journal of Cereal Science, 2007, vol. 46, no. 2, pp. 101–118.
8. Xu, J., Inglett, G.E., Chen, D., and Liu, S.X., Viscoelastic properties of oat β-glucan-rich aqueous dispersions, Food Chemistry, 2013, vol. 138, no. 1, pp. 186–191.
9. Comin, L.M., Temelli, F., and Saldaña, M.D.A., Barley β-glucan aerogels as a carrier for flax oil via supercritical CO_2, Journal of Food Engineering, 2012, vol. 111, no. 4, pp. 625–631.
10. Fink, D., Rojas-Chapana, J., Petrov, A., Tributsch, H., Friedrich, D., Küppers, U., Wilhelm, M., Apel, P.Yu., and Zrineh, A., The "artificial ostrich eggshell" project: Sterilizing polymer foils for food industry and medicine, Solar Energy Materials and Solar Cells, 2006, vol. 90, no. 10, pp. 1458–1470.
11. Titchenal, C.A. and Dobbs, J., A system to assess the quality of food sources of calcium, Journal of Food Composition and Analysis, 2007, vol. 20, no. 8, pp. 717–724.