Addition of pollen and honey to improve the quality of sugar-containing cakes

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Summary
In the search for new natural components used to enrich food products, over the recent years particular attention has been paid to bee products. The aim of the work was to develop a new range of sugar-containing cakes using bee pollen and honey produced in the mountainous region of Georgia. Modern, standard and commonly accepted research methods were used in the study. Statistical processing of the obtained results and the data reliability were evaluated by the methods of mathematical statistics. According to the dispersion and stability parameters of the emulsion, the optimal amounts of replacing sugar and invert syrup with bee pollen and honey in the cake recipe were determined. These corresponded to partial replacement of 10 % of sugar to be added with bee pollen and complete replacement of the total amount of invert syrup to be added with honey. This improved the properties of the semi-finished product, as well as organoleptic and physico-chemical quality parameters of the finished product. The stability parameter of the emulsion containing 10 % pollen was by 6 % higher after a 12-hour delay compared to the control sample. The duration of the technological process of cakes production was reduced by 240 s.

Keywords
bee-collected pollen; honey; cake; invert syrup; emulsion; quality

Nutrition is one of the most important factors determining human health, which includes good diet, safe food adequate to lifestyle and age. Health-promoting eating requires the production of mass-consumed foods fortified with functional components. Promising objects for modification in this regard are cereal products including confectionery. To this end, it is important to offer customers high quality products based on local raw materials and fortified with biologically active substances [1–3]. Micronutrients are not synthesized in the human body, so they must be regularly supplied to the body with food proportionally to physiological needs. In the production of functional products, along with fortification with nutrients, low energy food products are preferred [1].

In the search for new natural components to enrich food products, over the recent years particular attention has been paid to bee products. Due to a high content of biologically active substances, they are considered to be a "functional food". They are used in food technology as a functional supplement and, in addition, can be directly eaten. Bee products strengthen the immune system, help the body to actively fight various infections, promote tissue regeneration and, consequently, improve the general condition of the body [4].

Honey and other bee products are quite complex and varied in chemical composition. Honey contains simple sugars, proteins, enzymes, vitamins and minerals, 98–99 % of which are absorbed by the human body. The concentration and ratio of some micronutrients in honey is the same as that of micronutrients in human blood plasma [4–11]. Just like honey, bee products such as bee-collected pollen, are characterized by complex chemical composition and useful properties. Bee-collected pollen is unique in terms of the concentration of nutrients necessary for normal functioning and development of the body. It contains approximately 50 biologically active substances

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that have a positive effect on the human body. It contains 240 substances necessary for the normal course of biochemical processes in the body [6, 12–14]. Honey and bee-collected pollen contain also aromatic substances that improve the taste of foods. Honey contains significant amounts of vitamins, mostly from group B – thiamin (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6) and folic acid (B9) [9].

CHEKUROVA [15] explored the possibility of using bee-collected pollen and bee-bread as raw materials containing physiologically functional food ingredients in the design of bakery products. Their use had a positive effect on the properties of semi-finished products and the quality of the finished product, as well as increases the nutritional value of food.

Flour confectionery products are high in energy value due to the high level of sugar (up to 270 g·kg^{-1}) and fat (from 50 g·kg^{-1} to 250 g·kg^{-1}), which is incompatible with the recommended energy balance [2, 3]. Accordingly, in order to improve the health status of the population and prevent diseases, the development of the recipe and technology of sweet confectionery products that are fortified with essential macro- and micronutrients and have a lower energy value, is an urgent and priority task. The novelty of the research is the possibility of correcting the sugar-containing cake recipe using bee products, which allows to reduce the energy value of cakes and to increase their biological and nutritional value.

Therefore, the aim of this research was to develop a new range of sugar-containing cakes with an increased content of biologically active substances such as vitamins, mineral substances and food fibres necessary for the human body, using bee-collected pollen and honey rich in biologically active substances produced in the mountainous region of Georgia. Our scientific hypothesis was that the addition of honey and bee-collected pollen to the cake formulation will improve the quality of the finished product and reduce the duration of the technological process of cakes production.

For the research, we developed a plan for an experiment:

1. Determination of the optimal amount of honey and bee-collected pollen to be added to the recipe.
2. Study of the effect of bee-collected pollen and honey on the stability of the emulsion.
3. Study of the effect of bee-collected pollen and honey on the quality of the cakes according to the parameters of moisture content, swelling capacity, density and alkalinity.
4. Study of the effect of bee-collected pollen and honey on the technological parameters, such as the duration of emulsification and the baking time.

MATERIALS AND METHODS

Samples

As research samples, reference samples of sugar-containing cakes without additives [16] and experimental samples with additives were used. Field flower honey and bee-collected pollen used as the enriching additives were taken from the newly established social enterprise Honey from Lechkhumi in the high mountain region of Lechkhumi in western Georgia, harvested in 2021. Premium wheat flour produced by the grain-processing plant Bevrili (Tbilisi, Georgia), sugar produced by the sugar processing plant Sugar Company Agara (Kareli, Georgia) and vanilla essence (Yamuna, Rovno, Ukraine) were used.

Equipments

The stability of emulsion was determined on the basis of the state of the fat droplets. In particular, the more droplets of fat therein, the more stable the emulsion. We conducted studies using an Omax brand microscope digital camera (Ningbo Handa Precision Equipment, Zhejiang, China). To assess the quality of the finished product, moisture content of the cakes was determined using an electronic digital analytical balance SF-400C model (Toms, Qilin, China) with a weighing accuracy of 0.01 g. To determine the moisture content of products, we used a drying chamber Pol-Eko Aparatura (Pol-Eko-Aparatura company, Wodzislaw Slaski, Poland). The emulsion was churned in a laboratory emulsification machine AE70 (Shenzhen Yason General Mashinery, Guangdong, China). For baking of cakes, an electric oven with a proofer FDE-903-HR Primax Fast Line Combi Oven, (Primax, San Vito al Tagliamento, Italy) was used.

Methods

Stability of the emulsion was measured by measuring the thickness of the separated part after 2 h, 6 h and 12 h of storage and it was expressed in percent.

The moisture content of the cakes was determined by drying the test sample at a temperature of 130 °C to constant weight. The loss of mass was calculated by the difference between the masses of the test sample before and after drying, according to the standard GOST 5900-2014 [17], and expressed as percentage:

$$W = \frac{M_1 - M_2}{M_1} \times 100 \quad (1)$$

where W is moisture content of the sample (in percent), M_1 is the mass of the test sample before drying (in grams) and M_2 is the mass of the test sample after drying (in grams).

To determine alkalinity of the cakes, the alkaline substances in the sample were neutralized with a solution of sulfuric acid or hydrochloric acid at a concentration of 0.1 mol·l^{-1} in the presence of bromothymol blue indicator (≥ 99.5 %, LenReaktiv, Simchoice Chemical, Shenyang, China) until the yellow colour appeared. The method is used to determine alkalinity of flour confectionery produced by using chemical leavens [18].

Cake density was determined by measuring the volume of the liquid displaced when immersing a test sample pre-coated with a paraffin layer [19]:

$$\rho = \frac{M}{V} \quad (2)$$

where ρ is density of cake (in kilogram per cubic metres), M is the mass of the cake (in grams) and V is the volume of the cake (in cubic metres).

In order to determine swelling capacity of cakes, the finished product were immersed in water at a temperature of 20 °C for 2 min and the weight gain was determined using a digital analytical balance. Swelling capacity of the cake was expressed as a formula [20]:

$$\psi = \frac{M_2}{M_1} \times 100 \quad (3)$$

where Ψ is swelling capacity of the cake (in percent), M_1 is cake mass swelled with water (in grams), M_2 is a mass of dry cake (in grams).

Organoleptic parameters were determined on a 10-point scale according to the following characteristics: surface condition, colour, taste, smell, sectional view and shape [21].

Due to the high content of fat and sugar, we made the dough in two stages. To obtain a homogenous dispersion system, an emulsion in the first stage was prepared to dissolve fat and water. Emulsion plays a special role among the determinants of the cake's quality, as it greatly determines the nature of the technological process. We used an AE70 laboratory emulsifier machine (Shenzhen Yason General Machinery, Guangdong, China) to make the emulsion and mixed all raw materials, except for flour, required in the recipe.

The cake's emulsion is a multi-component dispersion system. The main components of the emulsion are fat, sugar, water and invert syrup. Since emulsion is the main semi-finished product in the production of the sugar-containing cake, we considered it expedient to investigate the impact of bee-collected pollen and honey on the quality of emulsion. To do this, we prepared a reference sample of the emulsion (without the addition of bee-collected pollen and honey) and a test sample, in which we replaced the sugar from 0 % to 15 % (step 5 %) with bee-collected pollen, completely replacing the invert syrup with honey at 0–100 % in 25% increments. The emulsion was churned for 10–12 min at a laboratory temperature (20–22 °C).

The temperature of the finished emulsion was 32–34 °C. The temperature in the baking chamber was 230–240 °C, the baking time was 300 s. The moisture content of the sugar dough was 160–165 g·kg^{-1}. Readiness of the cake was determined based on the moisture content and appearance. The moisture content of the finished product was 80 g·kg^{-1}.

The content of proteins, fats, carbohydrates and biologically active substances in new products was determined by calculation based on data from tables of the chemical composition of food products [22].

Statistical analysis

Statistical analysis of the obtained data was undertaken to explore the physico-chemical parameters of the sugar-containing cake test samples (moisture content, swelling capacity, density, alkalinity), the reliability of the obtained data was evaluated by the mathematical statistics methods using Windows IBM SPSS Statistics software (version 20.0, IBM, Armonk, New York, USA). Arithmetic average of the measured values was calculated. Then, error of each measurement was calculated together with squared errors in order to compute the absolute measurement error. We selected the value of reliability $p = 0.95$ [23]. To describe the ordered sample, we used statistical functions of the average arithmetic value and average standard error.

RESULTS AND DISCUSSION

Based on the purpose of the research, a part of the sugar was replaced with bee-collected pollen and all invert syrup was replaced with honey. We determined the optimal quantity according to the quality parameters of the finished products.

Emulsion stability is proportional to the dispersion of fat droplets [2]. In particular, the thinner the fat droplets in it, the more stable the emulsion. By microscopic examination of the emulsion, it was found that partial replacement of up to 10 %

of the total amount of sugar in the recipe with bee-collected pollen and complete replacement of the invert syrup with honey increased the number of thin fat droplets. At higher replacement levels, the number of thin fat droplets decreased and the emulsion becomes more viscous, which led to deterioration of the quality of emulsification. The minerals and amino acids contained in bee-collected pollen and honey probably interacted with emulsion proteins and polysaccharides, which promoted to the formation of a finely dispersed system.

Depending on the type of dispersion phase in emulsions, sedimentation processes may take place over time, leading to kinematic instability, which is manifested by the deposition of particles in the dispersion phase or by floating to the surface [2, 3]. Based on the above, we studied the effect of bee-collected pollen and honey on the emulsion resistance to layer separation for 12 h, which was determined by measuring the thickness of the stratified part. The results are shown in Fig. 1.

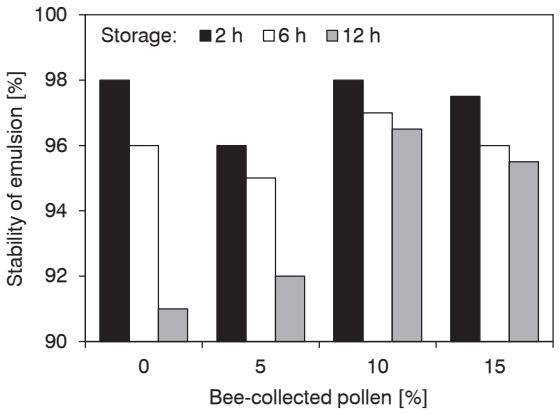

Fig. 1. Effects of bee-collected pollen dosage on stability of the emulsion after various storage times.

From the obtained data it follows that in samples of the emulsion with a content of 100 g·kg^{-1} pollen, the stability parameter after 2 h corresponded to the control sample (98 %). After 6 h, the stability parameter of the control sample was 96 %, and in the sample containing 100 g·kg^{-1} pollen it was 97 % (i.e. increased by 1.0 % compared to the control sample). After 12 h, the stability parameter of the control sample was 91 % and in the sample with 100 g·kg^{-1} pollen it was 96.5 % (i.e. increased by 6.0 % compared to the control sample).

It was established that increasing the dosage of bee-collected pollen increased the emulsion stability and exceeded the reference sample values. This was due to the increase in the dispersion of emulsion, which can be explained by the fact that the emulsion was saturated with minerals and amino acids present in bee products. It is clear that as the amount of protein in solution increased, the phase strength increased [2, 3, 24].

Thus, taking into account the parameters of dispersion and stability, 10 % of the mass of sugar in the recipe can be considered to be an optimal dose of bee-collected pollen to be added, which is 1.7 % of the total mass of raw materials in the recipe. These results were compatible with results of earlier studies, when physiological effects of bee-collected pollen on the human body were studied in 2014–2016 within the project funded by the Shota Rustaveli National Science Foundation of Georgia: "Production of healthy food products using honey and bee products" [6]. In particular, several recipes for flour-based culinary products with the addition of bee-collected pollen were then developed, on the basis of which the physiological effect of the prepared product on the organism of experimental animals was studied. The acceptable amount of bee-collected pollen to be added was 3–5 % of the total mass of raw materials, which is 3–5 g per 100 g of product. [6]. The results of our study are also in line with findings of other scientists, among which it should be noted Ayse Neslihan Dundar from Bursa Technical University (Bursa, Turkey) [25]. She added 5 %, 10 % and 15 % bee-collected pollen in the cake recipe compared to the mass of flour, which is 2.4 %, 4.8 % and 7.2 % of the total mass of raw materials. The data obtained on the shelf life of the sugar-containing cakes emulsion are consistent with data available in the literature. Thus, for example, according to Chernenkova et al. [26], the addition of honey and bee-collected pollen increases the strength of the emulsion and, after 12 h, it is by 2.1 % higher, while after 24 h it is by 7.7 % higher, compared with the emulsion stability parameter of the mass of raw materials.

At the next stage, we studied the effects of bee-collected pollen and honey on the quality of cakes according to moisture content, swelling capacity, density and alkalinity. Taking into account the types, compatibility, technological methods and modes of the selected functional ingredients, we prepared cake samples, in which sugar was replaced with bee-collected pollen at 0–15 % in 5% increments, while the invert syrup was replaced with honey at 0–100 % in 25% increments. The cake without additives was a reference sample.

The results of the study of the effect of bee-collected pollen on the properties of cakes are

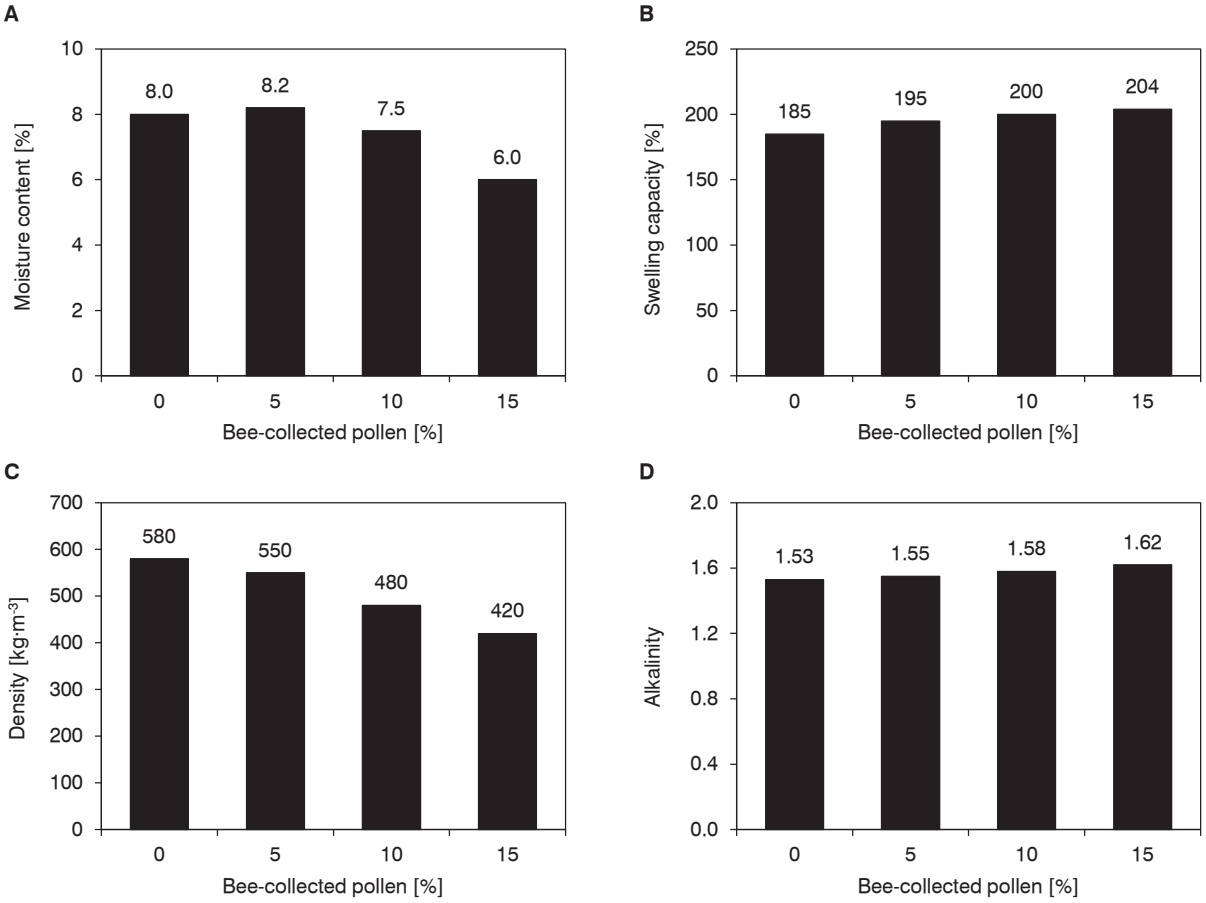

Fig. 2. The impact of bee-collected pollen dosage on the physico-chemical properties of sugar-containing cakes.

A – moisture content, B – swelling capacity, C – density, D – alkalinity.

shown in Fig. 2. They demonstrate that increasing the amount of bee-collected pollen reduced the moisture content and density of cakes, swelling capacity of the product increased and the structure was improved. However, adding more than 10 % of bee-collected pollen worsened the structure of the finished product, in particular it became crumbly. The addition of bee-collected pollen had almost no effect on alkalinity of the cakes, which remained practically unchanged and met the requirements of the standard GOST 24901-2014 [21]. It can be therefore concluded that the addition of 5–10 % of bee-collected pollen (compared to the sugar mass) led to improvement in the quality of the finished product, while the addition of more than 10 % of bee-collected pollen (compared to the sugar mass) worsened the quality of the sugar-containing cakes.

Tab. 1. Effects of the dosage of honey on the physico-chemical properties of sugar-containing cakes.

Honey dosage [%]	Moisture content [g·kg^{-1}]	Swelling capacity [%]	Density [kg·m^{-3}]	Alkalinity
0	81 ± 2	185 ± 5	600 ± 24	1.58 ± 0.03
25	81 ± 1	190 ± 4	580 ± 21	1.55 ± 0.02
50	80 ± 1	195 ± 5	570 ± 22	1.52 ± 0.02
75	80 ± 1	200 ± 4	530 ± 20	1.50 ± 0.02
100	79 ± 1	205 ± 4	550 ± 22	1.49 ± 0.02

Values represent mean ± standard deviation (n = 3). Honey dosage is expressed as compared with the invert syrup weight.

In order to determine the optimal amount of honey to be included in the sugar-containing cakes recipe, we determined the physico-chemical and organoleptic parameters of the product. The results are presented in Tab. 1. They indicate that the moisture content of the product changed slightly with the increasing amount of honey and remained within the standard requirements. The addition of honey increased swelling capacity of the cakes by 10.8 %, which had a positive effect on taste values of the product. Increasing the amount of honey decreased the density of the samples. The highest density was observed in a reference sample (600 kg·m^{-3}). Alkalinity of the cakes decreased by 7 % with an increase in the amount of honey, which can be explained by the fact that honey is acidic. The pH value of honey used in the studies was pH 4.5.

The invert syrup in the product prepared for organoleptic evaluation was completely replaced with honey, while 5 %, 10 % and 15 % of the sugar mass were replaced with bee-collected pollen. The effects of bee-collected pollen dosage on organoleptic parameters of sugar-containing cakes are shown in Fig. 3. It can be concluded that the inclusion of bee products in the recipe of the sugar-containing cakes improved organoleptic parameters of the product. As can be seen from the profile, the best organoleptic parameters were achieved by the product in which 10 % of the sugar required in the recipe was replaced with bee-collected pollen, while the invert syrup was completely replaced with honey. Thus, based on the study of physico-chemical and organoleptic indicators of the cakes, we found that samples in which the invert syrup was completely (100 %) replaced with honey, and 10 % of sugar was replaced with bee-collected pollen, met the requirements of the standard [20].

Changing the product recipe may make it necessary to adjust the parameters of the production technological process. To that end, we studied the effect of bee-collected pollen and honey on the technological parameters, namely, the duration of emulsification and the baking time. We prepared the reference samples without adding honey and bee-collected pollen, together with test samples in which we completely replaced the invert syrup with honey and 10 % of the sugar was replaced with bee-collected pollen.

We studied the effect of bee-collected pollen and honey on the duration of emulsification. Readiness was determined 2 h after churning according to the emulsion stability (we calculated the stability of the unbroken emulsion by volume) [1, 24, 27]. According to the results, 98 % of the emulsion stability after 2 h was achieved after

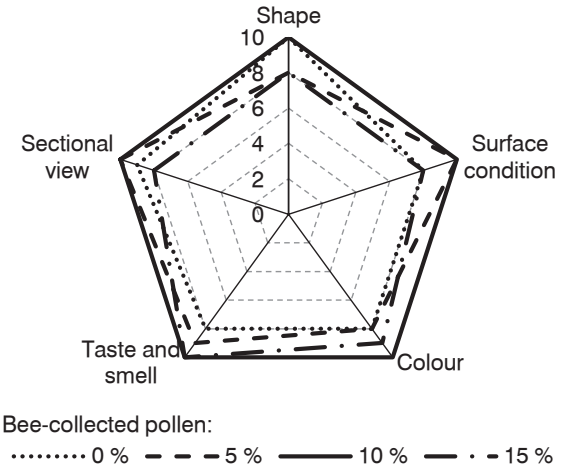

Fig. 3. Effects of bee-collected pollen dosage on organoleptic parameters of sugar-containing cakes.

10 min of churning the reference samples, while in the case of the samples with improved recipe, the same stability was achieved after 7 min of churning. Thus, adding 10 % of bee-collected pollen (compared to the sugar mass) and replacing the invert syrup with honey would reduce the duration of emulsification by 180 s. We think this was due to honey and the amino acid and mineral composition of bee-collected pollen, which accelerated the emulsification process.

At the next stage of the research, the influence of bee products on the duration of baking the sugar cakes time was studied.

The product obtained with the addition of honey and bee collected pollen acquired a light brown colour 240 s after the baking starts, in contrast to a reference sample, which maintained a light straw colour for this period of time. The

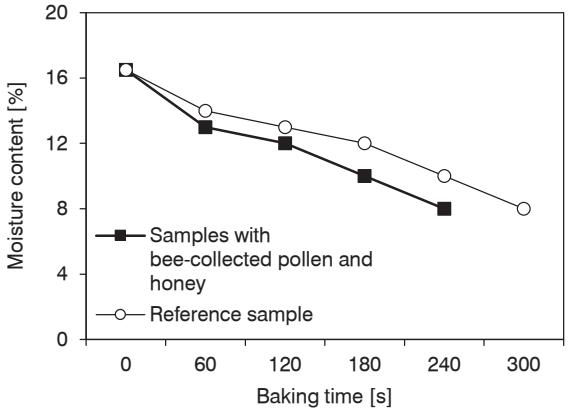

Fig. 4. Effects of bee-collected pollen and honey dosage on the baking time of cakes.

Tab. 2. Content of nutrients in reference and test samples of sugar-containing cakes.

Nutrients	Reference sample	Test sample
Protein [g·kg^{-1}]	80 ± 2	107 ± 3
Carbohydrate [g·kg^{-1}]	812 ± 2	754 ± 21
Fat [g·kg^{-1}]	56 ± 2	53 ± 2
Essential amino acids		
Lysine [g·kg^{-1}]	0.32 ± 0.01	5.92 ± 0.10
Methionine [g·kg^{-1}]	0.21 ± 0.01	2.21 ± 0.01
Threonine [g·kg^{-1}]	0.31 ± 0.01	5.23 ± 0.05
Tryptophan [g·kg^{-1}]	0.12 ± 0.01	3.23 ± 0.04
Leucine [g·kg^{-1}]	0.72 ± 0.02	11.21 ± 0.20
Isoleucine [g·kg^{-1}]	0.42 ± 0.01	7.31 ± 0.15
Mineral substances		
Potassium [g·kg^{-1}]	0.87 ± 0.03	1.06 ± 0.03
Calcium [g·kg^{-1}]	0.14 ± 0.01	0.20 ± 0.01
Phosphorus [g·kg^{-1}]	0.87 ± 0.02	0.97 ± 0.02
Vitamins		
Vitamin B1 [mg·kg^{-1}]	0.82 ± 0.02	1.62 ± 0.05
Vitamin E [mg·kg^{-1}]	9.83 ± 0.03	12.02 ± 0.10

Values represent mean ± standard deviation (n = 3).
Test sample with 10 % of bee-collected pollen was used for calculation of parameters.

results are shown in Fig. 4. As can be seen from the diagram, the mass fraction of moisture in the samples prepared with the addition of bee products decreased to 8 %, 240 s after the baking started, and in a control sample it was 300 s and more after the baking started.

In our view, this was due to the fact that the addition of bee products reduced viscosity of the emulsion and increased its dispersion, which in turn led to an increase in the thermic and moisture conductivity of the product during the baking process. As a result, the baking time of the cakes was reduced by 60 s.

We calculated the content of proteins, fats, carbohydrates and biologically active substances in reference and test samples of cakes (Tab. 2). The results showed that compared to the reference sample, the protein content in 1 kg of products increased by 28.9 %, the carbohydrate content decreased by 7.1 % and the fat content decreased by 5.4 %. The content of biologically active substances, such as essential amino acids, mineral substances and some vitamins, was increased.

Thus, based on the conducted studies, it has been established that the optimal dosage of honey and bee-collected pollen in the recipe improved the properties of the semi-finished product and the quality of the finished product according to the organoleptic and physico-chemical parameters. The developed products had a high nutritional and biological value, which was due to a high biological value of the contained bee products.

CONCLUSIONS

The optimal dosage of bee-collected pollen and honey in the sugar cake recipe was determined, which corresponds to partial replacement of 10 % of sugar with bee-collected pollen and complete replacement of the total amount of invert syrup with honey;

The stability parameter of the test samples of the emulsion obtained with the optimal amount of bee-collected pollen and honey after 2 h corresponded to the parameter of a reference sample. After 6 h, the stability parameters in the control sample was 96 %, and in the sample containing 10 % pollen 97 % (i.e. increased by 1.0 % compared to the control sample), after 12 h, the stability parameters in the control sample was 91 %, and in the sample with a dosage of 10 % pollen-pollen 96.5 % (i.e. increased by 6.0 % compared to the control sample).

As a result of replacing sugar and invert syrup with the optimal amount of bee-collected pollen and honey in the recipe, the physico-chemical and organoleptic parameters of the quality of finished products were improved.

The duration of the technological process of the sugar-containing cake preparation was reduced by 240 s (emulsion preparation by 180 s, baking time by 60 s).

The developed product had a high nutritional and biological value, which was due to a high biological value of bee products.

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