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Undesirable Transformations of Certain Nutrients During Pre-Processing and Protection Against them

G Madzgarashvili*

Doctor of Agric. Sci. Independent Researcher, "Demetra" LLC, Georgia

***Corresponding author:** G Madzgarashvili, Doctor of Agric. Sci. Independent Researcher, "Demetra" LLC, Georgia

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ABSTRACT

The article presents the negative results arising in the process of food processing using common technologies. The article discusses the factors contributing to these undesirable phenomena, as well as modern innovative processing methods, thanks to which it is possible to avoid undesirable transformations (oxidation, formation of 5-hydroxymethylfurfural and caramelans, biological activity reduction), the influence of temperature, atmospheric pressure and optimal gas regime on the preservation of certain nutrients in these processes, as well as the maximum reduction in the content of di- and monosaccharides in preserved fruits.

Keywords: Food Products; Transformation; Hydroximethilfurfural; Protein; Simple Carbohydrates; Oxidation; Microflora; Jam; Puree; Humidity; Pollen; Bee Bread; Churchkhela; Carotene; Amino Acids

Introduction

Such transformations occur in the content of protein, simple carbohydrates, vitamins and other substances. The main reasons for them include improper thermal regime, atmospheric oxygen, various types of microflorae, high water content, hydrogen ion concentration, sunlight, composition of packaging material, etc., and the consequence is a change in the quality of food and the appearance of undesirable, and sometimes harmful substances. Such a wide variety of factors and completely different chemical composition of food make the researcher look for optimal solutions for processing and storing certain types of food. Based on the above, we approached this issue primarily taking into account their chemical composition, in particular, understanding the possible reaction of the factors listed above to the substances (Protein, carbohydrates, excess moisture, etc.) included in their composition.

Results of the Research

Features of Processing and Storage of High-Protein Foods

In this case, the subject of our research was pollen - pollen grains, that bees collect as a source of basic nutrients (except carbohydrates), a product with high biological activity, perishable under natural conditions, with moderate (20-30%) moisture content and abundantly infected with yeast fungi [1]. The bee itself solved this issue in the process of evolution by carrying out lactic acid fermentation in a product placed in honeycombs, but it is quite difficult for a person to remove the product stored in a honeycomb and already turned into bee bread, not to mention its ecological purity, the volume of a marketable product is reduced due to the sharp seasonality of work. Man has developed simple methods to collect raw pollen from bees (see Figure 1- pollen collector) and dry it (Figure 2). For the last operation, it is recommended to use a simple drying cabinet with a thermal regime of 35-40°C. Obviously, this regime makes the drying process much longer (20-48 hours, taking into account its initial humidity) (Figure 3). A negative consequence of this process is the low stability of labile ingredients, especially in terms of preservation of carotene and amino acids (lysine, phenylalanine, arginine). During the comparative testing of drying units of different designs, we preferred a vacuum dryer. In addition, it was observed that: if the residual pressure does not exceed 0.05 kg/cm^2, and the temperature ranges from 60-65°C, then the drying process lasts 75-90 minutes, and the residual moisture content is 4 wt.% on average.

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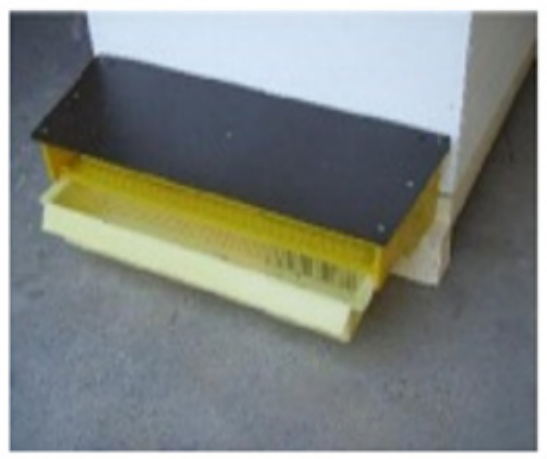

Figure 1: Pollen collector.

Figure 2: Pollen dryer.

Figure 3: Peach jam prepared by new technology (4) and initial material (5).

It should be noted that under these conditions, the temperature in the material to be dried does not rise above 45°C, which is explained by the increased release of heat and water vapor from the vacuum dryer. The fact that the negative effect of atmospheric oxygen on the preservation of carotene and amino acids is significantly weakened in vacuum conditions cannot be regarded as a factor contributing to the improvement of drying, in particular, the carotene content in the test sample of pollen (drying in vacuum) was 8.5 mg%, in the control of the sample (drying in a conventional drying cabinet 40-45°C) this indicator was 7.94 mg%, of Lysine- 3.23 and 2.55 mg%, respectively; of Arginine -4.21 and 1.27; of Phenylalanine -1.94 and 1.35. In the test group of bee colonies, which were given vacuum-dried pollen mixed with candy, the area of an adult brood at the end of the experiment was 29.4 dm^2, the same indicator of the control group was 25.5 dm^2. Furthermore, it should be noted that volatile essential oils - an important biologically active substance - are much more intensively lost in vacuum, which can be considered a disadvantage of this method. At the next stage of the work, we made bee bread from dry pollen without a bee colony (honeycombs).

The advantages of this step include clearly the best ecological purity of the pollen, the opportunity to do work literally all year round, and for the collection of pollen - during 5-7 months of the active season, reduction of labor costs by almost 40%, the duration of conservation of bee bread has been reduced from 2.5 weeks to 50 hours, using selective strain of lactic acid bacteria. This was also due to the fact that the mixture created the necessary minimum of simple sugars for the functioning of lactic acid bacteria, and also used a neutral gas-carbon dioxide was used both during incubation and storage of the finished product. Accordingly, the market price of finished bee bread has decreased from $100 to $64 per kg, which will significantly increase the consumption of the product by the population with the results obtained. To determine the biological activity of the bee bread made by the above technology, the sample was incubated with Clostridium botulinum spores, placed in a thermostat at 37°C for 10 days, after which a sample of bee bread was given together with the main feed to an experimental group of white mice. The control group received regular food (without bee bread) [2]. During the experiment, all numbers of mice were maintained, i.e. the bee bread inhibited the ability of Clostridium botulinum to multiply and produce toxin (Report of R.Lugar laboratory, Tbilisi) [3].

This product was also tested in the Microbiological Laboratory of "Biotex" LLC by including it in a meat-peptone agar on which strains of Escherichia coli and Staphylococcus aureus were incubated. Within 24 hours, the diameter of their inhibition zones was 33 and 31 mm, respectively. Unfortunately, we did not have the opportunity to determine the effect of bee bread made in this way on the condition of patients with the Covid-19. Due to technical difficulties, we were also unable to determine the level of carotene retention compared to the initial product using an improved research method (Biehler, et al. [4]). In addition, it would be very interesting to implement the entire process of product preparation (including final humidity conditioning) in the neutral gas zone.

Processing and Storage of Foods Rich in Simple Carbohydrates

Such products include fruits and honey. The water content in fruits is very high, and the fructose-rich raw materials almost do not emit water at low temperatures (<45°C) during the drying process. Prolonged low-temperature drying and the same process in short-term, but high-temperature conditions dramatically worsen the appearance of the product; Due to the oxidation of phenolic compounds, Badagi (grape juice) darkens, and 5-hydroxymethylfurfural, harmful to health, is formed. Under these conditions, it is very difficult to produce high-quality canned fruits, and conditioning of unripe honey (concentration 75-79 wt.%) takes several hours (Tew [5]), which leads to a further increase in the above-mentioned harmful substances. According to our observational data (certificate #5870, 2014), the intensity of thickening of solutions or liquid mechanical mixtures increases dramatically due to an increase in the surface area of liquid evaporation (a decrease in water content by 15-17% every hour) [6]. In this case, the intrinsic temperature of the solution becomes a secondary factor, due to the installation of a special device in a standard-sized boiler, this area can be increased several times, which allows to achieve intensive evaporation of the solvent at a temperature of 50-60°C.

Following this regime, at the beginning of the research, we developed a technology for the production of honey substitute - invert sugar for bees, in which the temperature required for concentration starts from 62°C and ends at 68°C, reaching a concentration of 82-83 wt.%. According to the testing laboratory "Multitest" (Georgia), the content of 5-hydroxymethylfurfural in invert syrup made using this technology did not exceed 5 mg/kg [7]. The same indicator ranged from 83 to 713 mg/kg in canned fruit brought from the International Food Exhibition in Istanbul (2017), as well as from Georgian enterprises. Below are photos of jams and purees prepared using these technologies, clearly indicating a sharp increase in the oxidation of phenolic compounds (Figures 2-4). Relatively low temperature used for canning (<70°C) excludes the possibility of the formation of caramelans.

Figure 4: White cherry jam by new (2) and to the traditional technologies (3).

Grape Juice Processing

When using grape juice in production of Churchkhela, Georgian delicacy, by traditional technology, a radical change in its color is observed- intensive oxidation of phenolic compounds above a temperature of 50°C, which indicates a high content of these substances in juice. Substances successfully used as antioxidants by various authors: sulfuric anhydride, polyacrylamide, and others (Tsereteli, 1995) (Shatirishvili [8]), protected this product from darkening. Sulfuric anhydride, used by us for a similar purpose, effectively purified juice from sediment for 36 hours, although sometimes granular Clinoptilolite (3-5 mm in size) had to be used for the same purpose. At the completion of this process, grape juice thickened to 82-83 wt.% at a temperature of 52-57°C was characterized by sufficient transparency and crystallized in a short time (2 weeks) (the result of excess glucose) to form a gray-white, fairly dense dough. This gives us an opportunity to make the Churchkhela production process permanent, that is, to get rid of seasonality (more equal provision of the market), while hydrogen ion concentration in juice before treatment and after concentration was almost the same and was pH 3.9.

This indicates that SO2 is removed along with water vapor during the concentration of juice. As for 5-hydroxymethylfurfural, we conducted a qualitative analysis of it by the effect of hydrochloric acid resorcinol on diethyl ether extract (after evaporation of the ether) (Fiehe's test). The control sample was presented by the Churchkhela dough prepared in the traditional way (50% juice+ a mixture of wheat flour as a result of prolonged cooking). The results of the analysis are given below (Figures 5 & 6). In the production of Churchkhela, it is worth noting that the product made in the traditional way, after drying in natural conditions, becomes very dense, which negatively affects its commercial qualities. It can be seen that there is no substance in grape juice that can break down starch, which is present in large quantities (48-57%) in flour. The enzyme α-amylase was used to correct the condition. As a result of carrying out a certain amount of experimental works, we achieved the formation of saccharides of a simpler structure in the required amount in the flour suspension maintaining sufficient elasticity of the dough in the finished product without violating the integrity of the surface: The internal rotation angle of the product was reduced from 1800 to 1460, which turned out to be a satisfactory indicator in terms of increasing the attractiveness of the product for the consumer [9].

Figure 5: Quince puree by new (8) and the same by industrial technologies (9).

Figure 6: Results of analysis (Fiehe's test) of churchkhela made: by new (10) and traditional (11) methods.

Reducing the content of simple sugars in canned fruits has become very relevant in the current century, because their excess in the human body is accompanied by undesirable complications, especially when using folk methods: as a rule, the proportion of food sugar in the finished product significantly exceeds the amount of dry matter of the main raw material. In our research, we focused on the use of invert syrup (>67 wt.%) instead of crystal sugar, given that invert syrup penetrates more easily into the product to be processed, thereby contributing to the removal of excess water from the fruit. Immediately after the initial processing of the fruits, they were carefully put into a heated (> 400°C) syrup, to which the antioxidant SO2 was previously added, the mixture placed in a container was kept in a thermostat at 65 ± 20C for 2 hours, after which the syrup concentration was reduced to 50-54 wt.%. The syrup drained from the container was condensed to 70-72% and poured back onto the fruit in the container. Through such step-by-step processing (with an increase in the concentration of syrup in the intervals up to 83-84%), the total concentration of jam increases to 81-82 wt.%, not accompanied by a decrease in the quality of jam during the shelf life. At the end of the process, the fruits were separated from the syrup and dried by enhanced aeration, and after transfer to the commercial vessel, the atmospheric air was replaced by carbon dioxide, providing complete preservation of the appearance, taste properties (absence of excessive sweetness) and, accordingly, pH (Figures 7 & 8) of the finished product.

Figure 7: Semi-dry Jams from: Quince (12).

Figure 8: Musk Strawberry (13).

Conclusion

1. To remove excess moisture from a food product with low heat resistance, solid, granular structure, it is preferable to limit the drying process to vacuum drying, with a residual pressure of no more than 0.05 kg/cm^2 in a move that provides the desired temperature within 45-50°C and a duration of 75-90 minutes. This makes it possible to preserve biologically active substances (carotene, amino acids), antimicrobial properties of the product as much as possible, to use neutral gas (for example, CO2) for the incubation of anaerobic microbes for the same purpose, during the drying and storage of the finished product;
2. To process liquid low-concentrated fruit juices containing simple sugars and phenolic compounds, it is advisable to use an antioxidant (sulfur anhydride), for concentration - innovative technology based on an increased evaporation surface area that prevents the formation of substances harmful to health (5-hydroxymethylfurfural, caramelans);
3. To preserve a product with a high protein content and a relatively low water content while maintaining its biological activity, it is advisable to use lactic acid fermentation by specific bacteria, with the necessary minimum of simple sugars, with their further conversion into organic acids, which makes it possible to create the necessary amount of hydrogen ions (pH) in the product to be canned to avoid the process of protein decomposition.
4. Making jams from various fruits with minimal consumption of food sugar is facilitated by using concentrated (>67% by weight) invert syrup, which more easily replaces the water in the fruit. By gradually concentrating the syrup used, the total concentration of jam increases to 81-82 wt.%, which ensures the shelf life of fruits by preserving their presentation without syrup, which is enhanced by placing fruits in an oxygen-free vessel.

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