Prospects for the use of sweeteners in the production of pastille confectionery

Anna Snegireva[1*], and *Larisa* Meleshkina[1]

[1]Polzunov Altai State Technical University, Barnaul, Russia

Abstract. Data on the current health condition of the population convincingly proves the need to reduce the caloric content of the diet, reducing the amount of added sugar and animal fats in products. However, people cannot give up confectionery and sweet dishes, which have a positive effect on the feeling of completion of a meal and mood. Therefore, the purpose of this paper is to develop a recipe and marshmallow technology with a full replacement of sugar for erythritol. Moreover, the author partially replaced the traditional mashed apple with black currant puree in the marshmallow recipe to improve organoleptic characteristics and increase the content of essential nutrients. The author also studied the effect of erythritol and black currant puree on the marshmallow mass and finished products quality parameters. The author carried out the research using commonly accepted methods. The author experimentally proved a positive effect of replacing apple puree with 40% black currant puree on the quality indicators of semi-finished and finished products. The author substantiated the possibility of replacing sugar with erythritol and investigated the addition of the FitParad No. 10 sweetener mixture to enhance the sweetness of the finished product. Considering the results of the research, the author has developed a recipe and technology for sugar-free white marshmallows. It is proved that marshmallow based on erythritol as a sugar substitute is not available according to literature data and market analysis of pastry confectionery products.

1 Introduction

Regardless of not being the main source of nutrition, confectionery is a part of the diet for all age groups. Their consumption has increased rapidly in recent years due to an outbreak of a new coronavirus infection (COVID-19). In conditions of self-isolation and in times of stress, a person begins to consume a lot more sugary, high-calorie foods, which have a negative impact on health.

A group of scientists from the National Medical Research Center for Internal Medicine and Preventive Medicine has developed a series of pandemic nutrition recommendations:

- Limiting the consumption of added sugar. The WHO recommended level of sugar intake is less than 5% of total energy intake (this corresponds to 6 tsp). Minimize the amount of added sugar or honey in foods and beverages.

* Corresponding author: sne.anna@mail.ru

- Limiting fat intake. The WHO recommends limiting fat intake to less than 30% of total energy intake, with saturated fat accounting for no more than 10% of the total [5].

These recommendations are relevant not only in self-isolation conditions but also in any condition that combines a sedentary lifestyle and excessive caloric intake.

Nutritional deficiencies are leading to the development of nutrition-dependent diseases, including type 2 diabetes. The global prevalence of this disease has increased by 30% over the past 10 years; currently, the approximate number of affected patients reaches 435 mln, which is ~9.5% of the total adult population [17]. In the Russian Federation, the prevalence of diabetes is also increasing; the number of patients diagnosed with it is ~4.5 mln (3.1% of the population) [18]. The author assumes that similar (if not higher) numbers of patients remain undiagnosed with diabetes, which leads to significant shortcomings in providing medical care. Among patients with diabetes mellitus in the Russian Federation, 92.1% have type 2 diabetes, and among the latter, the proportion of men is 71%, the proportion of those over 65 is 55% [1, 4].

Despite increasing public awareness of the principles of rational nutrition, people have consumed and will continue to consume confectionery products that induce gustatory pleasure and a sense of completion of the meal.

Therefore, it is relevant to develop confectionery products with a reduced amount of saturated fat and added sugar, and at the same time containing essential nutrients.

The pastilles, which contain fruit puree with a high pectin content and no added fats, are of great interest from this point of view. At the same time, these products contain large amounts of sugar, which can be successfully replaced with a sweetener.

The texture of the confectionery is formed depending on the phase condition of the sweetener. Consequently, the author selects the technological regimes and parameters. Consideration of factors affecting the behavior of sweeteners during production technology is essential for the formation of a defined structure and quality of confectionery products [13, 16].

However, when choosing a sweetener, it is also necessary to focus not only on its technological properties, without which it is impossible to produce whipped mass, but also on the naturality of the composition.

The food product sweetener erythritol E968, obtained by fermentation of carbohydrate sources with safe and suitable for food use osmophilic yeast microorganisms, fulfills these requirements.

Erythritol is reported to be as consistent as possible with the notion of a natural ingredient in many fruits, mushrooms, and fermentation products. The caloric value of the sweetener is from 0 to 0.2 kcal/g, which characterizes it as the perfect substitute for sugar in confectionery and other types of food products [21].

Therefore, the research aims to develop the technology of marshmallows with a complete replacement of sugar for erythritol. Moreover, the author partially replaced the traditional apple puree with black currant puree in the marshmallow recipe, studied the effect of erythritol and black currant puree on the quality indicators of marshmallows mass and finished products to improve organoleptic characteristics and increase the content of essential nutrients.

2 Materials and methods

The author used the following recipe components to make marshmallows:

- Fresh apples [12].
- Frozen black currants [2].
- Chicken eggs [9].
- Erythritol [7].

- Drinking water [3].
- First food grade agar [6].
- White crystalline sugar [10].

The author measured the volume of whipped mass with a measuring jug to determine the whipping properties of the fruit puree with protein. At the same time, the whipped mass was flattened in the whipping tank. The author made a mark on the wall of the tank and used a measuring cylinder to determine the volume of water required to bring it to this mark:

- Determination of organoleptic characteristics of marshmallows [20].
- Determination of the mass fraction of marshmallow moisture [8].
- Determining the density of marshmallows [19].

3 Results

Black currants exceed apples several times in dietary fiber, potassium, magnesium, iron, and vitamin C. At the same time, any changes in the traditional recipe affect the quality indicators of the finished product. The author took the recipe for vanilla marshmallow No. 14 as a basis [14].

Apples and black currants were mashed by rubbing and boiling with a dry matter content of 15%±1%. Then the author replaced apple puree with black currant puree in the amount from 20% to 100% in 20% increments. The author did not add lactic acid to the recipe because black currant puree has higher acidity than apple puree and vanilla essence.

According to classical technology, the first stage is whipping a portion of white sugar with fruit puree and egg white in the mixer bowl at a speed of 250–300 rpm for 8–10 minutes. In this case, there is an increase in the volume of the mass. The author measured the whipping mass to trace the effect of replacing the apple puree with black currant puree. Figure 1 shows the results of the research.

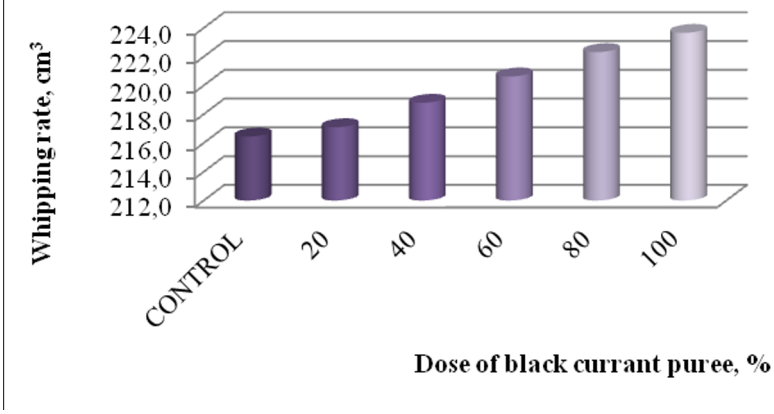

Fig. 1. Effect of the black currant puree dosage instead of apple puree on the whipping power of marshmallow mass. *Source*: Compiled by the authors.

The picture shows that with increasing the dosage of black currant puree, there is an increase in whipping. This is probably because black currant contains pectin and several organic acids, which increase the foaming ability of protein. Increased whipping certainly affects the airiness of the marshmallow and decreases its density.

For further research, the author gradually added hot agarose-sugar syrup to the whipped mass of mashed sugar and protein, according to the technology with continuous whipping,

which was pre-cooked to 84.5%±0.5%. Then, the author shook off the marshmallow mass from the confectionery bag and left it to stabilize for twenty-four hours. After stabilization, the author examined the quality indicators of the obtained marshmallows.

An important indicator normalized according to the GOST 6441-2014 [11] is the mass fraction of moisture, which varies depending on the input recipe components. In this regard, the next step was to analyze the effect of replacing the apple puree with black currant on the mass fraction of moisture marshmallows. Figure 2 shows the results.

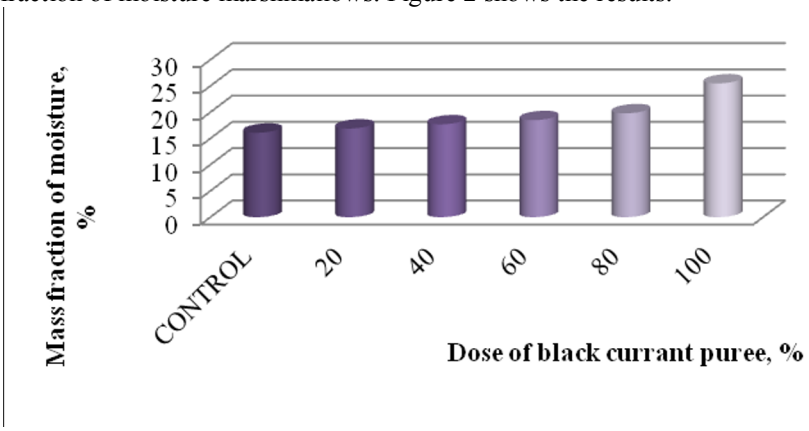

Fig. 2. Effect of the dosage of black currant puree instead of apple puree on the mass fraction of moisture in marshmallows. *Source*: Compiled by the authors.

The diagram shows that with increasing the dosage of black currant puree mass fraction of moisture in the finished marshmallow products increases. That is due to the higher moisture content of black currant puree, despite the same content of soluble solids in both types of semi-finished products.

According to the standard, the moisture content in the marshmallow should not exceed 25%. Therefore, marshmallow products, except for marshmallow, which is based on 100% black currant puree (its mass fraction of moisture is 25.5%), satisfy the requirements.

One of the most important indicators of the airiness of the finished product is the density, the value of which affects many factors, including the type of fruit puree. Therefore, the next step was to determine the impact of replacing the apple puree with black currant on the density of the finished product. Figure 3 shows the results of the research.

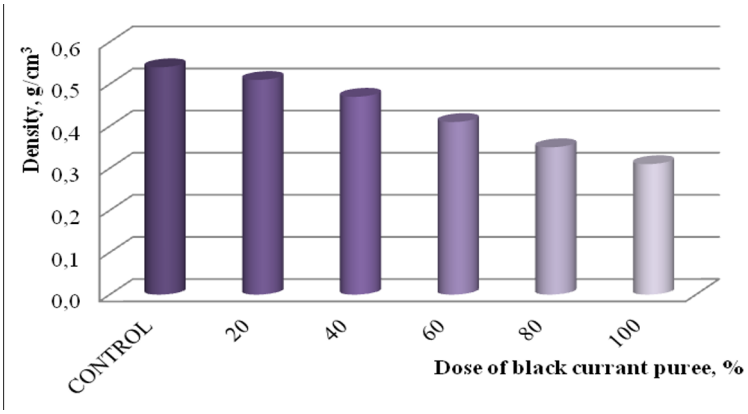

Fig. 3. Effect of the dosage of black currant puree instead of apple puree on the marshmallow density. *Source*: Compiled by the authors.

The density depends on the whipping rate, so as the amount of blackcurrant puree increases, the density of the products decreases. With an increase in the content of black currant puree in the recipe, there is an increase in the mass fraction of pectin and organic acids involved in the formation of the cellular foam structures. That affects the reduction of marshmallow density.

According to the standard, the density of the marshmallow should be no more than 0.6 g/cm^3. Therefore, this technology can be used to produce marshmallows with any ratio of apple puree to black currant puree. However, the decisive factor in choosing a consumer confectionery is its organoleptic characteristics, as reflected in Figure 4.

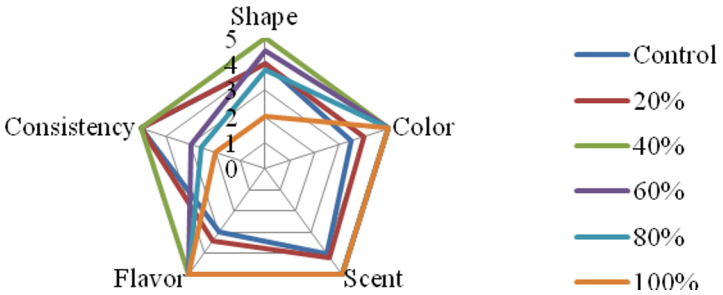

Fig. 4. Effect of the dosage of black currant puree instead of apple puree on organoleptic characteristics of marshmallows. *Source*: Compiled by the authors.

Analysis of organoleptic indicators suggests that increasing the dosage of black currant puree significantly improves the color, scent, and flavor of the product, along with a deterioration in the consistency of marshmallows due to excessive porosity. Excessive airiness makes the marshmallow brittle. It becomes crumbly, which also has a negative impact on the preservation of shape.

A comprehensive analysis of organoleptic and physic-chemical parameters allowed the author to stop at the optimal dosage of black currant puree instead of apple in the amount of 40%.

At the next stage, the author substituted white sugar for the natural sweetener erythritol and removed molasses from the recipe for marshmallows with black currant. Since the technological properties of erythritol are very similar to white sugar, the author replaced it in the same amount. At the initial stage, the author produced marshmallows according to the classic technology, according to which a portion of the erythritol was introduced in dry form into the puree with the protein during whipping. At the same time, the second part was used in the cooking syrup with agar. First, the author examined the organoleptic characteristics of the products, which revealed the presence of crystals in the marshmallow, possibly due to the poor dissolution of sweetener in the puree during the whipping process. Moreover, the whipping of the marshmallow mass decreased compared to the marshmallow with white sugar (Figure 5).

Therefore, the author decided to whip the puree with the protein and use the whole mass of erythritol only when cooking the syrup. The author also determined the density and organoleptic characteristics of the obtained marshmallows (Figures 6 and 7).

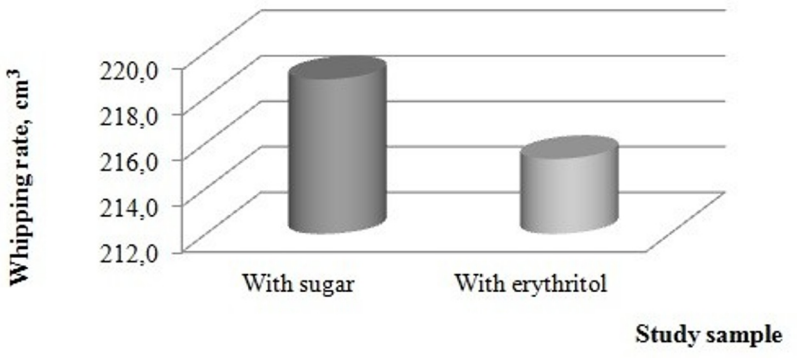

Fig. 5. Effect of replacing white sugar with erythritol on marshmallow whipping. *Source*: Compiled by the authors.

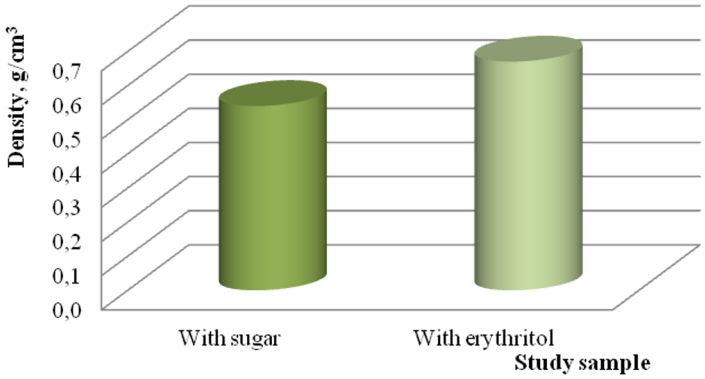

Fig. 6. Effect of sugar replacement with erythritol on marshmallow density. *Source*: Compiled by the authors.

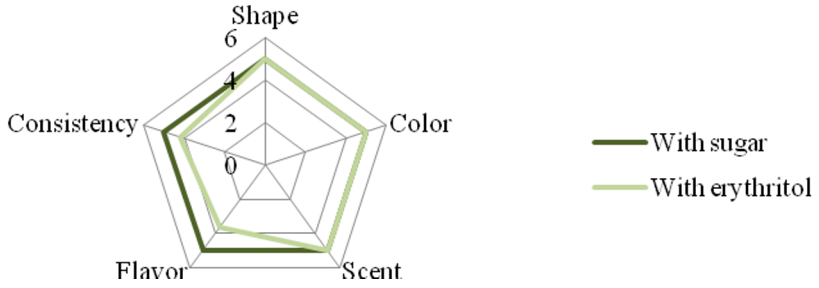

Fig. 7. Effect of sugar replacement with erythritol on organoleptic characteristics of marshmallows. *Source*: Compiled by the authors.

Figure 6 shows that when replacing sugar with erythritol there is an increase in the density of the finished product. This is due to the difference in physic-chemical parameters of erythritol and sugar. Syrup with erythritol is less viscous, incomparable with sugar syrup. After adding the syrup to the whipped mixture of fruit puree with protein, the volume of the mass increases slightly.

The density of marshmallows with erythritol reached 0.67 g/cm^3, which does not fully meet the standards for marshmallow products. However, these products can be attributed to specialized products with the development of appropriate regulatory documentation.

The consistency and taste of the finished product have also become worse, along with the increased density of the product. The consistency is less porous, and the taste is sourer due to less erythritol sweetness. Therefore, the author decided to increase the sweetness of the product by adding a complex food additive - a mixture of sweeteners FitParad No. 10. It has zero calories, natural composition, and high sweetness at minimal dosage, which does not affect the physical and chemical properties of the marshmallow.

The author produced marshmallows with erythritol in syrup from 1% to 10% of FitParad No. 10 to the mass of the finished product to select the optimal dosage. The tasting committee of nine people determined the taste of the received products. According to the results of the evaluation, the author found that 6% of FitParad No. 10 to the mass of the finished product is enough for optimum sweetness.

Therefore, the author developed the recipe presented in Table 1.

Table 1. Recipe for marshmallows with erythritol.

Raw materials, semi-finished products	**Raw material consumption, kg**	
	Naturally	**In solids**
Recipe for ready-made marshmallows from semi-finished products per 1,000 kg		
Marshmallows without erythritol powder	983.65	811.5
Erythritol powder	29.75	29.75
Total	1013.4	841.26
Output	1000	830
Recipe of marshmallow semi-finished product without erythritol powder for 983.65 kg		
Black currant puree	155.39	23.31
Apple puree	388.47	58.27
Egg white	64.64	7.76
Syrup with agar	854.58	726.39
Total	1463.08	815.73
Output	983.65	791.26
Recipe for semi-finished agar syrup for 854.58 kg		
Erythritol E968	670.16	663.46
FitParad No. 10	6	5.94
Food agar	8.54	7.17
Total	493.78	461.45
Output	854.58	726.39

Source: Compiled by the authors.

According to the developed technology, black currant puree and apples with a solids content of 15%±1% and egg white were loaded into the mixer bowl and beat at a stirrer speed of 250–300 rpm from 8 to 10 min. Then the author slowly added agar syrup and continued whipping for 1–2 min. Then, the mass was shooked off and left at room temperature for 24 hours to stabilize. To prevent the adhesion of the finished products, they were rolled in erythritol powder.

To prepare the syrup, agar was first soaked in water (in the amount of which does not exceed 80% of the weight of erythritol) for 15 minutes. Then the author boiled it and added erythritol and FitParad No. 10. The syrup is boiled with stirring to a dry matter content of 84.5%±0.5% and a temperature of 110 °C.

Therefore, the author developed a recipe and technology that eliminates white sugar in the pastille confectionery and improves its nutritional value by replacing the mashed apple with a puree of black currant.

4 Discussion

The concern for low-calorie diets and the growing incidence of diabetes among the population has set the food industry the task of developing new types of confectionery products using sweeteners in their composition. The pastilles with fruit puree, rich in vitamin and mineral composition, and mass fraction of pectin, cause an interest for the industry. Literature review and market analysis showed that there are not enough goods of this kind. There are studies aimed at the development of recipes and technology of marshmallows using black currant puree, fructose, and inulin [15]. The authors evaluated the quality indicators of developed products and blood glucose levels of volunteers after consuming marshmallows. In this case, pectin was used as a texture-forming agent.

According to the results, the density of marshmallows on sweetener, as well as in the author's research, increased, compared to traditional marshmallow (0.45 g/cm^3), and was 0.55 g/cm^3 for products with fructose and 0.6 g/cm^3 for products developed with the use of inulin. The analysis of glucose levels in the blood of volunteers showed that sugar substitution leads to a decrease in the hyperglycemic response of the body half an hour after the consumption of the analyzed sample and contributes to obtaining a "sugar" curve without dangerous abrupt peaks [15].

In the retail network, there are marshmallows with apple puree, produced by the "Rot Front" confectionery factory, using sorbitol, isomalt, maltitol, and maltitol syrup as sweeteners. Apple marshmallow with stevia and isomalt is produced under the "Smart Sweets" brand. The confectionery company "Neva" also produces marshmallows using isomalt. The "Giselle" brand sells apple marshmallows with maltitol syrup, maltitol, and sorbitol.

Therefore, at this stage, there is no production of marshmallows using erythritol.

5 Conclusion

The author experimentally proved the positive effect of adding black currant puree on whipping marshmallow mass, density, and organoleptic characteristics of the finished marshmallow. The author justified the dosage of black currant puree instead of apple puree in the amount of 40%. The author studied changes in the whipped marshmallow mass, density, and organoleptic characteristics of marshmallows. The author also studied the results of excluding white sugar from the formulation and its replacement with erythritol. The author found that the marshmallow with erythritol does not deteriorate color, flavor, and shape but slightly increases the density and, consequently, affects the consistency. This fact suggests the need to develop separate regulatory documentation for this type of product. The author found the taste deterioration due to decreased sweetness, which was balanced by the addition of the sweetener mixture FitParad No. 10. As a result of this research, the author developed the recipe and technology of marshmallow with partial replacement of apple puree with black currant and full replacement of sugar with erythritol.

The practical significance of the work lies in expanding the range of confectionery products used in the diet for people with diabetes mellitus and a low-calorie diet. To strengthen the evidence base, it is necessary to conduct clinical trials of the developed marshmallow and to determine the blood glucose level when consuming it.

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References

1. A.E. Bagriy, E.V. Suprun, E.S. Mikhailichenko, Chronic heart failure and Type 2 diabetes: The problem's state, Russian Journal of Cardiology, **25**, **4**, 79–85 (2020)
2. Committee of the Russian Federation for Standardization, Metrology Certification, Quick-frozen fruits and berries. General specifications, GOST 29187-91, 23 December 1991, Moscow, Gosstandart, (1993)
3. Committee of the Russian Federation for Standardization, Metrology Certification, Drinking water. General requirements for organization and quality control methods, GOST R 51232-98, 17 December 1998, Moscow, Gosstandart (1998)
4. I.I. Dedov, M.V. Shestakova, O.B. Vikulova, Diabetes mellitus in the Russian Federation: prevalence, morbidity, mortality, parameters of carbohydrate metabolism and structure of hypoglycemic therapy according to the Federal Register of Diabetes Mellitus, Diabetes Mellitus, **3**, **21**,144–159 (2018)
5. O.M. Drapkina, M.G. Gambaryan, B.E. Gorny, Health promotion and prevention of chronic non-communicable diseases in the context of the COVID-19 pandemic. Consensus of experts of the National society of evidence-based pharmacotherapy and the Russian society of the prevention of non-communicable diseases, Cardiovascular Therapy and Prevention, **3**, 270–293 (2020)
6. Federal Technical Regulation and Metrology Agency, Food grade agar. Specifications, GOST 16280-2002, 30 May 2002, Moscow, Rosstandart (2002)
7. Federal Technical Regulation and Metrology Agency, Food additives. Sweeteners of food. Terms and definitions, GOST R53904-2010, 2 November 2010, Moscow, Rosstandart (2010)
8. Federal Technical Regulation and Metrology Agency, Confectionery. Methods for determination of moisture and solids, GOST 5900-2014, 5 December 2014, Moscow, Rosstandart (2014)