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# Development of a Technology for Chocolate Mass with a Complex of Functional Ingredients

**Manana Tkeshelashvili and Galina Bobozhonova***

*Plekhanov Russian University of Economics, Moscow, Russia*

***Correspondence to:**
Galina Bobozhonova
Plekhanov Russian University of Economics
Moscow, Russia.
**E-mail:** mananatk@yandex.ru

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## Abstract

The modern consumer is making efforts to adhere to health-conscious eating trends. This shift in consumer behavior compels manufacturers to innovate, altering production methods and ingredient compositions of familiar products. Investigating the potential of chocolate as a vehicle for beneficial, functional ingredients, this study pursued the development of a novel chocolate mass production technology. The method involved careful dosing of functional ingredients, assuring consumption levels comparable to physiological norms. The process consisted of various stages and sequences, determining the optimal integration of both primary and functional ingredients into the fundamental chocolate recipe. A crucial aspect of the research was the design of a protein component, achieved through a blend of high-protein sunflower meal and whey protein concentrate. This composition provides an array of essential amino acids, closely matching those found in an ideal protein. The inclusion of this simulated protein component in the chocolate formulation aimed to increase the content of complete protein. Simultaneously, the carbohydrate profile of the chocolate was altered, replacing sugar with maltitol, a natural sugar substitute. Maltitol's lack of hyperglycemic effect contributes to the overall goal of transforming the confectionery item into a more health-conscious choice. Moreover, the research introduced milk thistle sprouts sublimate into the formulation, providing silymarin, a natural amalgamation of biologically active substances. This inclusion not only boosted the nutritional value of the chocolate but also imbued it with the characteristics of a functional food product. In conclusion, the deliberate introduction of physiologically functional ingredients in the formulation of chocolate significantly enhances its nutritional profile, thereby offering consumers a healthier, beneficial alternative in the realm of confectionery.

## Keywords

Food chemistry, Maltitol sugar substitute, Silymarin

## Introduction

Analysis of global trends in the development of confectionery technology suggests that, along with an expanding range of traditional products, there is a growing number of products that have increased nutritional value through the introduction of physiologically functional ingredients that promote better health [1-4].

Considering global trends in the development of the food industry with a focus on functional foods, there is a need for a significant change of the chemical composition of confectionery products to raise the content of essential ingredients and macro- and micronutrients, while reducing the energy value [5-8].

At present, chocolate remains one of the most popular confectionery products not only among children but also adults. In this connection, an urgent and promising direction of development of confectionery production is the scientifically grounded development of competitive technology for manufacturing chocolate enriched with physiologically functional ingredients [9].

Traditional chocolate based on cocoa butter and sugar contains a maximum of 9.2 g of protein, 50.4 g of carbohydrates, and 34.7 g of fat per 100 g of product [10]. These data clearly show that traditional chocolate contains a low percentage of protein and that the content of essential amino acids in it is not balanced.

Various attempts have been made to increase the nutritional value of chocolate masses: the inclusion of additional types of protein-containing raw materials and additives with a higher protein content; the introduction of biologically active additives or components with a higher content of micronutrients [11, 12]. A common disadvantage of known analogs is the insufficient nutritional value of the finished product due to the low protein content, high carbohydrate content, and inadequate balance of the amino acid composition of the introduced protein components. Furthermore, none of the compositions have a hepatoprotective component, which provides appropriate properties.

This study aims to develop the technology and formulation of chocolate mass containing a complex of physiologically functional ingredients. To achieve the goal of this study, we have set several objectives:

- We endeavor to validate the selection of physiologically functional ingredients that would integrate seamlessly into the composition of the chocolate mass.
- We plan to engineer a comprehensive protein component, employing a blend of animal and plant proteins that embody a complete array of amino acids, thereby meeting the criteria for an ideal protein.
- We are committed to studying how both the core formulation and functional ingredients impact the qualitative and technological attributes of the chocolate masses.

# Materials and Methods

## Materials

The criterion for the selection of functional ingredients was the presence of a proven physiological effect, as well as technological efficiency associated with the formation of given rheological properties.

The protein component was formulated using high-protein sunflower meal (OZRKD Biotekh-Pro LLC), a functional product of deep biotechnological processing of sunflower meal with a pleasant taste and smell, neutral color, and 45 - 48% protein content. The second ingredient in the mixture is the Lacprodan 80 whey protein concentrate (Arla Foods Ingredients amba, Denmark), a free-flowing powder of pale cream color with humidity not exceeding 6.0%.

As a sugar substitute, the chocolate formulation used Bionova maltitol (Russia). Maltitol has a pleasant, sweet taste with an intensity of almost 90% of that of regular sugar. It has a low glycemic index (GI = 45) and does not cause a sharp increase in blood glucose levels. The caloric value is half that of sugar. Maltitol is also as close as possible to sugar in its technological properties. It protects teeth from caries and inhibits the activity of cariogenic bacteria.

Bionova inulin (Russia) is a natural soluble dietary fiber derived from chicory roots. It has prebiotic properties, strengthens the immune system, increases the absorption of calcium, reduces hunger, and has a low glycemic index (GI = 5).

To increase the biological value, we used the Floradar milk thistle sprout sublimate (Tsentr nezavisimykh ekspertiz LLC, Russia). It contains the antioxidant silymarin – a hepatoprotector of the liver that actively protects and restores liver cells. The temperature of silymarin decomposition is above 200 °C, so it can be added not only to chocolate and candy, where the heat treatment is at about 45 °C but also to pastry products, where the temperature treatment is 180 - 200 °C.

## Methods

This study was conducted using the following methods:

- The organoleptic method – determination of physical and organoleptic characteristics (appearance, taste, aftertaste, degree of sweetness, structure, and texture).
- Extraction and gravimetric method – presence and content of fat using the Soxtherm automatic extraction unit by Gerhardt.
- The calculation method – total dry cocoa residue (according to GOST 31682), skimmed dry cocoa residue (according to GOST 31723).
- The calculation method and Kjeldahl method (GOST 34551) – determination of the mass fraction of protein.

### Viscosity and yield strength of chocolate according to Casson

To determine the viscosity and yield strength of chocolate, we used the method developed by the International Confectionery Association (ICA) – Method 46 Viscosity of Cocoa and Chocolate Products. For measurements, we used a HAAKE Viscotester iQ viscometer. The measuring geometry CC25 DIN/Ti was used for the tests. We placed 16.1 ml of the sample in a glass container, heated it, and kept it at a temperature of 52 °C for 45 - 60 min. Further, we carried out testing in accordance with a given profile of changes in shear rates and automatic processing of the obtained test results. The traditional Casson extrapolation model was used to calculate the yield strength.

### Determination of the mass fraction of fat using the extraction-gravimetric method

Extraction of fat from the analyzed sample of chocolate weighing 10 - 15 g was carried out according to the Soxhlet method with petroleum ether. The mass fraction of fat was determined after the removal of the solvent using a Soxtherm (Gerhardt) automatic extraction unit. The mass fraction of fat X, %, was calculated using the formula:

$$X = \frac{(m_2 - m_1)\ \text{x}\ 100}{m} \tag{1}$$

Where, $m_1$ is the mass of the empty flask, g; $m_2$ is the mass of the flask with the resulting fat, g; and $m$ is the mass of the analyzed chocolate sample, g.

### Determination of defatted cocoa solids content and total cocoa solids content

A sample of chocolate weighing 10 - 15 g was placed in a centrifuge tube. 30 - 35 cm$^3$ of petroleum ether was added, mixed, and centrifuged for 10 min at a speed of 3,000 rpm. The supernatant was discarded. The formed precipitate was dried in an oven at 100 °C. The resulting dried precipitate was ground into powder, poured into distilled water, shaken, and centrifuged for 10 min at a speed of 3,000 rpm. The supernatant was discarded. The procedure was repeated until a clear supernatant was obtained. The precipitate was dried in an oven at 100 °C until a constant weight was reached. The mass fraction of the defatted cocoa solids content in chocolate Y, %, was calculated using the formula:

$$Y = \frac{(M\ \text{x}\ 1.43)100}{m} \tag{2}$$

Where, $M$ is the mass of the dried precipitate, g; 1.43 is the conversion factor; and $m$ is the mass of the analyzed sample of chocolate, g.

The mass fraction of the total cocoa solids content in chocolate Z, %, was determined using the formula:

$$Z = X + Y \tag{3}$$

Where, $X$ is the result of determining the mass fraction of fat in chocolate according to formula 1, %,

$Y$ is the result of determining the mass fraction of defatted cocoa solids content in chocolate according to formula 2, %.

### Determination of the mass fraction of protein using the Kjeldahl method

Mineralization was carried out using a system including a BUCHI K-350 semi-automatic distiller and a BUCHI IR SpeedDigester K-425/436 digester (Switzerland). From a homogeneous chocolate sample, a sample weighing 0.7 - 0.8 g was placed in a Kjeldahl flask for mineralization. The catalyst and 15 cm$^3$ of concentrated sulfuric acid were added. The prepared flasks were placed in a mineralizer and heated at 440 °C for 20 min. Mineralization was considered complete when the contents of the flask became transparent. After mineralization, ammonia was distilled off. The protein content was calculated considering the conversion factor for nitrogen per protein. The mass fraction of nitrogen N, %, in the sample was calculated using the formula:

$$N = \frac{(A - V)\ \text{x}\ K\ \text{x}\ 0.0014\ \text{x}\ 100}{m} \tag{4}$$

Where, A is the volume of 0.1 mol/dm$^3$ sodium hydroxide solution used for titration of the sulfuric acid solution in the control experiment, cm$^3$; V is the volume of 0.1 mol/dm$^3$ sodium hydroxide solution used for titration of sulfuric acid in the test solution, cm$^3$; $K$ is the correction factor to the titer of 0.1 mol/dm$^3$ sodium hydroxide solution; and 0.0014 is the amount of nitrogen equivalent to 1 cm$^3$ of 0.05 mol/dm$^3$ of sulfuric acid solution.

The mass fraction of protein C, %, was calculated using the formula:

$$C = N\ \text{x}\ 5.30 \tag{5}$$

Where, $N$ is the mass fraction of nitrogen, %; and 5.30 is the nitrogen-to-protein conversion factor for chocolate.

### Energy value

The energy value (EV) of chocolate was calculated using the formula:

$$EV = P\ \text{x}\ 4.0\ +\ F\ \text{x}\ 9.0\ +\ C\ \text{x}\ 2.4 \tag{6}$$

Where, EV is the energy value of 100 g of chocolate, kcal; Content in g/100 g of the product: P – proteins, F – fats, C – carbohydrates; and the number of kcal formed from nutrients: P – 4.0; F – 9.0; C – 2.4.

### Taste evaluation

Experts from the Research Institute of Food Security took part in the taste evaluation of chocolate samples. Sample evaluation was carried out based on appearance, taste, aftertaste, degree of sweetness, structure, and texture for compliance with the requirements of the regulatory and technical documentation for this type of product by controlling the sample of products.

## Results and Discussion

### Chocolate mass composition

To obtain chocolate enriched with physiologically functional ingredients, we propose the following composition of chocolate mass (Table 1).

The required properties are provided by combining the components of the composition. The developed chocolate mass contains from 30 to 35 wt.% cocoa mass and 15.0 - 21.0 wt.% cocoa butter, which ensures the most harmonious organoleptic properties and optimal technological properties of the obtained product mass. Cocoa mass below 30 wt.% and cocoa butter below 15 wt.% will lead to the deterioration of technological and organoleptic properties of the product expressed in the loss of shrinkage and the distinctive gloss.

**Table 1:** Composition of the developed chocolate mass.

| Component | Functional Property | Content, wt.% | | |
|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 3 |
| Cocoa mass | Cocoa product that provides the basic properties and characteristics of chocolate | 30.0 | 33.0 | 35.0 |
| Cocoa butter | Cocoa product that provides the basic properties and characteristics of chocolate | 21.0 | 18.0 | 15.0 |
| Protein | Protein-containing product including all essential amino acids | 29.0 | 30.0 | 31.0 |
| Maltitol | Provides sweetness to the product and reduces the energy content of the product | the rest | | |
| Inulin | Dietary fiber, harmonizes the taste of high-protein chocolate | 0.1 | 0.3 | 0.5 |
| Stevia | Provides taste harmonization in high-protein chocolate, especially when sugar substitutes are used | 0.1 | 0.15 | 0.2 |
| Concentrated soybean phosphatide | Thinner, reduces viscosity and increases flowability | 0.4 | 0.5 | 0.6 |
| Milk thistle germ sublimate | Contains silymarin | 1.4 | 2.5 | 3.5 |
| Flavoring | Flavor enhancer | 0.1 | 0.15 | 0.2 |

An increase in the amount of cocoa mass above 35 wt.% and cocoa butter above 21 wt.% will result in a deterioration of the technological properties of the resulting chocolate masses. An increase in cocoa liquor and cocoa butter content will generally result in a more fluid chocolate mass. High cocoa-content chocolates tend to have a lower viscosity, which can make them more difficult to work with in some applications [13, 14]. Moreover, increasing the cocoa content in chocolate products will raise the cost of production, which may translate to higher retail prices. This could make the product less competitive in the market. With a higher content of cocoa liquor and cocoa butter, there is less room for other ingredients, including protein sources.

A soybean phosphatide concentrate (lecithin) content of 0.4 - 0.6 wt.% ensures optimum viscosity and flow of the chocolate mass. Reducing the amount of soy phosphatide concentrate (lecithin) below 0.4 wt.% will increase the viscosity of the chocolate mass. Raising the amount of soy phosphatide concentrate (lecithin) above 0.6 wt.% will result in greater fluidity of the chocolate mass. Both changes will make the process much more difficult [14].

The developed chocolate mass has 29.0 - 31.0 wt.% of the protein component, which consists of a mixture of high-protein sunflower meal flour and whey protein concentrate in the ratio (7.9 - 8.0):(2.5 - 2.6).

Variation in the ratio of these protein products in the mixture depends on the actual content of essential amino acids in the specific batches of raw materials used. Of the wide range of protein products used, it was suggested to use a combination of whey protein concentrate and high-protein meal from sunflower meal. As a secondary product obtained in the processing of sunflower seeds, this flour is much cheaper than other protein ingredients and is expedient for use in the composition of protein mixtures [15, 16].

Protein is most effectively used when the content of all essential amino acids in the diet corresponds exactly to the norms of need. In world science and practice such a protein is called ideal. The concept of the ideal protein was introduced in the early 1950s by Dr. William Rose [17], a biochemist at the University of Illinois. In his studies, Rose found that protein utilization in the body was limited by the availability of the least abundant essential amino acid. Therefore, he suggested that an ideal protein would contain all the essential amino acids in the proportions required by the body for growth and maintenance. This concept was later confirmed by other researchers, such as Elango et al. [6] who conducted a study on the effects of different types of dietary proteins on nitrogen balance in healthy adults. They found that a protein source containing all the essential amino acids in the right proportions (i.e., an ideal protein) resulted in the most efficient nitrogen utilization.

Furthermore, a review article by Wu et al. [7] summarizes the current understanding of the concept of ideal protein and its importance in human nutrition. The authors state that an ideal protein contains all the essential amino acids in the correct proportions and that this type of protein is most efficiently utilized by the body for protein synthesis and other metabolic functions. The authors also emphasize that consuming a varied diet that includes different types of protein sources (e.g., animal and plant-based) can help ensure that all the essential amino acids are consumed in the right amounts.

Given these norms of individual amino acid requirements, and using the method of computer modeling, we compiled three mixtures that approximate the content of essential amino acids to the ideal protein.

Reducing the amount of protein component below 29.0 wt.% is not advisable given the goal of obtaining chocolate enriched with physiologically functional ingredients. Increasing the amount above 31.0 wt.% leads to a deterioration of organoleptic properties, the chocolate bar is poorly structured when cooling, the mass gets a plasticine-like structure, and the protein essence of the product is excessively pronounced.

The chocolate mass contains 0.1 - 0.5 wt.% of inulin. Inulin is prebiotic from the group of soluble dietary fiber. It is introduced into the chocolate mass to ennoble the taste of the product. Inulin can combine and bind together the flavors of individual ingredients, creating a single integrated taste of high-protein chocolate mass [18]. The amount below 0.1 wt.% does not affect the taste of the mass. Increasing the amount above 0.5 wt.% does not produce a further taste-ennobling effect on the mass.

The chocolate mass composition also includes stevia 0.1 - 0.2 wt.%. This ingredient combined with maltitol at the lower level ensures the most optimal palatability of the chocolate mass, especially with high protein content. The amount below 0.1 wt.% will not yield the desired sweetness of the mass. Adding more than 0.2 wt.% leads to the retention of the traditional taste of sweeteners, and more than 0.2 wt.% produces a bitter aftertaste.

Next, the chocolate mass includes milk thistle sprout sublimate at 1.4 - 3.5 wt.%. This amount of ingredient contains from the adequate (30 mg) to the upper allowable (80 mg) level of silymarin daily intake. Silymarin provides the main pharmacological action of milk thistle [19]. It is widely used in clinical practice as a hepatoprotector, antioxidant, and immunomodulator [20]. Milk thistle sprouts sublimate contains 2.25 g of silymarin per 100 g of sublimate. Its introduction in an amount of only 1.4 wt.% can ensure an adequate level of consumption.

The rest of the chocolate mass includes maltitol. This ingredient is intended to ensure the sweetness of the chocolate mass. Maltitol is used when necessary to reduce the caloric value of products since its caloric value is lower than in sucrose [13, 21].

## Procedure for the preparation of chocolate mass

The developed chocolate mass is prepared as follows. The first stage consists in obtaining the protein component from two ingredients: high-protein flour from sunflower meal and whey protein concentrate. Based on the data of quality certificates on the content of essential amino acids in the batches of raw materials used, a mathematical model of the protein component with a complete set of essential amino acids and the maximum possible amino acid score of the limiting essential amino acid for the given protein component has been calculated.

At the second stage, the chocolate is prepared. The chocolate of the proposed composition is prepared as follows. The recipe components are dosed in the following sequence: grated cocoa, cocoa butter, a protein component, inulin, stevia, sugar, maltitol, and milk thistle germ sublimate. Then they are mixed in a mixer for at least 20 min until the mass has a homogeneous, plastic consistency. Grinding of the resulting chocolate mixture is carried out with a ball mill. The degree of grinding should be 20 - 30 microns.

The processes of dissolution and homogenization of the chocolate mass are a single technological stage. At this stage, flavoring and lecithin are added and the chocolate mass is transformed into a fluid state with the required viscosity. Conching of the chocolate mass is performed in a conching machine for 4 - 5 hours at 45 - 55 °C.

The finished chocolate mass is filtered and transferred to the tempering receivers. Tempered chocolate mass is fed into the funnel of the pouring head. Then, the chocolate mass is transferred to fill the molds. Next, a vibrating conveyor is used to remove air bubbles and distribute the mass evenly.

The physicochemical and organoleptic characteristics of the developed chocolate established in the course of this study do not contradict the requirements of GOST 31721-2012 for dark chocolate (Table 2). GOST 31721-2012 provides chocolate with at least 35% of the total dry residue of cocoa products, including at least 18% of cocoa butter and at least 14% of skimmed cocoa product dry residue. As can be seen from the data presented (Table 2), it is possible to use the term "chocolate" for the developed product.

The evaluation of the consumer properties of the three chocolate samples revealed consistent characteristics across all three samples. Immediately following the molding process, the surface of each sample exhibited a shiny appearance that was adequately maintained after storage.

Other properties were similarly uniform among the three samples. The intensity of the chocolate flavor was robust and well-defined, with a pleasant aftertaste that subtly suggested the flavor of sunflower seeds. Notably, the sweetness level was identified as being lower than that typically associated with traditional chocolate.

The samples were described as having a hard structure, yet featured a texture that melted easily, without any sensation of

**Table 2:** Properties of chocolate.

| Indicator | Value | | |
|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 |
| Total dry residue of cocoa products, % | 50.40 | 50.34 | 49.30 |
| Dry skim residue of cocoa products, % | 14.94 | 16.47 | 17.51 |
| Cocoa butter in the total dry residue of cocoa products, % | 36.72 | 35.23 | 33.23 |
| Amount of protein per 100 g of product, g | 26.59 | 28.25 | 29.72 |
| Amount of silymarin per 100 g of product, mg | 31.00 | 56.00 | 78.00 |
| Amount of high-protein flour from sunflower meal, wt.% | 4.11 | 4.25 | 4.39 |
| Energy value, kcal | 542.44 | 531.23 | 517.42 |

individual granules.

The developed chocolate with maltitol decreases the energy value of the products by 8 - 33 kcal, and with the introduction of a protein component, the protein content increases by 2.9 - 3.2 times.

The addition of physiologically functional ingredients (a protein component close to an ideal protein by its content of essential amino acids and silymarin) to the chocolate formulation improves its nutritional value by forming the properties of a functional food product.

Based on the totality of the conducted research, a patent "Composition for the preparation of chocolate mass" was obtained [22].

## Conclusion

Drawing from set objectives, we have successfully established a technology and formulated a chocolate mass designed to yield chocolate enriched with a comprehensive array of physiologically functional ingredients. This functional chocolate was created by integrating a simulated protein component into the composition of the chocolate mass. This component boasts a full set of essential amino acids, achieving the highest possible amino acid score based on the limiting essential amino acid. Additionally, a micronutrient possessing hepatoprotective properties was included in the formulation. Though our achievement is significant, we acknowledge the need for additional research. Further analysis is essential to authenticate the proclaimed biological activity of the chocolate mass and to firmly establish its standing as a functional food product.

## Acknowledgements

None.

## Conflict of Interest

None.

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