Edible cream-like mass: better quality, higher productivity

G O Magomedov¹, I V Plotnikova¹, A A Zhuravlev², M G Magomedov¹, T A Sheviakova¹ and N V Tychinin¹

¹Voronezh State University of Engineering Technologies, 19, Revolutsii Ave., Voronezh, 394036, Russian Federation
²MESC AF «N.E. Zhukovsky and Y.A. Gagarin Air Force Academy», 54A, Starykh Bolshevikov St., Voronezh, 394064, Russian Federation

E-mail: txmkp2010@rambler.ru

Abstract. Edible cream-like mass has a number of advantages over other confectionery masses. Being more efficient in production, they are also more digestible, more popular, and have a gentle creamy structure. However, they also have a number of drawbacks such as inconsistency, low porosity, high sugar capacity and caloric content. It is not just the chemical composition of ingredients or their basic physical, structural, and mechanical properties, but also the design of whipping machines and the whipping settings that affect the way such pastes develop their creamy structure and other properties. The paper evaluates the production of sugar-less maltodextrin-based cream-like pastes using a highly efficient experimental semi-industrial whipping machine. For production, we used high-DE maltodextrin as well as special fats. We have studied how the ratio of ingredients could affect the quality and the structural-mechanical properties of such mass. We have managed to optimize the recipes to assure the best quality. The samples we produced are of better quality, lower sugar capacity and caloric content. Realization of the presented development will allow one to intensify production process twice, to lower power- and labor input of production, prime cost of products 1.5 times, content of digestible carbohydrates by 50%, the caloric content of products by 126 kcal, to reduce floor spaces.

1. Introduction
Confectionery with cream-like mass has gained acceptance in recent years [1]. However, such confectionery has greater caloric content and sugar capacity due to high sugar and fat contents; they are thus excluded from school meals. As people become more interested in healthy lifestyles and diets, we need to expand the range of such products by developing recipes and efficient innovative technologies to produce better confectionery with higher consumption quality [2].

2. Relevance and literature review
Edible cream-like mass with a creamy structure is of great practical and theoretical interest [3]. Such mass is widely used in the production of cream candies, waffle fillings, chocolate mass, etc.

Their main feature is their viscous and plastic consistency, making them easily and flexibly shapeable [1, 4]. This is achieved by whipping a mixture of basic structure-forming ingredients (fats, powdered sugar, and various foodstuffs) into a mass that is no denser than 900 kg/m³. One of the main
A drawback here is that you need to use a finely dispersed powdered sugar with particle size not exceeding µm; such powders are made using high-performance grinding machines, which makes the entire production process longer and more energy-intensive while causing the dispersion of the product, thus worsening the working conditions of the facility [5].

To meet the demands of nutrition science, foodmakers have come to develop low-sugar foods. Why is sugar so undesirable? It necessitates multi-stage production, it has very high caloric content (339 kcal/100 g) and is 99.75% sucrose; consumption of sugar in large amounts results in tooth decay, obesity, diabetes, cardiovascular diseases, etc. [2].

One of the promising ways to improve the quality of products while attaining higher productivity consists in replacing sugar with a starch byproduct, that is, high-DE maltodextrin. Compared to sugar, maltodextrin is more efficient for production, has higher plasticity, lower caloric content and sugar capacity, lower relative sweetness (0.5 with 1 being the sweetness of sugar), a lower energy value of 316 kcal/100 g, and is a not crystallized while stored. Polysaccharides give it great dietary properties making it a popular baby product [7–11].

This proves relevant the problem of inventing better-quality cream-like mass by replacing sugar with maltodextrin, which will make products less costly, energy- or labor-intensive while intensifying the entire process, using less production equipment and floorspace as well as offering a greater range of low-sugar, low-caloric cream-like mass.

3. The purpose of the study
We tasked ourselves to find out how usage of different ingredients could affect the weight-per-volume, the effective viscosity, the plastic strength of cream-like mass, as well as to optimize the recipe and the quality of cream-like dairy mass.

4. The object of the study
The objects of the study were food cream mass obtained by churning a fat product with sugar or liquid molasses in a different ratio of prescription components, as well as milk cream mass using dry milk whey protein and dry molasses.

5. Materials and methods
Traditionally, cream-like mass is whipped by periodic-action whipping machines [11]; for this study, we used an experimental semi-industrial whipping machine (ESIWM), see Figure 1 [5].

Figure 1. Experimental semi-industrial whipping machine: 1 — whipping chamber; 2 — planetary agitator; 3 — electric motor; 4 — control panel; 5 — pressure gauge for compressed air pressure control
For experimental studies, we used liquid and dry starch-based high-DE maltodextrine produced by spray-drying. Cream-like mixtures with various ratios of S/F (powdered sugar/fat, the control sample), M/F (maltodextrin/fat) and dM/F (dry maltodextrin/fat) were whipped at 26-27 °C with the agitator rotation speed \( n = 5 \text{ c}^{-1} \) over 12 minutes. The quality of mass was assessed by the alteration of weight-per-volume and structural-mechanical properties such as the effective viscosity and plastic strength.

6. Discussion of the results
Longer whipping first reduces the weight-per-volume to a minimum, then gradually increases it; these changes are minimized if more fat is used. Figure 2 presents the minimum weight-per-volume values.

Maltodextrin makes a lower WpV paste of more gentle consistency. Dry-maltodextrin mixtures have the lowest WpV and the best creamy quality. The structural-mechanical properties were analyzed using a rotary viscometer. Higher speed gradient and shear stress reduces the effective viscosity, which classifies such mixtures as non-Newtonian. Replacing sugar with maltodextrin lowers the effective viscosity of M/F mixtures, which is at the lowest at a speed gradient of 25-45 s\(^{-1}\), see Figure 3, corresponding to maximum structural destruction. Compared to S/F mixtures, M/F have 2 to 5 Pa·s lower effective viscosity.

Cream-like mass must have a specific strength when formed [13]. They are dispersed structured systems that are crystallized at temperatures below the fat solidification point, i.e. lower than 30 °C [14].

Using the conventional technology (S/F = (60÷75):(40÷25)), such mass are formed at 26 to 30 °C [15]; when formed, they are first cooled down to 6 to 10 °C over 4 to 8 minutes before they can be structured; the plastic strength is then about 50 to 70 kPa.

By cooling the mixtures down to 10 °C, we found that for S/F 75/25, structuring takes 45 minutes before a plastic strength of 78 kPa is reached; for M/F 75/25, it takes only 30 minutes to get to 27.5
kPa. Thus, using maltodextrin instead of powdered sugar reduces the plastic strength of the mixture by 49.5 kPa, or 2.8 times. If we compare the S/F, M/F and dM/F mixtures with a 50/50 component ratio, the final plastic strength when cured equals 49, 35, and 31 kPa, meaning that dry maltodextrin enables more intense structuring thanks to the high dispersion and the amorphized structure of the powder.

To produce a paste of optimal density and plastic strength, we need to optimize the ratio of fat, maltodextrin, and the dry component (dried skimmed milk) [16]. The condition holds:

\[ x_1 + x_2 + x_3 = 100, \]  

where \( x_1, x_2, \) and \( x_3 \) are the amounts of the dry component, maltodextrin, and fat, respectively, g.

To make milk-based cream-like filling, we used \( x_1 = 15 \) g of dry milk. With more milk, we would have got a stratified mass; with less, milk's taste would have remained unpronounced.

Thus, the condition (1) can be written as:

\[ x_2 + x_3 = 85, \]  

maltodextrin and fat dosage alteration limits are \( 0 \leq x_2 \leq 85 \) g and \( 0 \leq x_3 \leq 85 \) g, respectively.

To make the study less calculation-intensive, we decided to carry out a symmetric and uniform experiment.

As the condition (2) would not enable such an experiment, we had to move from the natural factor values \( x_1 \) and \( x_2 \) to the coded values \( X_1 \) and \( X_2 \).

A transition to the new coordinates \( X_1 \) and \( X_2 \) meant that the reference point was moved to another point in factor space (the experiment center) with coordinates \( x_{02} = \frac{x_{2\text{ max}} - x_{2\text{ min}}}{2} = \frac{85}{2} = 42.5 \) g and \( x_{03} = \frac{x_{3\text{ max}} - x_{3\text{ min}}}{2} = \frac{85}{2} = 42.5 \) g.

The uniformity was achieved by using a constant variation interval for each factor \( \lambda_2 = \frac{x_{2\text{ max}} - x_{2\text{ min}}}{N-1} = \frac{85}{4} = 21.25 \) g and \( \lambda_3 = \frac{x_{3\text{ max}} - x_{3\text{ min}}}{N-1} = \frac{85}{4} = 21.25 \) g, where \( N \) was the number of experiments (\( N = 5 \)).

Thus, the correlation of the natural \((x_1 \text{ and } x_2)\) and coded \((X_1 \text{ and } X_2)\) values could be expressed as follows:

\[ X_2 = \frac{x_2 - x_{02}}{\lambda_2} \text{ and } X_3 = \frac{x_3 - x_{03}}{\lambda_3}. \]
Table 1 contains the natural and the coded values that conditioned the experiment. It’s easy to see that the plan was symmetric for each factor, i.e. \( \sum_{i=1}^{N} X_{2i} = 0 \) and \( \sum_{i=1}^{N} X_{3i} = 0 \).

| Experiment No. | Natural values of the factors [kg] | Coded values of the factors | Response function \( y_{1u} \) [g/cm\(^3\)] | Response function \( y_{2u} \) [kPa] |
|---------------|----------------------------------|-----------------------------|---------------------------------|-----------------|
| 1             | 0                                | 85                          | -2                              | 2               | 64                           | 73                           |
| 2             | 21.25                            | 63.75                       | -1                              | 1               | 52                           | 62                           |
| 3             | 42.5                             | 42.5                        | 0                               | 0               | 37                           | 55                           |
| 4             | 63.75                            | 21.25                       | 1                               | -1              | 33                           | 51                           |
| 5             | 85                               | 0                           | 2                               | -2              | 21                           | 46                           |

As a result of the experiment, we obtained the response function values: weight-per-unit and plastic strength, see Table 1. The experimental data were processed by a well-known method \[16, 17\] to estimate the factors of the 4th-degree regression equation:

\[
y_1 = -1.375X_2^4 + 0.4167X_2^3 - 6.875X_2^2 - 9.0833X_2 + 37
\]

\[
y_2 = -0.125X_2^4 + 0.4167X_2^3 - 1.625X_2^2 - 5.0833X_2 + 55
\]

where the coded values \( X_i \) are linked to the natural values \( x_i \) by the ratio:

\[
X_2 = \frac{x_2 - 42.5}{21.25} = 0.047x_2 - 2.\]

Substitute the latter in the equations (4) and (5) and make some obvious transformations to obtain an equation that expresses the dependency of weight-per-volume and plastic strength \( y_1 \) and \( y_2 \) on the amounts of maltodextrin \( x_2 \) and fat \( x_3 \):

\[
y_1 = -7E - 0.6x_2^4 + 0.0011x_2^3 - 0.0523x_2^2 - 0.1137x_2 + 64
\]

\[
y_2 = -6E - 0.7x_2^4 + 6E - 0.5x_2^3 - 0.0025x_2^2 - 0.5922x_2 + 73.
\]

Below are the response-function plots we obtained (see Figure 4).

**Figure 4.** Graphic dependency of response-function curves on maltodextrin \( x_2 \) and fat dosage \( x_3 \).
Thus, these plots can be used to find such ingredient ratio that will make a creamy milk filling with the properties, i.e. the plastic strength and the weight-per-unit you need.

7. Conclusion
It has been found out that samples with 12–14% of dry milk, 55–65% of fat, and 30–20% of maltodextrin has the best quality: a WpV of 0.4 to 0.44 g/cm² and a plastic strength of 34 to 45 kpA at t = 30 °C.

Implementing this invention will double the productivity while making confectionery products less energy- and labor-intensive, 1.5 times less costly to produce; besides, this method increases the content of digestible carbohydrates by 50%, the caloric content by 126 kcal, and requires less floorspace.

Due to the significant content of protein raw materials in the product, reducing its sugar content and calorie content, this product can be recommended for athletes’ nutrition [18].

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