Application of combined methods for the production of ingredients for the confectionery industry

Zinaida Baranova[1], *Irina* Krasina[1], *Natalia* Tarasenko[1,*], and *Rimma* Elemanova[2]

[1]Kuban State Technological University, 2 Moskovskaya Street, Krasnodar 350072, Russian Federation
[2]Kyrgyz State Technical University named after I.Razzakov, 66 Aitmatov Ave., Bishkek 720044, Kyrgyzstan

Abstract. The production of confectionery products, especially those coated with chocolate or confectionery glaze, faces the challenges of selecting high-quality and technological fatty bases for the glaze or filling on a daily basis. In nature, the amount of vegetable oils that have an optimal fatty acid and triglyceride composition for use as such a base is significantly limited. Indeed, most of the vegetable oils and fats require a partial hydrogenation stage, that is, a change in the saturation level. As a result of these modifications, trans-fatty acid fatty acids are formed, which both impart hardness and form the basic rheological characteristics of the fatty base. The development of new, combined methods for the production of fatty ingredients for the confectionery industry and the improvement of processes for the modification of oils and fats are current trends in food production. In order to produce fatty ingredients – non-tempered mixed type cocoa butter substitutes with a low content of trans-fatty acid isomers and with optimal crystal formation properties, a research was carried out in respect of a set of indicators that form the consumer properties of the finished product: physical and chemical properties and main indicators of melting and solidification, as well as structural-mechanical and organoleptic characteristics. The research objectives included the study of the physical and chemical characteristics of the initial components of fatty ingredients, laboratory-based obtaining of samples of fatty ingredients for the production of confectionery glazes, the study of the physicochemical, structural, mechanical and rheological properties of the obtained fatty ingredients. The result of the research was the developed combined technology for the production of a non-tempered mixed type cocoa butter substitute with optimal consumer characteristics.

Consumer market research has shown that the majority of respondents among various groups of Russian citizens realize that their health and well-being are closely related to nutrition. People want to be healthy without resorting to medication. Therefore, food

* Corresponding author: natagafonova@mail.ru

products of the 21st century should not only satisfy human needs for basic nutrients and energy, but also perform preventive and curative functions.

Confectionery products should also become one of the important segments of the market for functional products.

An efficient and cost-effective way to increase the nutritional value of confectionery products is the use of local raw materials – the seeds of modern breeding varieties of oil crops (including flax), which necessitates the study of the system of fats that are a component of praline masses [1].

Fatty foods are not usually marketed as “good for health” (due to the risk of obesity or cardiovascular disease). However, the role of fats in nutrition is determined by their high calorie content and their participation, together with proteins, in plastic processes. They also contain fat-soluble vitamins (A, D, E) and fatty polyunsaturated acids, such as linoleic and arachidonic acids, which are essential, since their synthesis in the body is extremely limited. They play an important role in metabolism: their lack in nutrition adversely affects the life of the human body.

It should be noted that fats improve the taste of food and cause a long-lasting feeling of fullness, as they are digested and absorbed more slowly than other nutrients. But we must not forget that an excess amount of fat even in the diet of a healthy person is harmful.

The main raw materials used for the production of specialized fats and cocoa butter substitutes are natural fats and oils of vegetable origin, belonging to different hardness groups. Conventionally, according to their consistency, all fats and oils can be divided into three groups: liquid, semi-solid and solid. The consistency of all oils and fats, as a rule, depends on the set of fatty acids that make up triglycerides. The higher the proportion of saturated acids in the fat composition, the higher its hardness will be, and, accordingly, the more unsaturated acids in the composition, the more liquid the fat will be.

But, as it is known, most natural oils and fats are of limited use in their natural form due to their chemical composition. To expand the scope of application of such oils, they are subjected to various modifications, the best-known of which are hydrogenation, transesterification, and fractionation [2]. But the modern food market is determined by a number of consumer demand requirements, particularly by an increase in demand for healthier and better quality products, and on January 1, 2018 the requirements of the Eurasian Customs Union TR CU 024/2011 Technical Regulations for Fat and Oil Products came into force in terms of standardization of trans isomers of fatty acids in confectionery fats up to 2%. In accordance with this requirement, the transition to fats with a trans-isomer content of up to 2% is inevitable. Until recently, this regulation did not apply to non-tempered non-lauric and mixed type cocoa butter substitutes. If Amendment Draft 2 to TR CU 024/2011 is approved, this norm will establish the limitation of trans fatty acid isomers to 2% in these products (starting from January 1, 2026 for non-tempered non-lauric type cocoa butter substitutes).

Table 1. Solid fat content of vegetable oils at + 20 °C

Oil name	**SFC,%, at +20°C**
Sunflower, soybean, rapeseed, peanut, cottonseed, olive oil	liquid state
Coconut oil	38.0
Palm kernel oil	43.0
Palm oil	25.0
Cacao butter	76.0

There were many reasons to use hydrogenated fats in the production of cocoa butter alternatives. Firstly, it allowed access to fats with a wide range of melting profiles and melting points from what were originally simple oils. Secondly, this method was used to improve oxidative stability and reduce the level of more unstable polyunsaturated fatty acids. Finally, hydrogenated fats do have some functional characteristics such as crystallization and aeration properties that are difficult to achieve by other means [3, 4].

Table 2. Physicochemical properties of the studied fats

Component name	**Melting point, °C**	**SFC in mixture,%, at temperature, °C**			**Mass fraction of fatty acids,%**			
		10	**20**	**35**	**$C_{12:0}$**	**$C_{16:0}$**	**$C_{18:0}$**	**$C_{18:1}$**
Palm oil	37.3	53.9	30.2	6.4	0.2	43.3	4.2	40.1
Palm oil olein	21.0	35.9	9.6	0.01	0.3	39.0	4.0	43.3
Palm oil stearin	54.0	82.1	74.3	44.9	0.2	61.5	4.8	25.5
Palm oil stearin stearin	60.0	94.0	93.4	86.7	0.2	47.9	5.2	37.2
Palm oil middle fraction	26.2	70.9	45.6	2.4	0.2	47.3	5.0	37.5
Olein by-product fraction of palm oil	18.5	0.4	0.1	0.01	0.4	34.9	3.8	45.6
Palm kernel oil	28.0	76.0	50.4	0.01	46.2	8.9	2.5	16.7
Palm kernel oil stearin	32.2	92.9	84.7	0.2	54.4	9.0	2.2	6.7
Palm kernel oil olein	22.8	60.2	20.6	0.01	40.3	10.2	3.1	21.2
Hydrogenated palm kernel oil	37.5	96	91.4	15.4	45.9	9.8	20.7	0.1
Hydrogenated palm kernel oil stearin	34.5	96.8	95.7	4.0	54.4	8.6	9.6	0.03
Coconut oil	24.9	81.3	35.3	0.1	48.5	8.5	2.5	6.5

The coating of the glazed confection should have a fairly high level of SFC (solid fat content) at ambient temperature, and the glaze should melt completely at mouth temperature. That is, a certain melting profile is required – some kind of solid fat content. If this hard fat cannot be produced through hydrogenation then at least we must start with oils that have natural amounts of hard fat [5, 6].

Many oils used in the food industry are liquid at 20 °C (Table 1).

Table 3. Physicochemical indicators of the quality of intermediate products

Quality indicators	**Blending**	**Modification-transesterification**	**Modification-fractionation**		
	Triglyceride blend	**Triglyceride blend after transesterification**	**I stage**	**II stage**	**III stage**
Iodine number, g I_2/100g	36.36	36.36	50.10	40.31	36.46
Melting temperature, ºC	55.40	56.00	27.80	42.30	37.8
SFC, %, at a temperature:					
10 ºC	84.3	86.2	78.0	59.1	95.2
20 ºC	68.7	72.1	56.4	30.6	89.5
35 ºC	38.4	34.5	17.0	0.1	9.8
Lauric acid content, %	0.21				
The content of trans isomers of fatty acids, %	0.05				

Therefore, in order to have solid fat in the composition, it is necessary to base products on oils, such as coconut, palm, palm kernel oils and their fractions.

In this work, we have studied the physicochemical properties of a number of traditional and tropical oils and fats, as well as their products after their modification. The data are shown in Table 2.

At the first stage of the study, a number of experiments were carried out on the blending of tropical oils and/or their fractions and the chemical transesterification of the resulting mixtures in the presence of the sodium methoxide active substance. At the same time, the original triglyceride composition did not contain trans fatty acid isomers. In the second stage, each of the obtained transesterified fats was subjected to multi-stage fractionation in order to obtain a solid stearic fraction. At the filial stage, the resulting solid fraction was blended with fully hydrogenated lauric-type oils. The assessment of physical and chemical quality indicators was carried out before and after each stage of modification.

The results of the physicochemical parameters of the initial compositions and the resulting transesterified fats and functional fractions are presented in Table 3.

Transesterification reduces the melting point of the mixture of fats, but they still remain highly melting, which does not allow them to be used for the production of glazes. Whereas, fractionation with the selected parameters allows you to reduce the melting point of the semi-finished product, to obtain a given content of solid triglycerides and the required technological characteristics.

At each stage of fractionation, it is necessary to stage-by-stage multistage cooling of the triglyceride composition obtained in the previous stage in the temperature range of 16-30°C, with the initial heating of the initial mixture to 45-60 °C in order to eliminate random crystallization centers. At each stage of cooling, the mixture must be kept at a set temperature for up to 9 hours with a gradual temperature transition time set for a maximum of 210 minutes. The mixing speed of the mixture is limited to 35-45 rpm at the stage of heating the initial semi-finished product of the first stage, and 10-20 rpm at the stage of the main steps of the fractionation program. After the completion of the crystallization step, when the triglyceride mixture is fed to filtration, the SFC content in the mixture is preferably 12 to 22.5%. In this case, the filtration pressure should not exceed 30 bar. Detailed crystallization parameters are given in Table 4.

Table 4. Crystallization parameters at the fractionation stages

Phase	**Warming up, ^{0}C**	**Cooling , ^{0}C**	**Exposure , hour**	**Temperature transition time, min.**	**Mixing speed, rpm**		**SFC in the mix , %**	**Pressure, bar**
					warming up	**main stage**		
1	57.5 ±1.5	35.0± 1.5	9.00	210	37.5±3.0	13.0±3.0	22.5±1.0	16
2	57.5 ±1.5	31.5± 1.5	7.50	150	37.5±3.0	10.0±3.0	12.0±1.0	16
3	48.0 ±1.5	26,0± 1.5	7.30	140	40.0±3.0	20.0±3.0	14.6±1.0	30

At the last stage of the development of a combined method for the production of a non-tempered mixed type cocoa butter substitute (CBM), to the obtained non-lauric fat base, by the blending method, fully hydrogenated palm kernel oil stearin was included in the composition in the amount of 5% (CBM-2) and 10% (CBM-3) in the mass fraction of the fat phase. Table 5 shows the main characteristics of the obtained CBM for confectionery glazes.

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Table 5. Characteristics of CBM experimental samples

Indicator name	Experimental fatty semi-finished products		
	CBM-1	**CBM-2**	**CBM-3**
Melting temperature, ºC	36.8	37.0	37.3
SFC, %, at temperature:			
10	95.2	96.0	96.1
20	89.5	87.5	86.4
35	9.8	7.3	6.5
The content of trans isomers of fatty acids, %	0.05	0.05	0.05
Lauric acid content, %	0.21	4.01	4.66

For a comparative analysis of the characteristics of solidification, the samples were analyzed according to the characteristics of solidification according to Zhukov at + 20 °C (Table 6).

Table 6. Characteristics of CBM solidification

Sample name	Pour point, ºC	Pour time, min	Subcooling temperature, ºC	Cooling time, min	Crystallization time, min
CBM-1	35.0	15.0	31.4	4.0	11.0
CBM-2	33.3	16.0	30.3	6.0	9.0
CBM-3	34.2	17.0	30.2	7.0	11.0

Crystallization rates were investigated and cooling curves were plotted at a temperature of + 17.6 °C for each sample of a fat semi-finished product using a high-precision MultiTerm device. Cooling curves for the developed laboratory samples of the CBM are shown in Figure 1.

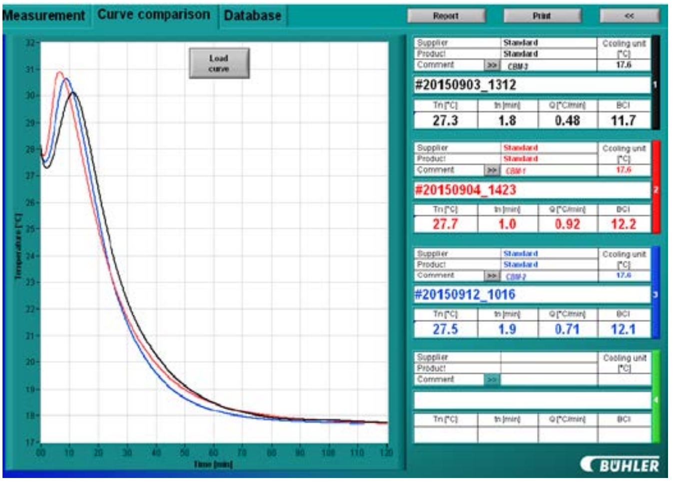

Fig. 1. Crystallization curves at the temperature of + 17.6 ° C

The Buhler Crystallization Index (BCI) describes the cooling curve of the CBM and predicts its behavior during crystallization in glaze: the higher this value, the higher the crystallization rate [7].

Summarizing the experimental data obtained, we can conclude that the developed CBM samples have a steep melting profile, optimal physicochemical characteristics, high BCI and are recommended for use in the production of confectionery glazes. Experimental samples of CBM will make it possible to obtain glazes of different hardness, degree of shrinkage and viscosity, that is, to obtain a product with specified technological parameters.

The developed technology for the production of a non-tempered mixed type cocoa butter substitute is combined, and includes known methods for modifying vegetable oils and fats, while the samples contain a minimum of trans fatty acid isomers, which is consistent with modern trends in the field of healthy nutrition and legislative requirements.

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