Effect of sucrose on the physical and mechanical characteristics of carbohydrate-protein sports gel

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Abstract. The creation of functional and specialized products from dairy raw materials, in particular those aimed at athletes, is an urgent direction in food technologies. The objects of the study were sports gel samples based on curd whey concentrate obtained by nanofiltration (NF concentrate). To increase the food density of the product, 5% whey protein concentrate was added to the NF concentrate samples: with a protein mass fraction of 30% (KSBUF-30). Rosehip syrup and sucrose were used as an additional source of carbohydrates. To impart a gel structure to the product, the vegetable hydrocolloid c-carrageenan was used in an amount of 0.5%. Ingredients of Russian origin were used in the work. Two options were investigated: with the addition of only fruit-berry syrup (experiment 1) and the addition of a combination of fruit-berry syrup and sucrose (experiment 2). The consumer characteristics of the samples (consistency, appearance, taste and smell, colour) were evaluated by the organoleptic method. At the same time, there were no obvious differences in these indicators. The rheological properties of the samples were investigated by rotational viscometry. Deterioration of structural and mechanical properties, such as loss of viscosity and restoration of the structure in the sample with added sucrose, was established.

In recent decades, food technology innovation has been driven by the demand for functional and specialty foods due to the growing consumer focus on health, sports, active lifestyles and nutrition. These changes are pushing manufacturers to look for new ways and means that not only provide economic production, but also guarantee maximum food safety and quality, including nutritional value, organoleptic properties, as well as indicators that determine health benefits, the combination of which directly depends on the ingredient composition of food product [1, 2].

The creation of functional and specialized products from dairy raw materials, in particular those aimed at athletes, is an urgent direction in food technologies. Thanks to the use of innovative methods of processing raw dairy products, including secondary dairy raw materials, great prospects for obtaining new types of dairy products are opening up. These methods include baromembrane processes, which entailed a radical change in whey processing technologies.

On the basis of previous studies, it was for the first time proposed to use curd whey concentrate obtained by nanofiltration (NF concentrate) as a basis for the development of new specialized products, in particular, for the production of sports nutrition [3]. Such processing of raw whey allows you to adjust the ratio of its aqueous phase and dry matter and helps to increase the profitability of whey processing by increasing the biological value of the concentrate.
A popular form of sports foods are carbohydrate and carbohydrate-protein gels. Athletes note the following positive aspects of this consumer form: high absorption rate, high concentration of carbohydrates in a compact format, convenient consistency for swallowing (there is no need to chew), simplicity of calculations before starting, resistance to low and high temperatures, variety of tastes, the use of the gel does not create a sensation full stomach [3, 4].

In this work, the goal is to study the effect of added sucrose on the physical and mechanical properties of the product. The objects of the study were samples with different mass fractions of carbohydrates.

The organoleptic characteristics of raw materials and experimental samples were evaluated by a group of qualified experts. The mass fraction of protein and fat was determined by the instrumental express method using an infrared analyser MilkoScan FT 120. The acidity, titratable and active, was analysed, respectively, by indicator and potentiometric methods. The rheological characteristics of the product samples were determined on a Fungilab SMART R-series rotational viscometer. To determine the indicators characterizing the resistance of the structure to fracture under mechanical action and its ability to thixotropic recovery, the samples were exposed to a uniform shear field at a constant shear rate for 2 min. The clot was left at rest for 15 min to restore the structure, and measurements were taken again [5]. Loss of viscosity (Pₖ, %) is a value equal to the ratio of the difference between the initial viscosity of the product and the viscosity of the structure maximum destroyed in 120 s to the initial viscosity. Recovery of the structure (Bₖ, %), calculated as a percentage, is defined as the ratio of the viscosity of the restored structure to the initial viscosity, and characterizes the ability of the structure to return the initial viscosity. The studies were carried out in triplicate.

NF concentrate was obtained from curd whey with titratable acidity (68 ± 2) °T and pH (4.65 ± 0.05). Whey was obtained in the production of cottage cheese at a local milk processing enterprise, then processed in a pilot nanofiltration unit equipped with a polymer membrane separating proteins with a molecular weight of 300 Da [4, 6].

Physicochemical analysis of NF concentrate showed a significant increase in biologically valuable components such as lactose and whey proteins (table 1).

Table 1. Nutritional and energy value of curd whey and concentrate obtained by nanofiltration.

| Sample     | Content in 100 g | Energy value (caloric value) kJ / kcal |
|------------|------------------|---------------------------------------|
|            | protein | fat | carbohydrates |                                   |
| Curd whey  | 0.5     | 0.05| 4.0           | 78.0/18.0                           |
| NF concentrate | 2.0 | 0.2 | 14.0          | 280.0/65.0                          |

In addition, in comparison with the initial raw material, the NF concentrate had better organoleptic characteristics: less pronounced and less sour whey taste. The analysis of the previously obtained results showed that the most significant in terms of the nutritional value of the NF concentrate are macronutrients - protein and lactose, and of mineral compounds - calcium [4].

A hydrocolloid of plant origin, κ-carrageenan, was used as a stabilizing additive to impart the required consistency to the developed product. This compound belongs to natural hydrocolloids, allows to have a prebiotic effect on the positive autoflora of the human intestine, to improve the functioning of the gastrointestinal tract and liver by detoxifying ammonia and other nitrogenous toxins formed during a high-protein diet and as a result of heavy physical exertion, has a normalizing effect on sugar levels and blood cholesterol, reduces the glycemic index of the product. Despite the source of origin - seaweed, this type of carrageenan does not negatively affect the taste characteristics of the product. A series of experiments carried out earlier showed that 0.5% κ-carrageenan is sufficient to provide the desired gel structure of the product [6].
It is known that a combination of carbohydrates of different nature is welcomed in sports products, which contributes to better restoration of carbohydrate reserves during muscle load [7]. To form the carbohydrate component of the product, two options were considered: adding only fruit and berry syrup (experiment 1) and adding a combination of fruit and berry syrup and sucrose (experiment 2). The recipe composition of the mixtures was formed according to the technological map presented in table 2.

Table 2. Prescription composition of gel mixtures based on NF-concentrate of curd whey.

| The amount of raw materials, % | Variants          |
|-------------------------------|-------------------|
|                               | Experiment 1      | Experiment 2      |
| NF concentrate                | 80.0              | 85.0              |
| KSBUF-30                      | 5.0               | 5.0               |
| Rosehip syrup                 | 10.0              | 10.0              |
| Sugar                         | 5.0               | 0.0               |
| κ-carrageenan                 | 0.5               | 0.5               |

The organoleptic method did not reveal any obvious differences between the samples. Both samples had a pleasant whey taste and smell. They had a moderately sweet taste with a sourish aftertaste. It was found that the decrease in the content of NF concentrate and the added sugar in experiment 1 did not eliminate the whey flavour. The colour was characterized as caramel, light brown, uniform throughout the mass. The consistency was homogeneous, dense, gel-like, without separation of the dispersion medium. At the same time, an insignificant grit content was noted, which did not impair the overall impression of the product.

It was found by rotational viscosimetry that both samples had the same intact structure viscosity of 6971.06 Pa · s. Figure 1 shows the curves of the effective viscosity of the prototypes.

Figure 1. Influence of the shear rate on the effective viscosity of the test samples:

a - sample 1; b - sample 2.

Analysis of figure 1 showed that the viscosity curves of the samples have a similar bend and slope and are described as power functions: \( y_1 = 15729x^{0.879} \) for sample 1 and \( y_2 = 10776x^{0.726} \) for sample 2 with the corresponding correlation coefficients 0.9926 and 0.9968.

However, further studies of physical and mechanical parameters revealed differences in the strength of the structures of the samples. The results are shown in figure 2.
Figure 2. Indicators of resistance of samples to mechanical stress.

The data in the figure indicate that the addition of added sugar negatively affected the strength characteristics of the gel. The indicators of viscosity loss and structure recovery in sample 1 are worse than in sample 2. After mechanical destruction, the structure of the product with added sucrose was destroyed by more than half, and recovery was only 16.67%.

In this experiment, in addition to κ-carrageenan, high molecular weight hydrocolloids - NF concentrate proteins and KSBUF-30 - are responsible for the formation of the structure. The main difference between the experimental samples is the change in the ratio between proteins and low molecular weight carbohydrates, which was 0.18 in sample 2, and 0.33 in sample 2.

Based on these results, it was concluded that the structural and mechanical characteristics of the samples depend not only on the total dry matter content, but also on the ratio of high-molecular and low-molecular components in the product formulation. Based on the data obtained, it was decided to exclude added sugar from the formulation and to continue testing to form the composition of the product with a gel consistency using other types of carbohydrate ingredients.

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