Selection of thickening agents for whey concentrate

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Abstract. The creation of athletes-oriented products from raw milk is a current trend in food technology. The object of the study was a curd whey concentrate obtained by nanofiltration (NF concentrate) with a dry matter content of 18.0%. To increase the food density of the product, different types of whey protein concentrate were added to the samples of NF concentrate in an amount of 5%: with protein mass fractions of 30% (KSBUF-30) and 80% (KSBUF-80). To give the product a gel-like structure, natural pectins from apple pulp and citrus peel were studied. The amount of pectin in the samples was 2%. The work uses ingredients industrially produced by Russian manufacturers. The dry ingredients were completely dissolved at a temperature of (20±2) °C in the NF concentrate, the resulting mixture was pasteurized for 10-15 minutes at (92±2) °C and cooled to a temperature of (20±2) °C. The consistency of the freshly worked samples was not fluid and looked uniform and smooth. The taste characteristics of all variants slightly changed after 7 days of refrigerated storage at (4±2) °C. The effect of whey protein concentrates and pectin on the consistency of the product was established by the method of rotational viscometry. KSBUF-80 promotes better thickening and gelation, enriches the fermented milk taste of the product. Pectin from citrus peel produces a product with a more uniform structure. In the experimental conditions, the best consumer qualities were manifested when combining KSB-UF80 with pectin from citrus peel.

Physical activity is one of the key parameters in modern nutritional science. Energy consumption during systematic sports activities increases by an average of 1050-1400 kcal per day compared to persons with a low level of physical activity. And for highly qualified male athletes during the training period, this difference reaches 1650-1800 kcal per day [1, 2, 3, 4]. This is the first basis for the creation of specialized nutritional products for athletes.

Another approach takes into account the choice of raw materials. In this sense, dairy raw materials have a number of unique qualities. By-product milk raw materials, which are often not used in full, are no exception. That is why dairy products are definitely recommended for constant consumption by the Russian Ministry of Health. However, the production of domestic dairy, dairy compound and milk-containing products for athletes is practically absent. Consequently, the creation of athletes-oriented products from raw milk is a topical trend in food technologies [5].

A critical point in milk processing is curd whey, which is not always used for food purposes due to its low storage capacity due to its high water and carbohydrate content. Low protein content also affects the profitability of whey processing. Membrane technologies are a technological way to adjust the ratio of the aqueous phase and dry matter of whey.
In this work, for the base of the product, we used a curd whey concentrate obtained by nanofiltration (NF concentrate). To obtain the NF concentrate, serum with titratable acidity (68 ± 2 °T and pH (4.65 ± 0.05), obtained from the production of cottage cheese on a continuous flow line, was used (table 1).

Whey was processed at a constant rate up to a pressure of 27 bar in a pilot nanofiltration plant equipped with a polymer membrane with a molecular weight cutoff of 300 Da [6].

Table 1. Physicochemical parameters of serum and NF concentrate.

| Index                        | Curd whey | NF-concentrate of curd whey |
|------------------------------|-----------|-----------------------------|
| Mass fraction of fat,%       | 0.05±0.02 | 0.17±0.02                   |
| Mass fraction of protein,%   | 0.46±0.04 | 2.02±0.04                   |
| Mass fraction of lactose,%   | 4.10±0.02 | 14.00±0.08                  |
| Mass fraction of dry substances,% | 5.72±0.04 | 18.0±1.0                    |
| Titratable acidity, °T       | 68.0±2.0  | 164.0±1.0                   |
| Active acidity, pH           | 4.65±0.05 | 4.4±0.4                     |
| Calcium content, mg/100 g    | 53.94±2.00| 227.81±2.0                  |
| Density, kg/m³               | 1023.70±1.00 | 1090.00±1.00               |
| Viscosity, Pa·s              | (1.55±0.01)·10⁻³ | (2.22±0.01)·10⁻³ |

It can be seen from the table that despite the significant concentration of macronutrients by baromembrane treatment, with a dry matter content of 18.0%, the NF concentrate of curd whey is a mobile liquid [7]. However, when developing food products for athletes, in addition to indicators of nutritional and biological value, it is necessary to take into account the possibility of their use without additional processing, to transfer and store food outside the refrigerator, in conditions of outdoor competitions, training, training camp, on the road. In connection with this convenient consumer solution for a sports product, there will be a gel that is ready to use without prior culinary preparation.

To impart a gel structure to the product, natural pectins from apple pulp and citrus peel were studied. All pectins, by their chemical nature, are polygalacturonoglycans. The technology for obtaining pectins affects their structural characteristics: the degree of polymerization and the number of esterified acid residues. As a consequence, it affects the physicochemical properties of pectins: the ability to hydrate, stabilize food systems, etc.

To increase the food density of the product, two types of whey protein concentrate with protein mass fractions of 30% (KSBUF-30) and 80% (KSBUF-80) were used. These fillers not only increase the dry matter content, but are also functional food ingredients, since they significantly increase the biological value of the protein component of the product.

All ingredients used in the work are industrially produced by Russian manufacturers.

Model mixtures were formed according to the flow chart presented in Table 2, bringing the sample volume with curd whey concentrate to 100 cm³.

Table 2. Composition of the studied samples.

| Sample number | Sucrose | KSBUF-30 | KSBUF-80 | Apple pectin | Citrus pectin |
|---------------|---------|----------|----------|--------------|---------------|
| 1             | 5       | 5        |          | 2            |               |
| 2             | 5       | 5        |          | 2            |               |
| 3             | 5       |          | 5        | 2            |               |
| 4             | 5       |          | 5        | 2            |               |

The dry ingredients were added to the NF concentrate of curd whey heated to a temperature of (20±2) °C, the resulting mixture was thoroughly mixed at the same temperature for 15-20 minutes until the sucrose and hydrocolloids were completely dissolved, and then pasteurized for 10-15 minutes at (92±2) °C and cooled to a temperature of (20±2) °C.

Fresh samples were evaluated visually and organoleptically. The sweetness of all samples was sufficient. In the samples with KSBUF-30, a not intensely pronounced taste of milk powder was felt and the taste of NF concentrate was lost, which was attributed to organoleptic deficiencies. In this regard,
these samples (1 and 2) were evaluated slightly lower than the samples with KSBUF-80 (3 and 4). The most acceptable flavor was observed when using KSBUF-80, since these variants were distinguished by a clean, not intense fermented milk taste. The consistency of all samples was not pourable and looked uniform and smooth.

After 7 days of refrigerated storage at (4±2) °C, the taste characteristics of all variants changed somewhat. Regardless of the type of pectin and whey protein concentrate, a feeling of insufficient sweetness appeared, which, apparently, is associated with the blocking of taste molecules by hydrocolloids. Also, in the samples with KSBUF-80 there was a slight mealy. The consistency of samples with KSBUF-80 was thicker than that of samples with KSBUF-30, but no differences were found depending on the type of pectin. Considering the described changes, the final marks for the organoleptic characteristics of the samples were different (table 3).

Table 3. Organoleptic characteristics of gel samples based on NF concentrate with the addition of whey protein concentrate and pectin.

| Ingredient composition of samples | Organoleptic indicators, score | Total |
|----------------------------------|-------------------------------|-------|
|                                  | taste | color | consistency |
| **freshly produced samples**     |       |       |             |
| Pectin from apple pulp           | 4.0±0.1 | 4.0±0.1 | 4.8±0.1 | 12.8±0.1 |
| and KSBUF-30                     |       |       |             |
| Pectin from citrus peel          | 4.0±0.1 | 4.0±0.1 | 4.8±0.1 | 12.8±0.1 |
| and KSBUF-30                     |       |       |             |
| Pectin from apple pulp           | 4.6±0.1 | 4.0±0.1 | 4.8±0.1 | 13.4±0.1 |
| and KSBUF-80                     |       |       |             |
| Citrus pectin and                | 4.9±0.1 | 4.0±0.1 | 4.9±0.1 | 13.8±0.1 |
| KSBUF-80                         |       |       |             |
| **samples for 7 days of storage**|       |       |             |
| Pectin from apple pulp           | 3.1±0.1 | 3.0±0.1 | 2.5±0.1 | 8.6±0.1 |
| and KSBUF-30                     |       |       |             |
| Pectin from citrus peel          | 2.0±0.1 | 2.0±0.1 | 2.0±0.1 | 6.0±0.1 |
| and KSBUF-30                     |       |       |             |
| Pectin from apple pulp           | 4.0±0.1 | 3.0±0.1 | 2.2±0.1 | 9.2±0.1 |
| and KSBUF-80                     |       |       |             |
| Citrus pectin and                | 3.2±0.1 | 4.0±0.1 | 3.0±0.1 | 10.2±0.1 |
| KSBUF-80                         |       |       |             |

The consistency of the samples after 7 days of storage was studied on a Fungilab SMART R-series rotational viscometer using an R2 measuring device.

Figure 1 shows the indicators of the effective viscosity of the samples. To determine the indicators characterizing the stability 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 [8].

The figure shows the effect of both hydrocolloids, whey protein concentrate and pectin on the consistency of the product. Obviously, in the samples with KSBUF-30, the effective viscosity indicators are lower than in the samples with KSBUF-80. There is a direct relationship between viscosity and the total protein and solids content of the product. With an increase in the mass fraction of protein in samples 3 and 4 to 5.8%, and the total solids content to 26.8%, the effective viscosity of the samples increased to a maximum value of 268.9 mPa·s.

While in samples 1 and 2, with a total dry matter content of 24.5% and a protein mass fraction of 3.3%, the maximum value of the effective viscosity did not exceed 183.3 mPa·s.

Figure 1 also shows that lower values of effective viscosity were observed when the system was thickened with pectin from citrus peel. But at the same time, it was in sample 2, which was distinguished by the minimum effective viscosity, that the structure was completely restored. While in denser samples
1, 3, and 4, the structure recovery after mechanical failure occurred by 93.3%, 86.4%, and 93.8%, respectively.

![Figure 1. Effect of whey protein concentrate and pectin on consistency.](image)

After two weeks of storage of the samples under the same conditions, no deterioration in the taste of the products was found. However, noticeable changes in consistency were observed. In the samples with citrus peel pectin and KSBUF-80, the consistency remained uniform, but acquired a fine granularity, similar to that felt in fruit purees. At the same time, in the samples with pectin from the peel of citrus fruits and KSBUF-30, the system exfoliated with the separation of the sediment. Apparently, this is the result of both the lower dry matter content, and the result of the mutual influence of the ingredients during storage. Samples thickened with pectin from apple pulp were very dense, without separation of the dispersion medium. However, the structure of the product lost its homogeneity, and compacted grains with a diameter of 0.2 to 0.5 cm appeared, regardless of the type of whey protein concentrate. It is possible that there was not enough free moisture in the system for the complete swelling of this pectin. The mechanism of the observed changes remains to be clarified in further studies.

On the basis of experimental data, it was established that the indicators of taste and texture of the gel based on NF concentrate depend on the total content of dry substances in the sample and on the type of whey protein concentrate used. KSBUF-80 promotes better thickening and gelation, enriches the fermented milk taste of the product.

The structural and mechanical parameters of the prototypes depend on the type of added hydrocolloids: whey protein concentrate and pectin. Under experimental conditions, samples thickened with pectin from citrus peel had a more uniform consistency and better structure recovery after a week of product storage. The destabilization of this system observed during further storage can be corrected by adding other stabilizing food additives, or using a combination of KSBUF-80 with pectin from citrus peel.

It is planned to continue the selection of the optimal combinations of ingredients to obtain a product with a stable gel structure that does not have consistency defects during storage.

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