Chemical composition, functional and technological (processing) properties of whey ingredients

E I Melnikova, E V Bogdanova, D A Paveleva

Department of Technology of Animal Origin Products, Voronezh State University of Engineering Technologies, 19, Pr. Revolyutsii, Voronezh, 394036, Russian Federation

E-mail: ek-v-b@yandex.ru

Abstract. The growth in volumes of the milk whey manufacturing has revealed the new field of processing, such as dry whey ingredients production. The authors have made investigations of chemical composition, functional and technological (processing) properties of whey protein concentrates with protein of 35, 55, 80 % in dry matter, whey protein hydrolysate and cheese whey permeate. We used standard methods, generally accepted in research practice. The chemical composition of the tested samples has been determined, including their rehydration properties in terms of wettability, dispersibility and solubility. Heat denaturation of whey proteins during the processing is the reason for the bound groups–SH release and their reactivity enhancement, which provides antioxidant effect of whey ingredients (the antioxidant content in the tested samples is 0.031; 0.058; 0.095; 0.146 and 0.024 mg/g for the whey protein concentrates with protein of 35, 55, 80 % in dry matter, whey protein hydrolysate and whey permeate respectively). The functional and technological properties of whey ingredients make possible their application while producing different product line groups in order to control the technological processes and the quality factors of the enriched products.

1. Introduction

More than 204 million tons of milk whey is produced annually in dairy industry. Whey production in Russia in January – October 2020 amounted to 825 thousand tons, which is 21.6 % higher than in the same period of the previous year. At the same time, there were 503.8 thousand tons of liquid milk whey (+32.6 %), 149.7 thousand tons of dry milk whey (+13.7 %), 171.5 thousand tons of demineralized whey and other whey products (+ 2.6 %) [1, 2].

The perspective for development is the drying ingredients production based on ultra processing of cheese whey, whey protein concentrates and hydrolysate as well as permeates, in particular. These products are widely used in baking and confection formulas, dairy products, infant and sport food formulas [3]. Their functional and technological properties depend on the chemical composition features and technical operation modes for their production [4].

2. The purpose of the study

The purpose of the research was to study the chemical composition, functional and technological properties of whey protein concentrates with protein of 35, 55, 80 % in dry matter, whey protein hydrolysate and cheese whey permeate.

The following tasks were determined to reach this goal:
- to identify the chemical composition and the quality characteristics of the investigated samples;
- to study the features of the dry whey ingredients solubility;
- to determine the antioxidant activity of whey ingredients and the effect of processing modes on its change.

3. The object of the study
The study objects were whey protein concentrates with protein of 35, 55, 80 % in dry matter; whey protein hydrolysate (produced using proteolytic enzymes Flavorpro 766MDP and Promod 439L) and whey permeate, obtained using the baromembrane method and spray drying with the further drying process at the branch office manufacturing site of PJSC Dairy Plant “Voronezhskiy”.

4. Materials and methods
We used standard methods, generally accepted in research practice, to analyze the resilience capability of dry whey ingredients. The limiting wetting angle was determined as follows: the tested sample was distributed over the solid surface in uniform layer. The liquid was laid on the surface in a way to provide minor effect of the gravity on drop spreading. For this purpose, the microliter syringe was used to set up water drop of 0.1 µl on the prepared surface. The dosing unit was placed in a way that the drop could spread over and then turn to equilibrium state with the surface. A goniometer was used to make all the measurements [5]. To determine the solubility index (sludge quantity in cm$^3$) of whey ingredients, we blended 6 g of the dry sample for 90 seconds in 100 cm$^3$ of water with $t = 24 \, ^{\circ}C$, then let deposit for 15 minutes, then mixed with the help of spatula and subjected to centrifugation in the cone centrifugal tube for 5 minutes [6].

The total quantity of free sulfhydryl groups was defined with the help of 60% methanol solution as a precipitating agent. We were mixing 1-2 cm$^3$ of the previously prepared sample, 2-3 cm$^3$ of tris-acetate-EDTA-buffer and 5.9 cm$^3$ of methanol (air-free N$_2$), adjusted to pH 8.2, added 0.1 cm$^3$ of DTNB solution, and then let deposit for 10 minutes. Then the sample was subjected to centrifugation for 15 minutes, filtrated and measured for optical density at 412 nm and 540 nm in 1.25 hours after DTNB addition. The standard curve was lined up to correct the turbidity [7].

To identify the active sulfhydryl groups content they adjusted 2 cm$^3$ of the tested sample and 7.9 cm$^3$ of the buffer to pH 8.2, then added 0.1 cm$^3$ of DTNB solution, and let stay for 20 minutes. The sample was subjected to centrifugation for 30 minutes, filtrated and measured for optical density, correcting the turbidity.

The results of the experimental investigations were processed with the help of mathematical statistics methods after analyzing data of the trials at a triple sequence. The represented data were obtained, based on the results of processing according to least-square method.

5. Results
The chemical composition of the developed samples WPC-35, WPC-55, WPC-80, whey protein hydrolysate and cheese whey permeate is shown in Table 1.

Resilience capability is an important quality factor of whey ingredients. Rehydration is carried out in three stages: wettability, dispersibility and solubility. Wettability is the water absorption capability, which may be defined as the fluid penetration into cavernous agglomerative system by capillary activity. The second stage of resilience is dispersibility, which is defined as the capability of the watered powder to be divided into separate particles at a slight mixing, which may pass through sieve of 210 µm. The result may be expressed by the proportion of particles numbers, given in %. The duration of these stages depends on the properties of the surface of certain particles of whey products, if they repel water or absorb it too fast, as well as on geometrical [8].

The dry particles of whey products dried with the help of spraying are not homogeneous. It is based on the fact that water will be diffusing to the particle surface from its center during drying process, and the dissolved solids will be diffusing from the particle surface to the center due to concentration gradient resulted from water evaporation from the surface of each particle. The process speed depends directly on the solute diffusion constant. In milk products this indicator is of the same order for lactose
and mineral salts, and the solute diffusion constant of whey proteins and fat globules is an order lower due to big sizes of these molecules [9].

| Indicator description          | WPC-35  | WPC-55  | WPC-80  | Whey protein hydrolysate |
|-------------------------------|---------|---------|---------|--------------------------|
| Dry matter, %                 | 96.48   | 97.10   | 95.10   | 93.88                    |
| Total protein in dry matter, %| 34.96   | 56.33   | 75.98   | 37.06                    |
| Lactose in dry matter, %      | 47.67   | 28.20   | 5.63    | 53.26                    |
| Fat in dry matter, %          | 13.00   | 9.0     | 6.50    | 2.09 Less than 0.01      |
| Ash in dry matter, %          | 6.11    | 5.20    | 3.49    | 7.22 4.55                |
| Active acidity                | 6.32    | 6.20    | 6.23    | 6.61 6.22                |
| Purity group                  | I       | I       | I       | I                        |
| Solubility index, cm³         | 0.1     | 0.2     | 0.2     | 0.2 0.1                  |

In order to study the peculiarities of water internal diffusion through the capillary structures of the cavernous dry particles of cheese whey permeate the adsorbed water mass was defined in comparison with whey protein UF-concentrates, with protein of 35, 55 and 80% in dry matter and whey protein hydrolysate (Fig. 1). The capillary effect depends on the particles number and size, pore air level and surface area of the powder.

The principal factor, determining wettability capacity, is dry particle-water interfacial tension. For that purpose the limiting wetting angle was determined for the developed products. This indicator is characterized by the wetting of dry powder with water drop, breaking solid-gas phase interfacial tension [10]. As a result, dry products with high content of whey proteins rapidly reach such a state when the adsorbed water weight is balanced by the capillary tension. This may be connected with formation of the initial limiting wetting angle (Fig. 2) and its slow time changing.

![Figure 1](image-url)

**Figure 1.** Water mass, adsorbed by the samples within 10 minutes, determined with the help of the fluid capillary rise method.
Figure 2. Change dependency of dry products limiting the wetting angle on the contact period with water.

The rehydration end point is dissolution, which may be determined as a system state, when the solid agent particles totally dissolve or become the stable suspension. This property characterizes the solubility index of the aqueous sludge and depends mainly on protein structure status in native, denaturated or aggregated form. Due to heat denaturation of whey proteins an increase of active sulfhydryl groups’ number is possible, they become more reactive as a result of protein molecule uncoiling with increasing temperature and lengthening the holding time [11]. This may impact functional and technological properties of whey ingredients and increase their antioxidant effect due to the bound groups release (Table 2).

### Table 2. Antioxidants and sulfhydryl groups content in whey ingredients.

| Sampling material       | Antioxidants content, mg/g | Sulphydryl groups content (mmol/L) |
|-------------------------|----------------------------|------------------------------------|
|                         |                            | Total                              | Active                           |
| Cheese whey             | 0.146                      | 0.32 ± 0.02                        | 0.11 ± 0.02                      |
| WPC-35                  | 0.031                      | 1.27 ± 0.02                        | 0.43 ± 0.02                      |
| WPC-55                  | 0.058                      | 2.54 ± 0.02                        | 0.86 ± 0.02                      |
| WPC-80                  | 0.095                      | 4.15 ± 0.02                        | 1.45 ± 0.02                      |
| Whey protein hydrolysate| 0.146                      | 4.86 ± 0.05                        | 2.07 ± 0.03                      |
| Permeate                | 0.024                      | 0.13 ± 0.02                        | 0.05 ± 0.02                      |

During proteolysis, a number of amino acids are released, which also increases the antioxidant activity of the hydrolysate. The binding of free radicals by peptides occurs due to the presence of hydrophobic terminal amino acids in them such as Ala (A), Pro (P), Val (V), Ile (I), Leu (L), Phe (F), Trp (W), Tyr (Y) and Met (M) [12].

Thus, the whey ingredients application in food products formulas will increase antioxidant effect of the finished goods.
6. Conclusion
The investigation of the composition, functional and technological characteristics of whey ingredients allows one to recommend their usage in manufacturing of different product line groups in order to control the technological processes and the enriched goods quality performance.

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