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Functional and technological properties of hydrocolloids: A comparative analysis

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Abstract. Hydrocolloids render certain properties to food products. Hydrocolloids are different in nature, but all of them can form colloidal solutions with designed properties. The market offers a wide range of animal and vegetable hydrocolloids. For instance, gelatin is in high demand in the food industry because its functional and technological properties make it possible to develop foods with particular technological characteristics. Gelatin is also used in pharmacy and biotechnology. This article introduces a comparative analysis of functional and technological properties of animal hydrocolloids obtained by different technologies in Tajikistan and Russia. Both samples demonstrated good water-binding capacity and viscosity. The resulting gels had the best foaming at pH 4.8 and a whipping temperature of 10°C. The foam resistance was about 98-100%. A higher whipping temperature resulted in unstable foam with poor foaming performance. The best quality profile belonged to the Halal collagen hydrocolloid from Tajikistan. Its technology was different from the methods used in Russia.

1 Introduction

The modern food industry uses a wide range of food additives to improve food structure. Hydrocolloids owe their ability to form colloidal solutions in the aqueous phase to the hydrophilic parts in their structure. Hydrocolloids include long-chain biopolymers that are dispersible, partially or completely soluble, and swellable in water. Such compounds provide food systems with the necessary viscosity or consistency, as well as stabilize dispersed systems [1,2].

Gelatin is a protein supplement of animal origin. It is a product of collagen hydrolysis obtained by thermal denaturation or physical and chemical degradation. Its amino acid composition includes up to 18 amino acids, including glycine (26-31%), proline (15-18%), hydroxyproline (13-15%), glutamic acid (11-12%), aspartic acid (6-7 %), alanine (8-11%), and arginine (8-9%) [3].

Gelatin varies in physicochemical properties, which makes it possible to use it in various industries and medicine. Gelatin solutions possess low viscosity and is more production-friendly than other hydrocolloids. Its viscosity depends on temperature, concentration, ion content, and pH. In addition, gelatin has a high foaming ability, which is an advantage in the production of foods with fluffy structure [4].

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2 Study objects and methods

The research featured hydrocolloids from different manufacturers:
- Sample 1 was collagen-produced beef hydrocolloid (animal protein) with a protein mass fraction of 87.2% (Halal, Tajikistan);
- Sample 2 was food beef hydrocolloid (animal protein) with a mass fraction of protein 87.2% (Stoing, Russia).

The functional and technological properties of the hydrocolloids were described based on the following methods:

1) The water-binding capacity (WBC), %, was calculated as follows:

$$WBC = \frac{m_a \cdot 100}{m_p} \quad (1)$$

where m_a is the maximal amount of added water that did not cause moisture separation in the test tube, g,

100 is the percentage conversion factor;

m_p is the animal protein mass, g.

Viscosity evaluation followed State Standard GOST 11293-89. Dynamic viscosity, mPa • s, was calculated by the formula:

$$\eta = k \cdot \tau \cdot \rho \quad (2)$$

where k is the viscometer constant, mm^2/s;

τ is the flow time, s;

ρ is the solution density, g/cm^3.

Foaming capacity and foam stability were determined as follows:

A small amount of the gel solution was whipped in a measuring cylinder at a one-minute interval to measure the foam volume. The measurements occurred at 35°C, 25°C, and 10°C.

Foaming capacity (FC) was calculated by the formula below:

$$FC = \frac{H_f}{H_{sol}} \cdot 100 \quad (3)$$

where H_f was the foam height, mm;

H_{sol} was the initial height of the solution in the cylinder, mm.

2) The foam resistance (R, %) was calculated for the foam that remained after the cylinder had been at rest for 15 min:

$$R = \frac{H_{fr}}{H_f} \cdot 100 \quad (4)$$

where H_{fr} was the foam height after the fifteen-minute rest, mm.

3 Results and discussion

Hydrocolloids are highly swellable water binders. Compared to dairy proteins, they have excellent water-binding, gel-forming, and foaming properties. Their structure and ions in the molecular chain render them with high solubility and water-binding capacity [1, 4, 5].

The abovementioned water-binding capacity and the ability to form a protein network are the most valuable technological properties of hydrocolloids.

Figures 1 and 2 illustrate the water-binding capacity and the dynamic viscosity of the hydrocolloidal solutions.

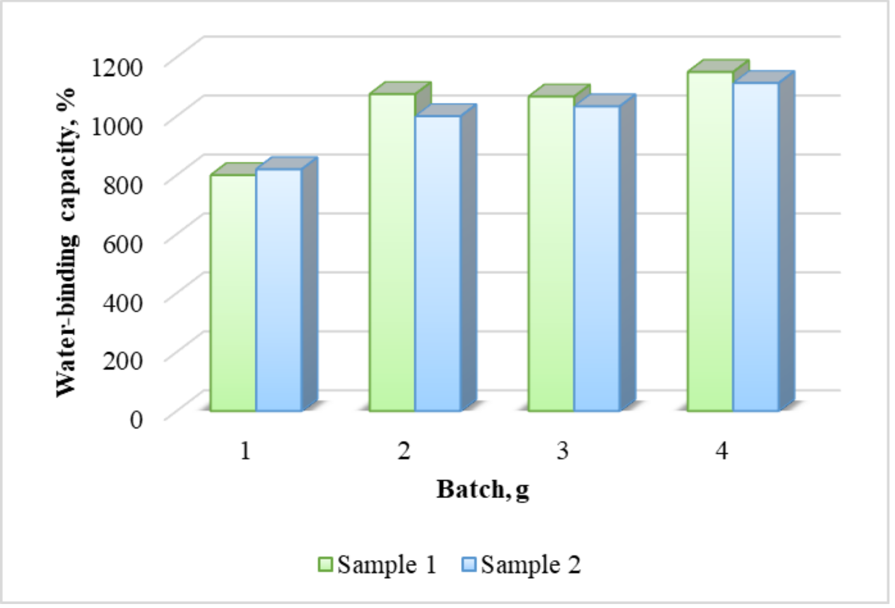


Fig. 1. Water-binding capacity of hydrocolloids: Sample 1 is the collagen-produced beef hydrocolloid (Halal, Tajikistan); Sample 2 is beef hydrocolloid (Stoing, Russia).

The water-binding capacity was determined by centrifugation. Centrifugal force releases liquid phase from the immobilized test sample. The volume of the liquid depends on the interaction between moisture and protein [3].

We weighed 1, 2, 3, and 4 g of hydrocolloids on a laboratory scale and added 10, 20, 30, and 40 g of distilled water. After that, they were homogenized for 30 s and stored at (4 ± 2) °C for 30 min for swelling. The resulting suspension was transferred into special 10 cm3 tubes and centrifuged for 10 min. If no liquid phase appeared, centrifugation was repeated after adding another 10 g. The procedure continued until the test tube showed some moisture separation.

Although both hydrocolloids were derived from beef protein, they had different characteristics, probably as a result of different production technologies. Sample 2 had a lower water-binding capacity.

As the concentration of hydrocolloid increased, the mass fraction of solids in the solution also increased. This process led to a greater liquid resistance. The high viscosity of hydrocolloidal solutions could be explained by the filamentous molecules that captured more solvent.

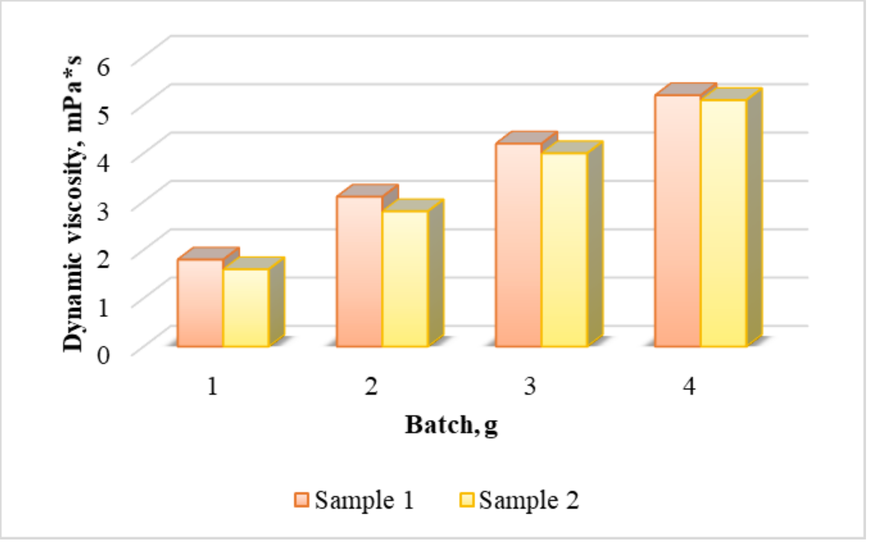


Fig. 2. Effect of hydrocolloid content on viscosity: Sample 1 is the collagen-produced beef hydrocolloid (Halal, Tajikistan); Sample 2 is beef hydrocolloid (Stoing, Russia).

Sample 1 showed the best dynamic viscosity: the solution viscosity increased together with the hydrocolloid concentration in the gel. The sample with 3-4 g hydrocolloid per 100 ml liquid provided a stabler and thicker structure of the food system.

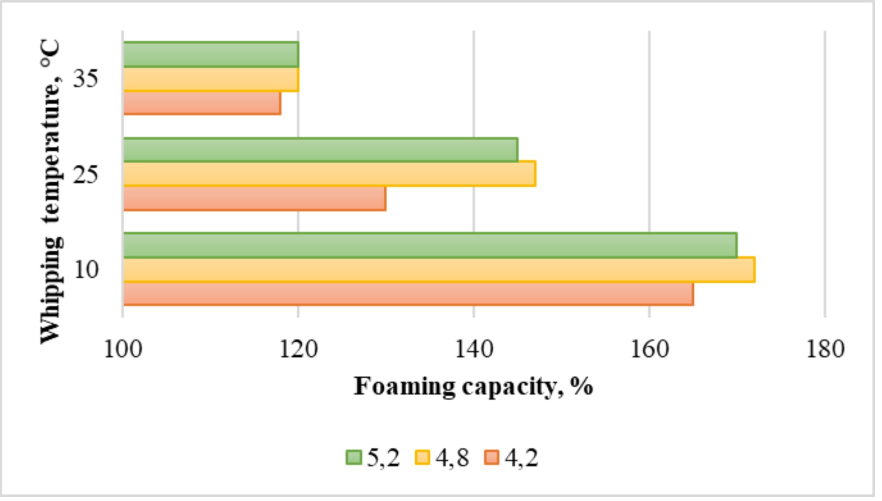
Gelatin usually serves as a gelation agent during thermodynamic processing. Gelation occurs when sol turns into gel. The process is associated with aggregation and fibril formation, which affect ionic strength, pH, and temperature.

Foaming capacity is as important for hydrocolloids as gelation. Foaming is the ability of proteins to form highly concentrated liquid-gas systems, i.e., foams. Foam systems appear when gas disperse in a liquid medium under the effect of a foaming agent. Foaming conditions involve temperature, time, and whipping rate. They are important technological factors for foods with a fluffy structure [7, 8].

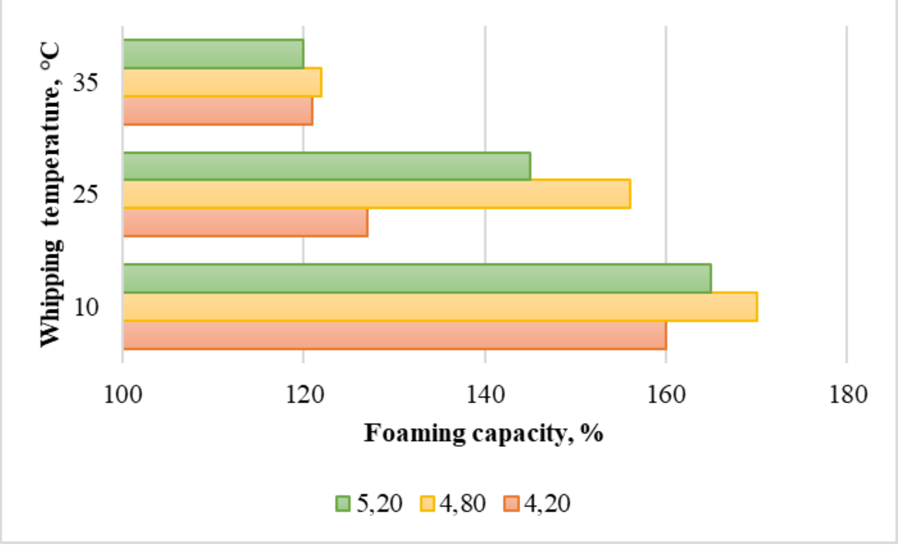
In laboratory conditions, foaming and its stability can be difficult to measure because they are limited by the methods applied. The next research stage involved evaluating the foaming ability of the hydrocolloid solutions at different pH and whipping temperatures.

The whipping temperature is of highest importance for aerated functional products since proper temperature provides storage resistance. We determined the optimal whipping temperature at various pH of the gels obtained at the previous research stage. The measurements involved three temperature parameters: 35°C, 25°C, and 10°C.

The foaming capacity of the gel samples was tested at pH 4.2, 4.8, and 5.2 because these pH regimes are known to provide the best gelation (Fig.3).



a)



b)

Fig. 3. Effect of temperature on foaming capacity of protein gels at different pH: a) Sample 1 is the collagen-produced beef hydrocolloid (Halal, Tajikistan); b) Sample 2 is beef hydrocolloid (Stoing, Russia).

The best foaming gels occurred at pH 4.8 and 10°C. This regime raised the foam resistance up to 98-100%. The foam was a fine-meshed dense system that maintained stability at the given temperature conditions. The increase in the whipping temperature reduced the foaming capacity down to 120-122%; the foam had poor resistance and settled down quite quickly.

4 Conclusions

In this study, the hydrocolloids demonstrated good water-binding capacity, and the resulting gels had good viscosity. These characteristics improved the technological properties and quality of food systems. The water-binding capacity and viscosity increased together with the hydrocolloid concentration in the gel.

The optimal foaming occurred at 10°C when gel formation started and stabilized the foam. When the whipping temperature reached 35°C, foam formation halved. High temperatures also destabilized the foam.

The best quality profile belonged to the collagen hydrocolloid made in Tajikistan. Its production technology was different from that of the Russian sample.

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