The influence of curd whey on biotechnological processes during bread baking

O Checheneshkina and G Larionov
Department of Biotechnology and Agricultural Processing, Chuvash State Academy of Agricultural Sciences, 29 Karl Marx Street, Cheboksary 428003, Russian Federation

1E-mail: checheneshkina1991@edu.academy21.ru

Abstract. The use of waste-free production in the food industry is an urgent problem for the entire world economy. Processing companies most frequently face challenges in managing their waste. This is one of the reasons for low return on production. An example of that is (curd) whey. When making dry-curd cottage cheese and cheese, many dairy plants often do not use whey for further processing, but dispose of it. Therefore, produced in the conditions of the educational and research lab of milk and dairy technology and the educational scientific-production lab of baking, biotechnology and agronomy faculty of the Federal State Budgetary Educational Institution of Higher Education Chuvash State Agricultural Academy, this publication explores the use of whey in baking and its influence on biotechnological processes when baking wheat rye bread. Test lab baking with added whey was successful in terms of organoleptic and physical-chemical properties. Found that in the first experimental group the acidity of the crumb of bread is equal to 9.50 degrees, in the second experimental group 9.02 degrees. The porosity in the second experimental group is 10% higher than in the first group. The moisture content of the crumb in the second experimental group is 2% higher than in the first experimental group.

1. Introduction
Curd whey results from milk ripening, which breaks down into whey and dry-curd cottage cheese when heated. Curd whey is a type of whey. Also known as acid whey, it is a byproduct of the manufacture of dry-curd cottage cheese and casein [1, 2]. It contains half of all milk nutrients, such as soluble proteins making up nearly 20% of milk proteins, milk sugar, mineral salts, water-soluble vitamins. Whey is a byproduct which is usually scrapped and sometimes recycled in food manufacturing, breeding and even in plant-growing [3].

There are several directions for its processing: the use of whey for feed purposes, the production of whey drinks, the production of mixes, the concentration of natural whey, the contact drying of whey, the use in other industries (in the pasta, confectionery, bakery industries) [4].

For many decades, domestic and international scientists have been exploring opportunities for using curd (milk) whey as a food supplement in bakery products. Curd whey is presumed to enhance gustatory qualities of certain baked foods. This is because it contains many organic acids (lactic, citric, acetic). In the right dosage, acetic acid is known to prevent potato disease that often happens in the warmer months [5].

Many scientists have also proved that curd whey added to dough enormously saves its fermentation time while quality parameters of bread remain within the standards [6]. Foreign scientists in their
research prove the positive influence of the components of curd whey in various branches of the food industry [7, 8].

Today, using all raw material resources in the food industry is relevant. Therefore, our publication is looking into the usage of curd whey, a byproduct of the production of dry-curd cottage cheese, in baking.

2. Materials and methods
The use of curd whey in wheat rye bread baking was researched in 2019 at the Department of Biotechnology and Agricultural Processing in the educational and research lab of milk and dairy technology and the educational scientific-production lab of baking, biotechnology and agronomy faculty of the Federal State Budgetary Educational Institution of Higher Education Chuvash State Agricultural Academy. The general technological scheme of curd whey bread the educational scientific-production lab of baking is shown in figure 1.

In the educational and research lab of milk and dairy technology, curd whey is produced by adding acid and rennet: 1.0-5.0% starter culture is blended with cooled standardized milk, then rennet or pepsin is added, made somewhat 6 hours earlier using boiled water (cooled to 35 °C). The fermentation process takes about 3 hours.

Curd whey quality was assessed using Klever-2M analyzer which measured major qualitative parameters of the mass fraction of protein, lactose, the mass fraction of solids, as well as the density, temperature of the sample and the calculated amount of added water.

To calculate the whey-based dough formula, we used a formula for plain wheat rye bread under GOST 2077-84 from the State Standard Baking Formulas Book (table 1) [9].

To develop technological properties and the process to produce wheat rye bread in the conditions of the educational scientific-production lab of baking at the Federal State Budgetary Educational Institution of Higher Education Chuvash State Agricultural Academy, we used Baking Process Manual.
Table 1. Formula for plain wheat rye bread, GOST 2077-84 [9].

| Raw material                  | Raw material used, kg |
|-------------------------------|-----------------------|
| Dark rye flour                | 30.00                 |
| Whole wheat bread flour       | 70.00                 |
| Baker’s compressed yeast      | 0.05                  |
| Edible salt                   | 1.50                  |
| Total                         | 101.55                |

A test lab baking included the following groups:
- control sample – a universal formula without curd whey;
- experimental sample 1 – manufacturing formula with 50% water and 50% curd whey added;
- experimental sample 2 – manufacturing formula where water was fully replaced by curd whey.

Bread in control sample was baked according to GOST 2077-84 formula [9]. In the experimental sample 1, the test sample was baked with water and curd whey added in the ratio 1:1. In the experimental sample 2, the test sample was baked with curd whey totally replacing water.

The quality of the final product was assessed on the basis of organoleptic (appearance, texture of the crust, color of the crumb, crust color, porosity, texture of the crumb, bread taste, bread odor) and physical-chemical properties (acidity, porosity, moisture content) in the conditions of Department of Biotechnology and Agricultural Processing of the Federal State Budgetary Educational Institution of Higher Education Chuvash State Agricultural Academy.

The quality of whey bread on its physical-chemical parameters was assessed in accordance with standards, regulations and specifications:
- acidity was measured using accelerated method as per GOST 5670-96 Bakery products. Methods for determination of acidity [10];
- moisture was measured as per GOST 21094-75 Bread and bakery products. Method for determination of moisture [11];
- porosity was measured as per GOST 5669-96 Bakery products. Method for determining porosity [12].

3. Research results

Table 2 shows the results of curd whey quality assessment using Klever-2M analyzer. The curd whey quality assessment showed physical-chemical parameters are keeping with the GOST 34352-2017. For a test lab baking, curd whey with the optimum GOST-matching values was used [13].

| Parameters | Mass fraction of protein, %, at least | Mass fraction of lactose, %, at least | Mass fraction of solids, %, at least | Density, °A | Mass fraction of salts, % | Added water, % | Temperature, °C, not higher than |
|------------|-------------------------------------|--------------------------------------|-------------------------------------|-------------|--------------------------|----------------|---------------------------------|
| GOST 34352-2017 requirements | 0.4 | 3.5 | 5.0 | - | - | - | 6.0 |
| Curd whey  | 2.89 | 4.27 | 7.47 | 29.87 | 0.67 | - | 5.5 |

The mass fraction of protein in curd whey was 2.89%, which is 7.22 times more than the standard requirement. The mass fraction of curd whey lactose increased by 1.22 times. And the mass fraction of dry substances is 1.49 times. The temperature of the curd whey was lowered by 1.5 °C. For the laboratory baking test, we selected curd whey with optimal values that met the requirements of the standard.

Table 3 shows technological parameters during dough fermentation in control sample, experimental sample 1 and experimental sample 2.
Table 3. Technological parameters during dough fermentation.

| Parameters             | Unit of measure | Control sample | Experimental sample 1 | Experimental sample 2 |
|------------------------|-----------------|----------------|-----------------------|-----------------------|
| Fermentation start time| h, min          | 10:00          | 10:00                 | 10:00                 |
| First punch time       | h, min          | 11:00          | 10:45                 | 10:30                 |
| Second punch time      | h, min          | 12:00          | 11:35                 | 11:00                 |
| Fermentation end time  | h, min          | 12:30          | 12:15                 | 11:30                 |
| Fermentation duration  | min             | 150            | 135                   | 90                    |
| Dough temperature:     |                 |                |                       |                       |
| initial                | °C              | 24             | 25                    | 26                    |
| end                    | °C              | 30             | 31                    | 32                    |

The start time of fermentation was the same for all three samples. However, during the first kneading, it was noticed that fermentation in 1 test sample accelerated by 15 min, and in 2 test sample by 30 min. Fermentation in the control sample met the requirements of the regulatory documentation. In 1 test sample, fermentation lasted 50 min until the second kneading, and in 2 test sample it lasted 20 min less. Fermentation in the control sample before the second kneading lasted 60 min, which is 10 min longer than in 1 experimental sample and 30 min than in 2 experimental sample. In general, fermentation in the 2nd experimental group ends 45 min earlier than in the 1st experimental sample and 60 min in the control sample.

After the end of fermentation, the dough pieces were melted and baked under equal conditions. After baking, the breads were cooled for two hours. Then the sensory evaluation of the finished products was carried out. The results control sample of laboratory baking test is shown in figure 2.

![Figure 2. Appearance of curd whey bread control sample.](image)

Organoleptic indicators (appearance, crust color, crust character, bread crumb, porosity, smell, bread color) of the control sample meets the requirements of the standard. The results experimental sample 1 and experimental sample 2 of laboratory baking test is shown in figure 3 and 4.

![Figure 3. Appearance of curd whey bread experimental sample 1.](image) ![Figure 4. Appearance of curd whey bread experimental sample 2.](image)
According to the results of the laboratory test baking of bread, 1 prototype and 2 prototypes had a product corresponding to the bread shape in which baking was performed, without side outflows, a dark brown crust, developed porosity. Bread of experimental sample 2 had a pleasant, savory sourdough bread flavor. The bread of the 2nd experimental group had a fragrant smell characteristic this type of product, without foreign smell.

Table 4 shows organoleptic assessment of curd whey bread. Trial laboratory baking of 2 prototypes met the requirements of the regulatory and technical documentation and showed the best results in terms of organoleptic indicators than in 1 prototype and control samples. By the nature of the crust in the control and 2 experimental samples, the bread had a smooth crust without large cracks and explosions. By the color of the crust 1 and 2, experimental samples differed from the control sample and had a dark brown color. In terms of the nature of the crumb, only 1 prototype had a difference, which had a slightly sticky crumb and, after light pressure with fingers, the crumb took its original shape for a long time. According to the smell 2, the test sample had a fragrant bread characteristic of this product, which significantly differed from the control and 1 of the test sample.

Table 4. Curd whey bread organoleptic assessment.

| Parameters          | GOST 2077-84 requirements [9] | Control sample | Experimental sample 1 | Experimental sample 2 |
|---------------------|--------------------------------|----------------|-----------------------|-----------------------|
| Appearance (shape)  | Shall have a shape of a loaf pan in which it was baked, without overflows. | Shall have a shape of a loaf pan in which it was baked, without overflows. | Shall have a shape of a loaf pan in which it was baked, without overflows. | Shall have a shape of a loaf pan in which it was baked, without overflows. |
| Texture of the crust | Smooth, free of large cracks and bread top separating. | Smooth, free of large cracks and bread top separating. | Small cracks and top separations. | Smooth, free of large cracks and bread top separating. |
| Colour of the crust | Light brown to dark brown. | Light brown to dark brown. | Dark brown. | Dark brown. |
| Porosity            | Well-developed, free of large gas cells and doughy flecks. | Well-developed, free of large gas cells and doughy flecks. | With moderate gas cells. | Well-developed, with uniform sized gas cells. |
| Texture of the crumb| Thoroughly baked, non-clummy, not damp by touch, spongy. When slightly poking a finger, the crumb shall spring back. | Thoroughly baked, non-clummy, not damp by touch, spongy. When slightly poking a finger, the crumb springs back. | Slightly clummy crumb. When slightly poking a finger, the crumb springs back. | Thoroughly baked, spongy. When slightly poking a finger, the crumb springs back. |
| Bread taste         | Typical for this type of product, free of any foreign tastes. | Typical for this type of product, free of any foreign tastes. | Typical for this type of product, free of any foreign tastes. | Pleasant, savory sour dough bread taste. |
| Bread odor          | Typical for this type of product, free of any foreign odor. | Typical for this type of product, free of any foreign odor. | Typical for this type of product, free of any foreign odor. | Flavory, typical for this type of product, free of any foreign odor. |
Table 5 shows physical-chemical assessment of curd whey bread. Physical-chemical assessment of bread demonstrated consistency with GOST 2077-84 [9]. Crumb acidity of bread in experimental sample 1 is 9.50 degrees, which is in line with the standard and is 5.05% higher than in experimental sample 2. Experimental sample 2 had porosity 10% higher than in experimental sample 1. Crumb moisture in experimental sample 2 is 2.0% higher than in experimental sample 1. We assume that this is due to a certain property and chemical composition of curd whey.

| Parameters                  | GOST 2077-84 requirements [9] | Control sample | Experimental sample 1 | Experimental sample 2 |
|-----------------------------|--------------------------------|----------------|------------------------|-----------------------|
| Crumb acidity, degree, max. | 10.0                           | 10.0           | 9.50                   | 9.02                  |
| Crumb porosity, %, at least | 50.0                           | 50.0           | 49.0                   | 59.0                  |
| Crumb moisture, %, max.     | 48.0                           | 48.0           | 44.0                   | 46.0                  |

4. Conclusion
The test lab baking for experimental sample 2 was successful in terms of organoleptic properties: its bread had pleasant, savory sour dough bread taste, the crumb was thoroughly baked, spongy, when slightly poking a finger, it would spring back, it had well-developed porous crumb structure with uniform sized gas cells, bread odor was flavorful, typical for this type of product, free of any foreign odor.

Physical-chemical assessment of bread in experimental sample 2 showed the best result and was in line with the standard, namely, the crumb acidity in experimental sample 1 is 9.50 degrees, which is in line with the standard and is 5.05% higher than in experimental sample 2. Experimental sample 2 has porosity 10% higher than in experimental sample 1. Crumb moisture in Experimental sample 2 is 2.0% higher than in experimental sample 1.

Thus, by fully replacing water with curd whey in the production formula, we can produce bread with the best organoleptic and physical-chemical properties.

Recommendations to manufacturers. To improve and enrich bakery products, dairy byproducts shall be used. This will diversify bakery products and will lead to gains for the dairy sector.

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