Practical and scientific basis for development of fermented bioproduct with dietary properties

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Abstract. Using vegetable raw materials in a fresh or processed form is of concern for food production sphere. A wide range of useful nutrients comprising fresh gourds crops, which grow in southern federal region, determines the prospects for their processing. The present article lists materials devoted to the issue of widening the range of functional properties of fermented products. The article substantiates the necessity of processing fermented products which were enriched with indispensable nutrients using the innovative vegetable raw material. To this end a production technology for fermented bioproduct with addition of gourds concentrates was developed. Gourds crops’ pulp is rich in food fibers, antioxidants, vitamins and folic acid. However, owing to seasonal cultivation, it is relevant to concentrate gourds’ pulps favouring to moderate temperature conditions under vacuum. Researches were conducted in the laboratory of the Department of Food Production Technology, Volgograd State Technical University. The material for studying was represented by biologically active additives “Euflorin-B” and “Euflorin-L”, yoghurt DVS-sourdough “Lactoferm ECO”, gourds pulps – watermelon’s, pumpkin’s, melon’s, – and also experimentally received samples of sour-milk clumps, concentrates and bioproduct. During the research, a selection of probiotic bacterial means was made. Technology of preparing the gourds concentrates was made and their nutrition value was assessed, including carbohydrate richness and measuring of sweetness. The recipe of innovative fermented bioproduct was optimized. The possibility of gourds processing was scientifically justified. It was also proved that gourds’ concentrate can be used to produce innovative fermented products for usual and dietary purposes.

Fermented, or sour-milk, bioproducts – are dietary products possessing curative and prophylactic purposes in alimentation. Fermented bioproducts are processed by the acidification of milk with souring microorganisms and by adding probiotic and symbiotic cultures, for instance, Bifidobacterium and Lactobacterium acidophilum. Due to the famous antagonism of probiotic cultures towards putrefactive and pathogenic microorganisms, bioproducts contribute to restoring and supporting the natural balance of flora in gastrointestinal and urogenital tracts, upper respiratory tracts, immune system strengthening and antimicrobial resistance of the human body. Bioproducts also impede the accumulation of toxins which are of bacterial origin [1-3]. An effective way of widening a range of functional properties of fermented bioproducts is their enrichment with physiologically active food ingredients. This causes a...
favourable effect to metabolic processes, organs and their systems functioning, in addition, it possesses prebiotic effect. Hence, in order to heighten physiological value, it is expedient to add food fibres, vitamins, essential amino acids and other biologically active substances in the recipe of bioproducts [4, 5].

According to market research it was determined that the majority of fermented products of traditional product line, mostly yoghurts, contain artificial flavours, colours, and, as a rule, contain unnecessary enormous amount of easily digestible carbohydrates – sucrose and starch, – which increases their caloric value, decreases functional influence and restricts consumption in a course of adequate nutrition. The established fact affirms the necessity of scientifically-based correction of fermented bioproducts’ nutritional content via raw materials selection and recipes variations according to their functional and technological properties. Food combinatorics should be considered here to avoid the usage of artificial additives and provide the achievement of necessary consumer properties [4-6].

Nowadays technology of producing milk products with dietary properties tends to involve new types of natural raw vegetable material. One of the most perspective type is gourds products. In southern regions of Russia, especially in the steppe areas of Volga region, gourds growing is one of the most profitable agriculture sector. Gourds crops, in particular, watermelons, melons and pumpkins, are cultivated with nutrition and forage aims. Nutrition gourds, which are grown on the territory of southern federal region, are juicy. Their high gustatory qualities enable them to be eaten raw and fresh and to be processed [7]. Practicability of their implementation into fermented products production resulted from containing a wide range of technologically and biologically active valuable components. Apart from gustatory, sweetening and colouring compounds, gourds pulp is rich in components contributing to physiological processes regulation in a human body, including food fibers, organic acids, vitamins, thiamine, niacin, riboflavin, folic acid, iron salts, phosphorus, potassium. Melon is known for containing big amount of silicon which participates in immune system functioning. Due to the amount of vitamins gourds are equal to fruit and the amount of carotene in pumpkins of “highly-carotene containing” types excels red carrot [7, 8].

Significant stock of gourds in Volgograd, Astrakhan, Stavropol, Krasnodarsky regions makes it efficient to justify the opportunity to use gourds’ processed products in technologies related to agroindustrial sectors, in particular, milk sector. However, seasonal cultivating of gourds reduces significantly the period of their consuming raw and fresh due to water content 80-90%, which creates a technological problem. Furthermore, such peculiarity of content lowers the concentration of dry components in a pulp which, in turn, reduces the gustatory level, colour, and weakens the functional effect. Above mentioned difficulties of using gourds can be solved by removing excess water which acts as material remover in a pulp and also as favourable condition for metabolic processes, organs and their systems functioning. Favoring to moderate temperature mode, water from the pulp should be removed to a state of condensed concentrate [8, 9].

The aim of the study created scientifically-based justification for processing dietary fermented bioproduct in the aspect of developing its consumer and technological properties by selecting sourdough microflora and adding to the recipe physiologically active components of gourds which are in a technologically adequate state.

Complex research of the topic was conducted in the laboratory of the Department of Food Production Technology, Volgograd State Technical University. Material of the research was represented by raw material ingredients of the recipe of bioproduct, namely, cow milk, biologically active additives (BAA) “Euflorin-B” and “Euflorin-L”, yoghurt DVS-sourdough “Lactoferm ECO”, gourds pulps – watermelon, melon, pumpkin, – and experimentally received samples of bioproduct and gourds concentrates.

At the first phase of studies, a selection of new sourdough microflora exhibiting probiotic properties was conducted. Thus, symbiotic BAA “Euflorin-B” was studied in order to be used as a source of Bifidobacterium longum, and BAA “Euflorin-L” – as a source of Lactobacterium acidophilum. Properties of dietary supplements studied were estimated alongside with applying the traditional yoghurt sourdough “Lactoferm ECO”. As it commonly known, combination of acid formers - Lactobacterium
bulgaricum and Streptococcus thermophilus, - provides fast forming of dense clots in the content of yoghurt sourdough. Lactobacterium acidophilum, on the contrary, forms sticky clots. Bifidobacterium longum as less active acid formers produce weak clots [10].

For the experimental selection of sourdough and probiotic microflora a line of fermented bioproduct samples was developed. The experiment was conducted in the laboratory of the Department of Food Production Technology. During experiments the reservoir method was used. These samples differed in content of bacteria materials used, according to table 1.

Table 1. Samples of fermented bioproduct’s clots.

| Sample, № | Source of sourdough microflora | Characteristics |
|-----------|-------------------------------|----------------|
| 1         | BAA “Euflorin-B”              | Bifidobacterium longum |
| 2         | BAA “Euflorin-L”              | Lactobacterium acidophilum |
| 3         | BAA “Euflorin-B” + BAA “Euflorin-L” | Bifidobacterium longum + Lactobacterium acidophilum |
| 4         | BAA “Euflorin-B” + DVS “Lactoferm ECO” | Bifidobacterium longum + Streptococcus thermophilus, Lactobacterium bulgaricum |
| 5         | BAA “Euflorin-L” + DVS “Lactoferm ECO” | Lactobacterium acidophilum + Streptococcus thermophilus, Lactobacterium bulgaricum |
| 6         | BAA “Euflorin-B” + BAA “Euflorin-L” + DVS “Lactoferm ECO” | Bifidobacterium longum + Streptococcus thermophilus, Lactobacterium bulgaricum |

Properties of sourdough bacteria materials were estimated due to energy of acid forming, titrated acidity achieved and clots’ viscosity of processed samples of fermented bioproduct. Acidity was determined by means of titrimetric methods of acidity determination according, viscosity was determined by means of capillary viscometers B3-246 with transforming units of viscosity (°E) to kinematic viscosity.

At the second phase of studies, method of obtaining gourds’ concentrate was tested [8]. Condensing samples of purified watermelon pulp, melon and pumpkin was made under vacuum by evaporation of moisture in a rotary evaporator IKA RV 10 digital. Its construction provides juice vapours discharge from vacuum-machine to tubular refrigerator for condensation with cold water which is circulating in between tubes as a reversed flow. Experimentally set modes of vacuum concentration for gourds pulp are presented in table 2.

Table 2. Gourds pulp concentration rate.

| Pulp     | Temperature, °C | Speed of rotor rotation, rev./min. | Time, h, no more than | Degree of concentration |
|----------|-----------------|-----------------------------------|-----------------------|------------------------|
| Watermelon | 65-75           | 75                                | 4.5                   | 9.65-14.47             |
| Melon    | 50-60           | 40                                | 4.5                   | 9.38-14.06             |
| Pumpkin  | 50-60           | 50                                | 4.5                   | 9.56-14.34             |

Usage of the gravimetric method determined that indicated modes provided up to 40-60% concentration of dry components [11]. Technological adequacy of the concentrates received for the usage in fermented bioproduct production was assessed according to organoleptic figures, nutritional and energy value, carbohydrate density and level of sweetness. Carbohydrate density of the gourds concentrates was determined according to the principles of food combinatorics [12]. Level of sweetness
of the gourds concentrates was assessed due to coefficient value of sweetness in carbohydrate fraction concerning the rule of additivity.

At the final phase of studies, experimental samples of fermented bioproduct with adding watermelon, melon and pumpkin concentrates were received in the same laboratory conditions. Fermentation was conducted via reservoir method using source of sourdough and probiotic microflora which was chosen at the first phase, after that the 10% concentrate was added. In the received samples the amount of carbohydrates was estimated using method of food combinatorics.

Results of studies of biochemical, technological and rheological properties of the samples received are presented in table 3.

| Sample, № | Duration of fermentation, h | Limit acidity, °Т | Kinematic viscosity, mm$^2$/s |
|-----------|----------------------------|-------------------|-------------------------------|
| 1         | 22 23 25 26 27 41 50 76    | 83                | 1.28·10$^5$                  |
| 2         | 28 34 40 52 66 92          | –                 | 8.27·10$^5$                  |
| 3         | 30 38 45 51 59 82          | –                 | 6.33·10$^5$                  |
| 4         | 22 23 26 32 39 46 54 83    | 90                | 1.59·10$^5$                  |
| 5         | 32 39 46 63 85 – – –       | 92                | 7.61·10$^5$                  |
| 6         | 36 47 60 86 – – – – – – – | 90                | 4.29·10$^5$                  |

According to table 3, BAA “Euflorin-B” possesses the smallest energy of acid forming, the least viscous clot with acidity of 76°Т in 9 h (hours). Biochemical and technological properties of BAA “Euflorin-L” are identical to traditional yoghurt sourdough, and its rheological properties excel traditional yoghurt sourdough. Thus, samples №1 and 4 are noted to have the smallest viscosity. Samples №1 and 4 with BAA “Euflorin-B” which, in turn, contain Bifidobacterium longum. Samples №2 and 5 with BAA “Euflorin-L”, containing Lactobacterium acidophilum, have the biggest viscosity.

Dynamics chart of fermentation, presented in figure 1, shows sample №6 required the shortest period of time for clot forming – 5 h, – which is because it contains energy acid formers Lactobacterium acidophilum, Streptococcus thermophilus and Lactobacterium bulgaricum. Samples №1 and 4 which were fermented in the presence of Bifidobacterium longum but without Lactobacterium acidophilum, required a longer period of time – 9 h, – for clot forming.

![Figure 1. Samples fermenting dynamics.](image-url)
Quality and specific properties of fermented milk products depend mostly on direction and intensity during their bio-chemical processing [10]. Considering limit acidity and rheological properties of clots it can be concluded that to receive fermented bioproduct of optimal properties it is appropriate to use BAA “Euflorin-B” only together with BAA “Euflorin-L” and yoghurt sourdough. At the same time BAA “Euflorin-L”, due to high acidity of the clot recieved, also cannot be recommended to use as an individual sourdough. It would be more effective to combine BAA “Euflorin-L” with “Euflorin-B” or yoghurt sourdough.

Organoleptic characteristics of the watermelon, melon and pumpkin concentrates are presented in Table 4.

| Sample, № | Concentrate | Characteristic | Consistency | Taste | Smell | Colour |
|-----------|-------------|----------------|-------------|-------|-------|--------|
| 1         | Watermelon  | watermelon     | smearing, with small pieces, equally spreaded | sweet, appropriate to raw material | melon | from red to maroon |
| 2         | Melon       | melon          | from yellow to orange |
| 3         | Pumpkin     | pumpkin        | orange |

According to table 4, concentration of gourds pulp intensifies sweet taste and increases concentration of yellow and red colours. Thus, they can be used as taste, sweetener and colouring components in recipes of fermented bio-product. At the same time, innovative organoleptic properties make it possible to develop new line of dietary fermented sugarless bioproducts.

Information about nutrition and energy value of gourds concentrates which were received during the experiment are presented in table 5 [12].

| Indicator | Concentrate | Concentrate | Concentrate |
|-----------|-------------|-------------|-------------|
|           | watermelon  | melon       | pumpkin     |
| Dry components, %, at least | 43          | 58          | 51          |
| Mono- and disaccharides, % | 36.25       | 45.63       | 26.25       |
| Starch, % | –           | 0.63        | 1.25        |
| Food fibers, % | 2.5        | 5.63        | 12.5        |
| Fatty acids, % | –           | 0.63        | –           |
| Organic acids, % | 0.63      | 1.25        | 0.63        |
| Minerals, % | 2.5         | 3.75        | 3.75        |
| Energy value, kcal | 156.3    | 218.0       | 137.5       |

According to table 5, gourds concentrate contains 43-51% of dry components depending on the type of raw materials which are rich in carbohydrates, namely: low 0.63-1.25% in easily digestible starch which hightens calories; presence of indigestible but valuable in physiological terms food fibers in watermelon concentrate –2.5%, in pumpkin – 12.5%; predominance of fructose among simple sugars in pumpkin concentrate – from 26.25%, in melon – up to 45.63%. Due to their carbohydrate content, gourds concentrates are to be recommended as ingredients for forming dietary properties of fermented bioproducts [11].

Owing to the prevalence of carbohydrates in dry components of the gourds used, scientific interest lies in carbohydrate content of concentrates. Information about carbohydrates in gourds concentrates is presented in table 6 [12].
Table 6. Carbohydrate density of gourds concentrates.

| Indicator       | Concentrate                                      |
|-----------------|--------------------------------------------------|
|                 | watermelon | melon | pumpkin |
| Carbohydrates   | g / 100 g  | % CR  | g / 100 g  | % CR  | g / 100 g  | % CR  |
| Mono- and       |            |       |           |       |           |       |
| disaccharides   |            |       |           |       |           |       |
| Glucose         | 47.19      | 18.75 | 51.88     | 18.75 | 40.625    | 12.5  |
| Fructose        | 36.25      | 72.5  | 45.63     | 91.25 | 26.25     | 51.25 |
| Sucrose         | 10.63      | 42.5  | 6.88      | 27.5  | 13.25     | 27.5  |
| Maltose         | 17.69      | 61.88 | 12.5      | 35.625| 8.63      | 16.25 |
| Starch          | 7.56       | 17.5  | 26.25     | 92.18 | 4.38      | 11    |
| Fiber           | 0.38       | –     | –         | –     | –         | –     |
|                 | 2.5        | 12.5  | 5.625     | 22.5  | 4.375     | 37.5  |

* recommended consumption rate

Threshold values of concentration of substances are compared in order to measure the level of sweetness. Sweetness of sucrose is taken as a sweetness rate, equals 1.0. The sweetest of all sugars existed is fructose, the least sweet is maltose. Levels of sweetness among gourds are listed in table 7.

Table 7. Level of sweetness of gourds’ concentrates.

| Item    | Sweetness rate | Watermelon | Melon | Pumpkin |
|---------|----------------|------------|-------|---------|
| Glucose | 0.81           | 8.61       | 5.57  | 10.73   |
| Fructose| 1.73           | 30.6       | 21.63 | 14.92   |
| Sucrose | 1              | 7.56       | 26.25 | 4.38    |
| Maltose | 0.32           | 0.12       | –     | –       |

Level of sweetness 46.9 53.44 30.3

According to data received melon’s concentrate is the sweetest. It is 1.78 times sweeter than that of pumpkin’s and is 1.14 times sweeter than watermelon’s.

The scheme in figure 2 shows clearly the difference in carbohydrate content of fermented bioproduct samples.

Figure 2. Carbohydrate content of fermented bio-product.

Based on the conducted studies, carbohydrate content of watermelon and pumpkin bioproduct samples proved to have dietary characteristics especially useful for those who have diabetes. Bioproduct
with the addition of melon concentrate has a notable amount of sucrose – 10%, – and, thus, cannot be considered a suitable product for people with diabetes.

Designed range of fermented bio-product possesses pleasant gustatory qualities, is highly digestible, is dietary and curative. It was revealed that BAA “Euflorin-B” is appropriate to use when forming probiotic properties in new fermented product only in the presence of BAA “Euflorin-L” or yoghurt sourdough. Presence of indigestible ingredient – gourds food fibers, – causes positive effect on human organism, improving survival of probiotic microflora of BAA “Euflorin-B” and “Euflorin-L” through transit in intestine. It also stimulates activity of bacteria in large intestine namely Bifidobacterium and Lactobacterium [1, 13, 14].

Preliminary concentration of watermelon, melon and pumpkin pulp via vacuum-condensing method removes gourds seasonal cultivation problems and heightens technological adequacy in using for fermented products preparation. Thus, concentration of mono- and disaccharides makes the product sweet so sugar can be removed from the recipe. Increasing of concentration of natural colouring provides products with pleasant red and yellow colours. This will make it possible to evade using artificial colours which are not considered to be part of healthy food. Concentration of food fibers provides functioning of gourds concentrates in the recipe of fermented bioproduct. This reveals itself in preserving the balance of micro-ecology in gastrointestinal tract, stimulating of peristalsis of intestines, binding and excretion from the body of xenobiotics.

Studies have resulted into opportunity of using vacuumly concentrated gourds as gustatory sweeteners and sources of food fibers in producing innovative fermented products for usual and dietary purposes.

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