Application of the technology of encapsulation of rowanberry extract to develop a functional cottage cheese dessert

I V Matseychik¹, S M Korpacheva¹, E G Martynova¹,³ and I O Lomovsky²

¹Department of Technology and Organization of Food Industries, Faculty of Business, Novosibirsk State Technical University, 20 Prospekt K. Marksa, Novosibirsk, 630073, Russian Federation
²Institute of Solid-State Chemistry and Mechanochemistry of the Siberian Branch of the Russian Academy of Sciences, 18 Kutateladze str., Novosibirsk, 630128, Russian Federation

E-mail: liz.martynova@mail.ru

Abstract. The possibility of using the technology of encapsulation of rowanberry extract to remove the natural bitter taste of raw material is discussed in this paper. Fruits of the rowan native to Novosibirsk city and the Altai region (Russia) were subjected to infrared (IR) drying (the rowanberries were collected in September 2017 and 2018). A plant extract produced using the IR-dried rowanberry powder was utilized for encapsulation. Two encapsulation technologies, spray drying and freeze drying, were discussed and compared. Polysaccharides (konjak gum and guar gum) were used as encapsulating agents. It was found that encapsulation could significantly improve properties of the finished product. The developed encapsulated powder can be used to produce value-added functional cottage cheese dessert. The functional properties of the samples before and after encapsulation were verified using physicochemical methods. The resulting powder had increased contents of vitamin C, β-carotene, flavonoids, and antioxidants.

1. Introduction

Development of the technologies and recipes of functional food products is a very promising new trend in modern food industry. Addition of food products containing functional ingredients to the food consumption pattern is one of the key objectives of developing novel added-value food products that can improve the nutritional status of the population. The content of functional ingredients in these food products is ≥ 15% per serving. These products are known as functional foods.

Today, there is a steady trend towards using natural plant-based raw materials and their derivatives in functional food technology [1]. It has been suggested that fruits of the rowan (Sorbus Aucuparia L.), which is widespread throughout Siberia, can be used for developing a functional ingredient. Rowanberries can be utilized as an important source of vitamin P and carotene, as well as macro- and microelements [2]. However, red rowan berries are bitter, due to the high content of phenolic compounds, therefore their use as functional food ingredients is limited [3].

The polyphenolic complex contained in the fruits of mountain ash, helps to restore the suppressed activity of the immune system, providing a stimulating effect on the formation of antibodies and the bactericidal activity of immunocompetent cells. This property researchers substantiate the presence in the fruits of a complex of phenolic compounds, primarily proanthocyanidins, which have antioxidant, immunotrophic, anti-inflammatory and capillary strengthening effect [4].
The objective of this study was to use the technology of encapsulation of rowanberry powder produced by infrared (IR) drying in order to improve its sensory properties and to utilize the resulting powder for production of a functional cottage-cheese dessert.

Cottage cheese is a valuable raw material in terms of eliminating the existing nutrient deficiency in the human diet. The advantage of encapsulation is that when using this technology on bitter, but useful, powder, you can add more useful substance to the recipe of curd dessert.

2. Experimental

2.1. Characteristics of the raw materials used

Rowanberries and their derivatives contain a broad range of biologically active substances, such as bioflavonoids (239.1±0.3 mg/100g), anthocyanins (105.4±0.4 mg/100g), vitamin C (377.4±0.3 mg/100g), β-carotene (15.0±0.2 mg/100g), etc. Furthermore, rowanberries exhibit a high antioxidant capacity (AOC = 4.2±0.5 mg quercetin/g) [5].

Rowanberries reach their peak ripeness in September or October. At this point, the content of biologically active substances, vitamins, and minerals in them is the highest. However, most of these substances are destroyed during storage so that only non-nutritive ballast components are left. Biological activity of the plant-based supplement can be preserved by using infrared drying, which is especially relevant for Siberia [6].

In human nutrition, cottage cheese is of great importance as a source of proteins (14–17%), fats (9–18%), carbohydrates (lactose occupies an important place – 1.3–2.8%), mineral substances (1%) and vitamins (A, B₁, B₂). Cottage cheese is rich in calcium, phosphorus, iron, magnesium – the substances necessary for the growth and proper development of the young organism. Its salts of Ca and P are in an optimal ratio. Protein and fat cottage cheese are easily digested. The water content in cottage cheese is 65–80%.

The encapsulation technology (entrapment of one material in another one giving rise to microparticles) was used to neutralize the bitter flavor of rowanberry powder (Figure 1) [7].

![Figure 1. Types of encapsulation: a – encapsulation; b – incorporation of a substance in another substance; c – a combination of these two technologies.](image)

In collaboration with the researchers from the Institute of Solid-State Chemistry and Mechanochemistry of the Siberian Branch of the Russian Academy of Sciences, we employed two technologies: spray drying and freeze drying.

2.2. Preparation of rowanberries for the study

Rowanberries harvested in the forest stands in the city of Novosibirsk and Ust-Muny rural locality (the Altai region, Russia) were subjected to infrared drying (SEDONA Express SD-6780). Drying was carried out at T ~ 55°C; ≥ 90% of biologically active substances was preserved.

The residual moisture content was measured using a WPS 50SX moisture analyzer. It was ≤ 5.7% [8].

The product was finely disintegrated on a DESI-11 disintegrator at 14,000 rpm under liquid nitrogen cooling. Intense mechanical treatment of IR-dried rowanberries gave rise to a brick-red fine-grained
powder with the average grain size of 70 µm. The resulting product was used as the reference sample; its chemical composition was determined. Table 1 summarizes the results of the analyses.

| Parameters                   | Actual value |
|------------------------------|--------------|
| Moisture content, g /100 g   | 5.7±0.01     |
| Crude protein, g / 100 g     | 5.5±0.01     |
| Crude fat, g / 100 g         | 4.5±0.01     |
| Crude fiber, g / 100 g       | 5.7±0.03     |
| Crude ash, g / 100 g         | 2.8±0.04     |
| Sugar, g / 100 g             | 25.4±0.21    |
| Calcium, g / 100 g           | 0.3±0.01     |
| Vitamin C, mg / 100 g        | 312.9±0.29   |
| β-carotene, mg / 100 g       | 12.5±0.15    |
| Flavonoids, mg / 100 g       | 224.2±0.02   |
| Iron, mg / 1000 g            | 102.0±0.18   |
| Zinc, mg / 1000 g            | 10.5±0.09    |
| AOC, mg quercetin / 100 g    | 5.6 ± 0.31   |

The content of water-soluble substances in the reference powder sample was determined for further experiments. Functional ingredients were extracted from the raw materials into a water phase on an ultrasonic bath at a 1:25 solid-to-liquid ratio (1 g of solid and 250 g (ml) of bidistilled water). Characteristics of an ultrasonic bath: model PS-40, volume 10 L, frequency 40 KHz, power 240W, manufacturer Omsk, Russia. Processing time – 1 hour. The extraction yield of water-soluble substances was 76% of the weight of the dry reference sample [9].

2.3. Preparation of encapsulation shells (polysaccharides)

Konjac gum was used as an encapsulating agent in spray drying encapsulation. This substance was chosen because it is stable at elevated temperatures that can be reached during spray drying. Guar gum was utilized for freeze drying encapsulation. Guar gum was chosen in this case because this substance retains its properties when the temperature is decreased to −30°C.

These two polysaccharides were prepared using the same scheme: the gum was added to water until it swelled. The as-prepared solutions of guar and konjac gums were mixed with rowanberry extract:

- for Spray drying encapsulation – 4 g of konjac gum + 250 g (ml) of bidistilled water and 5.3 g of rowanberry powder + 250 g (ml) of bidistilled water. Next, combine the two aqueous solutions and get 500 g of the working solution.
- for Freeze drying – 5.0 g of guar gum + 250 g (ml) of bidistilled water and 13.1 g of rowanberry powder + 250 g (ml) of bidistilled water. Next, combine the two aqueous solutions and get 500 g of the working solution for encapsulation.

2.4. Spray drying encapsulation

The working solution was spray-dried on a Buchi B290 spray dryer (inlet air temperature, 130 °C; outlet temperature, 70 °C) (Figure 2). After spraying, the resulting particles had a spherical shape; the average particle size was 10 µm [10].
Drying gave rise to a cream-colored powder with neutral flavour. However, its yield was < 15% of the anticipated value, so another method, freeze-drying encapsulation, was also tested.

2.5. Freeze drying encapsulation
Freeze drying (lyophilization) was conducted using an Inei-4 setup (chamber pressure, 3 Pa; coolant temperature, – 40°C; sample temperature ≤ – 5°C) (Figure 3). The working solution consisted of an aqueous solution of guar gum and the rowanberry extract [11].

A cream-colored powder with a neutral taste was obtained with the ~ 100% yield of the anticipated value.

3. Functional properties of the encapsulated powder and the dessert

3.1. Antioxidant capacity (AOC)
A series of studies was conducted to verify that the powders have functional properties. The antioxidant capacity was measured using a Cvet-Yauza 01-AA liquid chromatography system (Table 2) [12].
Table 2. Antioxidant capacity of rowanberry powders.

| Sample                        | AOC, µg quercetin / g |
|-------------------------------|------------------------|
| Unprocessed rowanberries      | 0.56 ± 0.02            |
| Rowanberries after disintegration | 0.46 ± 0.02            |
| Encapsulated powder           | 0.26* ± 0.01           |

* with allowance for 2:1 dilution, the AOC remains virtually unchanged (admissible error, 8%).

The AOC was elevated because the cell walls of the berries were ruptured during disintegration. When AOC was measured for the disintegrated powder, more substances exhibiting antioxidant properties were extracted.

Furthermore, a comparative analysis of the content of antioxidants in rowanberries stored throughout a year was carried out. The antioxidant capacity declined after storage. However, the loss of antioxidant capacity was less significant for the encapsulated powder. A plausible reason is that the outer shell of the encapsulated powder, which is made of polysaccharide, prevents oxidation of the encapsulated ingredient.

3.2. Flavonoids

The most characteristic reaction (with iron (III) chloride) was chosen for qualitative detection of flavonoids; complexes were analyzed spectrophotometrically [13].

A flavonoid forming a complex whose absorption peak lies closest to the absorption peak of the complex formed between the test sample and aluminum chloride was used as a reference sample (Figure 4).

![Figure 4. An absorption spectrum of the extract.](image)

The calibration curve was plotted using a solution of the reference sample in 60% ethanol (Table 3, Figure 5).

Table 3. The data used to plot the calibration curve.

| Absorbance (D), *10^-3 | Concentration (C), mg/ml *10^-4 |
|------------------------|---------------------------------|
| 2.1                    | 0.8                             |
| 3.7                    | 1.6                             |
| 5.4                    | 2.4                             |
| 6.3                    | 3.2                             |
| 8.6                    | 4.0                             |
| 1.1                    | 4.8                             |
The line of best fit (functional dependency, Figure 5) was estimated using Microsoft Excel:
- linear equation: \( y = 21.577x + 0.0178 \);
- the coefficient of determination is a figure showing how well the line of best fit represents the actual data; \( R^2 = 0.9819 \).

![Figure 5](image)

**Figure 5.** Absorbance \((D)\) as a function of rutin concentration \((C)\) in the solution analyzed spectrophotometrically.

The results are summarized in Table 4.

|                     | Absorbance \((D)\) | Concentration \((C)\), mg/ml * 10\(^{-3}\) | Rowanberry sample weight, g | Weight of flavonoids, mg | Content of flavonoids, mg/g |
|---------------------|---------------------|---------------------------------------------|-----------------------------|---------------------------|-----------------------------|
| IR-dried rowanberry powder | 0.21±0.03           | 9.00±0.01                                     | 4.12±0.1                    | 9.00±0.3                  | 4.24±0.02                   |
| Encapsulated powder  | 0.14±0.02           | 5.80±0.01                                     | 3.11±0.1                    | 7.25±0.3                  | 2.33±0.02                   |

* with allowance for dilution of the solution containing rowanberry and the polysaccharide (2:1), the total content of flavonoids remained unchanged.

### 3.3. Determination of vitamin C and β-carotene in powders

#### 3.3.1. Vitamin C
The method is based on the extraction of vitamin C solution of hydrochloric acid. After extraction, titration with a solution of sodium 2,6-dichlorophenolindophenolate is carried out until a light pink color is obtained. Processed results are presented in Table 5.

| Sample               | Vitamin C, mg/g |
|----------------------|-----------------|
| IR-dried rowanberry powder | 3.62±0.1       |
| Encapsulated powder  | 2.51±0.1        |

#### 3.3.2. β-carotene
The method is based spectrophotometric determination of the mass concentration of carotenoids. The proportions of individual carotenoids (of the total content of carotenoids) are determined by spectrophotometric measurement in fractions obtained during chromatographic separation of the extract. Processed results are presented in Table 6.
Table 6. β-carotene content in powders.

| Sample                        | β-carotene, mg/g |
|-------------------------------|------------------|
| IR-dried rowanberry powder    | 0.17±0.1         |
| Encapsulated powder           | 0.13±0.1         |

With allowance for dilution of the solution containing rowanberry and the polysaccharide (2:1), the total content of β-carotene and vitamin C remained unchanged.

3.4. Sensory evaluation of the developed rowanberry powders

The descriptor-profile method was used for sensory evaluation of the developed functional ingredients. It demonstrated that the encapsulated powder had better sensory properties (Figure 6) [14].

Figure 6. Flavor profile.

The technology of encapsulating plant-based rowanberry extract gives rise to a powder having no bitter, pungent, or astringent taste, unlike the IR-dried rowanberry powder.

3.5. Mathematical modeling of the formulations of cottage cheese desserts

Taking into account the enhanced properties of the samples under study, a series of functional cottage cheese desserts containing IR-dried rowanberry powder (2%) and encapsulated rowanberry powder (9%) was developed at the Technology and Organization of Food Industries Department of the Novosibirsk State Technical University. The optimal ratio between the main components was found using mathematical modeling by solving linear programming problems using MatLab software (Table 7) [15].

The table shows the content of flavonoids, vitamin C, β-carotene in each ingredient, which is included in the recipe of cottage cheese dessert.

Table 7. Mathematical modelling.

| Ingredients in the formulation               | Range of variation | Vitamin C, mg/100g | β-carotene, mg/100g | Flavonoids, mg/100g | Index, $X_i$ | Energy value, kcal |
|---------------------------------------------|---------------------|---------------------|---------------------|---------------------|-------------|-------------------|
| Fat-free cottage cheese                     | 15…20              | 0.5                 | 0                   | 0                   | $X_1$       | 76                |
| Cream                                       | 25…30              | 0                   | 0                   | 0                   | $X_2$       | 322               |
| Milk                                        | 10…18              | 1.32                | 0.01                | 0                   | $X_3$       | 54                |
| Granulated sugar                            | 3…6                | 0                   | 0                   | 0                   | $X_4$       | 399               |
| Water                                       | 6…26               | 0                   | 0                   | 0                   | $X_5$       | 0                 |
| Encapsulated rowanberry powder              | 6.5…14             | 251.31              | 13.09               | 233.07              | $X_6$       | 264               |
| Gelatin                                     | 1…5                | 0                   | 0                   | 0                   | $X_7$       | 0                 |
\(X_1-X_7\) stand for the unknown specific weights of each type of raw material within the product. One needs to determine the unknown values at which:

- \(F(x) = \min \{76\cdot X_1 + 322\cdot X_2 + 54\cdot X_3 + 399\cdot X_4 + 0\cdot X_5 + 264\cdot X_6 + 0\cdot X_7\}\) provided that the following conditions are met:
  - Vitamin C content is \(\geq 13.5\) mg (15% of the recommended daily intake): \(0.5\cdot X_1 + 0\cdot X_2 + 1.3\cdot X_3 + 0\cdot X_4 + 0\cdot X_5 + 152.12\cdot X_6 + 0.3\cdot X_7 \geq 10.5\);
  - \(\beta\)-carotene content is \(\geq 0.75\) mg (15% of the recommended daily intake): \(0\cdot X_1 + 0\cdot X_2 + 0.01\cdot X_3 + 0\cdot X_4 + 0\cdot X_5 + 6.86\cdot X_6 + 0.3\cdot X_7 \geq 0.9\);
  - Total flavonoid content is \(\geq 7.5\) mg (15% of the recommended daily intake): \(0\cdot X_1 + 0\cdot X_2 + 0\cdot X_3 + 0\cdot X_4 + 0\cdot X_5 + 145.38\cdot X_6 + 0\cdot X_7 \geq 7.5\);

Per product unit: \(X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 = 1\).

This problem is solved as follows: \(X_1 = 20.0\) g; \(X_2 = 25.12\) g; \(X_3 = 14.93\) g; \(X_4 = 7.84\) g; \(X_5 = 19.06\) g; \(X_6 = 8.97\) g; \(X_7 = 4.92\) g.

Mathematical modeling of the formulation using linear equations showed that 100 g of the cottage cheese dessert needs to contain at least 8.97 g of the encapsulated rowanberry powder to make the finished product functional.

3.6. Mathematical modeling of the formulations of cottage cheese desserts

Functional cottage cheese desserts containing IR-dried rowanberry powder and encapsulated rowanberry powder were developed at the Division of Technology and Organization of Food Production Facilities of the Novosibirsk State Technical University according to the data obtained by mathematical modeling of the dessert formulation. Four desserts have been developed: the ones containing IR-dried rowanberry powder at concentrations of 2% and 7% and the ones containing encapsulated rowanberry powder at concentrations of 9% (the rowanberry: polysaccharide ratio in the powder being 2:1) and 14% (1:1 ratio).

The formulation of the dessert containing encapsulated powder (2:1) at concentration of 9% is shown in Table 8.

| Raw materials/food products | Gross weight | Net weight | Weight of the finished product |
|-----------------------------|--------------|------------|-------------------------------|
| Fat-free cottage cheese, g  | 20.2         | 20.0       | –                             |
| Non-dairy creamer, g        | 25.0         | 25.0       | –                             |
| Milk (2.5%), g              | 15.0         | 15.0       | –                             |
| Sugar, g                    | 8.0          | 8.0        | –                             |
| Gelatin, g                  | 4.0          | 4.0        | –                             |
| Encapsulated powder, g      | 9.0          | 9.0        | –                             |
| Water, g                    | 19.0         | 19.0       | –                             |
| **Yield**                   | –            | –          | **100.0 g**                   |

Physicochemical analysis and sensory evaluation of the finished product were carried out to verify that the developed dessert has functional properties.

4. Results and Discussion

4.1. Sensory evaluation of the developed desserts

The sensory and physicochemical properties of the finished product samples were analyzed (Figure 7 and Table 9) [16].
Figure 7. Sensory evaluation of cottage cheese desserts: (a) desserts containing IR-dried rowanberry powder and (b) desserts containing encapsulated rowanberry powder.

The cottage cheese dessert containing encapsulated rowanberry powder (b) has better sensory properties than those of the dessert containing IR-dried rowanberry powder (a). In turn, sensory evaluation of the desserts containing encapsulated rowanberry powder only demonstrated that the cottage cheese dessert with 9% powder content was given the highest score.

Table 9. Physicochemical evaluation of the quality of cottage cheese desserts.

| Parameters                  | Control sample | Dessert containing the IR-dried rowanberry powder (2%) | Dessert containing the encapsulated powder (9%) |
|-----------------------------|----------------|--------------------------------------------------------|-------------------------------------------------|
| Dry solids content, g/100g  | 69.89 ± 0.04   | 68.36 ± 0.04                                          | 68.32 ± 0.04                                    |
| Acidity, °T                 | 54.00 ± 0.5    | 72.00 ± 0.5                                           | 62.00 ± 0.5                                     |
| Ash content, g/100g        | 0.04 ± 0.02    | 0.16 ± 0.02                                           | 0.21 ± 0.3                                      |
| Vitamin C, mg/100g         | 0.54 ± 0.02    | 6.17 ± 0.15                                           | 21.86 ± 0.2                                     |
| β-carotene, mg/100g        | –              | 0.32 ± 0.02                                           | 1.01 ± 0.05                                     |
| AOC, mg/100g               | 0.06 ± 0.01    | 2.05 ± 0.08                                           | 5.30 ± 0.2                                      |
| Flavonoids, mg/100g        | –              | 4.48 ± 0.12                                           | 20.30 ± 0.2                                     |

The recommended daily intake of biologically active substances is as follows: vitamin C ~70 mg; β-carotene ~ 5 mg; flavonoids ~50 mg; antioxidants (quercetin) ~30 mg [17].

4.2. Functional properties of desserts

The physicochemical studies have verified that the desserts had functional. The results are shown in Figs. 8–11 (the line shows the amount above which the product is considered functional: ≥ 15% of the recommended daily intake).

Figure 8. Total flavonoid content in cottage cheese desserts.
Figure 9. β-carotene content in cottage cheese desserts.

Figure 10. Vitamin C content in cottage cheese desserts.

Figure 11. Antioxidant capacity of cottage cheese desserts.

Because of the bitter taste of IR-dried rowanberry powder, the maximum content of this ingredient in the dessert is 2%.

Such a low content does not make the food product functional. Hence, the IR-dried rowanberry powder cannot be used as a functional ingredient. The encapsulation stage has increased the amount of functional component that can be added to the cottage cheese dessert sevenfold, thus ensuring the required amount of biologically active substances in the finished food product. The sample containing the encapsulated rowanberry powder satisfies more than 15% of the daily requirements for antioxidants, vitamin C, β-carotene, and flavonoids for humans.
5. Conclusions
A technology for producing encapsulated powders of IR-dried rowanberries by extracting functional ingredients from raw material has been developed. This method was used for the first time to produce functional food product from rowanberries. The encapsulation technology neutralizes the taste of the finished food product by masking the natural bitterness of the added raw material. The food product with improved sensory properties has been obtained, while its nutritional value and the total content of biologically active substances has not been reduced.

References
[1] Maceichik I V, Karpacheva S M, Tkach A N and Suvorova E A 2018 Use of complex natural additives for the development of new bakery recipes Izvestiya Vuzov. Prikladnaya Khimiya i Biotekhnologiya 8(4) 158–65
[2] Maceichik I V, Lomovskiy I O and Martynova E G 2018 Using the technology of encapsulation of the extract of mountain ash ordinary to create a functional curd product Eurasian Scientific Association 10(44) 66–9
[3] Sõukand R and Kalle R 2016 Use of wild food plants Changes in the Use of Wild Food Plants in Estonia 29–136
[4] Isaykina N V, Kolomiets N E, Abramets N Y and Bondarchuk R A 2017 Study of phenolic compounds in the extracts of berries of Sorbus aucuparia Chem. Plant Raw Materials (3) 131–9
[5] Hasbal G, Yilmaz-Ozden T and Can A 2015 Antioxidant and antiacetylcholinesterase activities of Sorbus torminalis (L.) Crantz (wild service tree) fruits J. Food Drug Anal. 23(1) 57–62
[6] Adak N, Heybeli N and Ertekin C 2017 Infrared drying of strawberry Food Chem. 219 109–16
[7] Đorđević V, Paraskovopoulou A, Mantzouridou F, Lalou S et. al. 2015 Encapsulation technologies for food industry Emerging Tradit. Technol. Safe, Healthy Quality Food 1 329–82
[8] Rigon R T and Zapata Noreña C P 2016 Microencapsulation by spray-drying of bioactive compounds extracted from blackberry (Rubus fruticosus) J Food Sci Technol. 53(3) 1515–24
[9] Nielsen S S 2017 Moisture content determination Food Analysis Laboratory Manual. Food Science Text Series (Springer, Cham) pp. 105–15
[10] Fang Z and Bhandari B 2016 Spray drying of bioactives Engin. Foods Bioactives Stability Delivery (Springer, New York) 261–284
[11] Yamashita C, Chung M, Santos C, Mayer C R M et. al. 2017 Microencapsulation of an anthocyanin-rich blackberry (Rubus spp.) by-product extract by freeze-drying LWT – Food Sci. Technol. 84 256–62
[12] Deineka L A, Makarevich S L, Deineka V I and Chulkov A N 2015 HPLC of anthocyanins with an amperometric detector: Evaluation of the antioxidant activity J. Anal. Chem. 70(8) 989–94
[13] da Silva L A, Pezzini B R and Soares L 2015 Spectrophotometric determination of the total flavonoid content in Ocimum basilicum L. (Lamiaceae) leaves Pharmacogn Mag 2015 11(41) 96–101
[14] L de Cock H 2019 Sensory evaluation, an important tool for understanding food and consumers Encyclopedia Food Security Sustainab. I 546–9
[15] Tarczyńska-Luniewska M 2018 The procedure of building stable fundamental database with the use of Matlab software Procedia Computer Sci. 126 2163–72
[16] Kumalasari R, Ekafitri R and Indrianti N 2017 Quality assessment of physical and organoleptic instant corn rice on scale-up process IOP Conf. Series: Earth Environm. Sci. 101 012025
[17] Maceichik I V, Lomovskiy I O and Martynova E G 2018 The use of encapsulation technology for improvement of functional properties of curd desserts Fundam. Bases Mechanochem.Techmol. (Novosibirsk: IPC NSU) p 150