Obtaining encapsulated powder from rowanberry for use in a food industry

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Abstract. Modern technologies of functional products show stable tendency of using plant raw materials in natural and processed forms. In Siberian region of the Russian Federation the typical plant is rowanberry (Sorbus aucuparia L.). The paper describes the development of encapsulated extract of rowanberry powder of infrared (IR) drying obtained from rowanberry trees grown in the city of Novosibirsk and Altai region. Two encapsulation technologies based on spray and freeze drying accordingly were carried out and compared with each other. The ratio of the encapsulating matrix (konjac and guar gums) and rowanberry powder of IR-drying was established experimentally. In the powder samples, the contents of antioxidants, flavonoids, vitamin C and β-carotene were determined. The formulations of cottage cheese dessert using encapsulated functional ingredient were developed and their functionality was established. The encapsulation technology allows one to mask native bitterness of rowanberry and thus improve the taste of culinary production. The obtained dessert samples have high sensory characteristics, and their nutritional value and biologically active substances content don’t decrease.

1. Introduction
Modern technologies of food production have got a stable tendency of using plant raw materials in natural and processed states [1]. One of the promising plant raw materials for developing of new dietary supplements can be rowanberry, which is common for Siberian region of the Russian Federation.

Even though rowanberry is widespread in a temperate climate zone, it is rarely used in food production. This is because rowanberries have bitter taste due to presence of the tannins [2].

The purpose of the researches was the study of rowanberry powder of infrared (IR) drying encapsulation technology for masking its natural bitterness and using in food production formulations.

2. Materials and methods
Rowanberry both in natural and processed states contain a wide range of biologically active substances, which are presented mainly by bioflavonoids (239.1±0.3 mg%), anthocyanins (105.4±0.4 mg%), vitamin C (377.4±0.3 mg%), β-carotene (15.0±0.2 mg%) et al. Besides that, rowanberry has got high antioxidant activity (AOA), which is equal to 4.2±0.5 mg of quercetin per 1 g of product [3, 4]. For keeping of rowanberries’ biological activity, it is advisable to use such conservation method as infrared
drying, which is actual for Siberian region [5]. It is known that during processing of raw berries the redistribution of mineral elements occurs [6], while IR-drying process allows to keep mostly all of them in dried production.

For masking of rowanberry powder bitter taste, the encapsulation technology (figure 1) was used. This technology supposes the inclusion of one material into another. As a result, the microparticles are formed [7].

![Figure 1. Encapsulation process in hot air flow](image)

Experimental researches were held at the Technology and Organization of Food Industries Department of Novosibirsk State Technical University in cooperation with the Laboratory of Solid State Chemistry of Institute of Solid State Chemistry and Mechanochemistry of the SB RAS.

For comparison two technologies of encapsulation with the use of spray and freeze drying processed were used. For selecting of required encapsulating matrix and encapsulated substance ratio, the watersoluble substances content in rowanberry extract was determined.

Rowanberries were dried with IR-radiation on SEDONA Express SD-6780 dehydrator (South Korea) at ~55 °C. Residual moisture content was determined on WPS 50 SX moisture analyzer (Poland). Its value didn’t exceed 5.7% [8].

The dried powder was finely ground on the DESI-11 disintegrator (Estonia) at a mode of 14000 rpm. It is known that mechanical treatment plant raw material among with obtaining of mechanocomposites can change its properties in the desired direction [9, 10]. As a result of intensive mechanical treatment, a brick-colored fine powder with average particle size of 70 μm was obtained. This powder was used as reference sample for determining of its chemical composition by standard methods (table 1).

| Characteristics                  | Value       |
|----------------------------------|-------------|
| Moisture, %                      | 5.7±0.01    |
| General ash, %                   | 2.8±0.04    |
| Sugar, %                         | 25.4±0.21   |
| Vitamin C, mg/g                  | 3.6±0.29    |
| β-carotene, mg/g                 | 0.17±0.1    |
| Flavonoids, mg/g                 | 2.33±0.02   |
| Iron, mg/kg                      | 102.0±0.18  |
| AOA, mg of quercetin per 1 g of product | 0.87±0.02 |

Further in powder reference sample the water-soluble substances content was determined. The extraction of functional ingredients from plant raw material was carried out in ultrasonic bath in ratio of solid matter and fluid of 1:25 accordingly. The extraction of functional ingredients was 76% from weight of dry reference sample. The extract solution was used as a base solution for further drying [11].

For spray drying encapsulation, the konjac gum (konjac mannan) as encapsulating agent was used. It is a plant polysaccharide, which consists of β-D-glucose and β-D-mannose in ratio of 1:1.6 accordingly. A distinctive feature of this gum is its stability at high temperatures.
For freeze drying encapsulation, the guar gum as an encapsulating agent was used because of keeping its properties at low temperatures and high solubility. Guar gum is a polymeric compound containing galactose residues.

The preparations of two polysaccharides were similar and included dilution of gums in the water until thickening.

Rowanberry extract was mixed with the prepared solution of konjac gum in ratio 1:1. The mix was spray dried in Buchi B290 dryer (China). The inlet and outlet temperatures were 130 °C and 70 °C accordingly [12, 13]. After process, obtained particles had spherical form and their average size was 10 µm. The obtained powder was cream-colored and had neutral taste. However, its yield was less than 15% from the expected result.

Therefore, it was decided to use one more encapsulation method, in which freeze drying was used. For this, rowanberry extract was mixed with guar gum solution in ratios 1:1 and 2:1 accordingly. The drying process was carried out in INEI-4 freeze dryer (Russia) at the pressure of 3 Pa, at the freezer temperature of –40 °C. The sample temperature didn’t exceed –5 °C. The experimental solution consisted of guar gum water solution and rowanberry extract [14]. The drying process was finished at moisture content in finished product about 0% and water vapor pressure in working chamber of 50 Pa. As a result, the cream-colored powder with neutral taste and yield of approximately 100% from expected result was obtained. Therefore, the freeze-dried powder was used in further researches.

For taste evaluation of obtained functional ingredients the descriptive and profile method was used, which clearly demonstrated high sensory characteristics of the encapsulated powder sample [15].

For confirmation of functional properties of powders, the following studies were carried out. The AOA was measured using Yauza Color-01-AA device (Russia) [16, 17] for rowanberries collected in 2017 and 2018. For a qualitative definition of bioflavonoids, the reaction with aluminum chloride (III) was chosen, and for complex definition the spectrophotometric method was used [18, 19]. The peculiarities of methodic is that the flavonoid, the maximum absorption of the complex of which is most consistent with the maximum absorption of the complex with aluminum chloride of the test sample, is used as a reference sample (figure 2).

![Figure 2. Dependence of the solution optical density on the wavelength](image)

The content of flavonoids, vitamin C and β-carotene in IR-dried and encapsulated powders were determined according to Russian national standards GOST 24556-89 “Products of fruits and vegetables processing. Methods for determination of vitamin C” and GOST R 54058-2010 “Functional food stuffs. Method for determination of carotenoids”.

The samples of encapsulated powders were studied using method of electron microscopy, which was carried out with magnification from 1 mm to 10 µm.

Considering the useful properties of encapsulated rowanberry powders, the formulations of functional cottage cheese desserts were developed. The powders of IR-drying were used in amount of 2% and 7% from total amount of ingredients, and the amount of the encapsulated powders were 9% and 14% accordingly. Sensory characteristics of desserts were determined according to Russian national standard GOST 31986-2012 “Public catering service. Method of sensory evaluation of catering products”. Physico-chemical characteristics were determined according to standard methods.
3. Results and discussion

The results of taste evaluation of powder samples are shown in figure 3.

![Figure 3. Taste evaluation of rowanberry powder samples](image)

Thereby, the encapsulation technology of rowanberry powders allows to obtain dietary supplement without bitterness, harshness and pungency, which are typical for non-encapsulated rowanberry powder of IR-drying.

Results of rowanberry powders antioxidant capacity evaluation are shown in table 2.

| Sample                        | AOA, mg of quercetin per 1 g of product |
|-------------------------------|---------------------------------------|
| Raw rowanberries             | 0.56 ± 0.02                           |
| Rowanberry powders of IR-drying | 0.46 ± 0.02                           |
| Rowanberry encapsulated powders | 0.26* ± 0.01                          |

* – with the dilution of rowanberry and polysaccharide solution of 2:1 accordingly, the AOA is kept approximately at the same level (admissible error is 8%).

Increasing of AOA is associated with the cell walls destruction in rowanberries during grinding process. Therefore, more substances with AOA are extracted from rowanberry powders than from raw berries.

Results of flavonoids content calculation in rowanberry powders samples are shown in table 3.

| Parameters                  | Rowanberry powder of IR-drying | Encapsulated rowanberry powder of IR-drying |
|-----------------------------|-------------------------------|-------------------------------------------|
| Optical density ($D$)       | 0.21±0.03                     | 0.14±0.02                                 |
| Concentration ($C$)         | 9.0±0.01                      | 5.8±0.01                                  |
| Rowanberry sample weight, g | 4.12±0.1                      | 3.11±0.1                                  |
| Flavonoids weight, mg       | 9.0±0.3                       | 7.25±0.3                                  |
| Flavonoids content, mg/g    | 4.24±0.02                     | 2.33*±0.02                                |

* – with the dilution of rowanberry and polysaccharide solution of 2:1 accordingly the total flavonoids content is kept at the same level

Results of vitamin C and β-carotene content definition in rowanberry powder samples are shown in table 4.
Table 4. Definition of vitamin C and β-carotene content in rowanberry powder samples

| Samples                        | Vitamin C, mg/g | β-carotene, mg/g |
|-------------------------------|-----------------|------------------|
| Rowanberry powder of IR-drying| 3.62±0.1        | 0.17±0.1         |
| Encapsulated rowanberry powder of IR-drying | 2.51*±0.1 | 0.13*±0.1 |

* – with the dilution of rowanberry and polysaccharide solution of 2:1 accordingly vitamin C and β-carotene are also kept at the same level.

The pictures of electron microscopy of encapsulated rowanberry powders obtained by spray drying and freeze-drying are presented in figures 4 and 5 accordingly.

Figure 4. Electron microscopy of encapsulated rowanberry powders obtained by spray drying

Figure 5. Electron microscopy of encapsulated rowanberry powders obtained by freeze drying

It is determined that spray drying allows to obtain particles of spherical form. The particles in powders obtained by freeze-drying have got the form of sheets with torn edges.

Results of sensory evaluation of cottage cheese desserts with rowanberry powders of IR-drying in non-encapsulated and encapsulated forms are presented in figures 6 and 7 accordingly. From the figures, it is seen that cottage cheese desserts with encapsulated rowanberry powder have got higher sensory characteristics than desserts with non-encapsulated powders. In turn, the comparative sensory evaluation of dessert samples with encapsulated powders showed that the dessert sample with powder in amount of 9% had got the highest points.
Figure 6. Sensory evaluation of cottage cheese desserts with rowanberry powders of IR-drying

Figure 7. Sensory evaluation of cottage cheese desserts with encapsulated rowanberry powders of IR-drying

Results of physico-chemical evaluation of desserts with the best sensory characteristics are presented in Table 5.

Table 5. Physico-chemical evaluation of cottage cheese dessert samples

| Parameters                  | Cottage cheese dessert (control sample) | Cottage cheese dessert with rowanberry powder of IR-drying in amount of 2% | Cottage cheese dessert with encapsulated rowanberry powder of IR-drying in amount of 9% |
|-----------------------------|----------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------|
| Dry solids content, g/100g  | 69.89±0.04                             | 68.36±0.04                                      | 68.32±0.04                                                                     |
| Acidity, °Т                 | 54.0±0.5                                | 72.0±0.5                                        | 62.0±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         | not found                               | 0.32±0.02                                       | 1.01±0.05                                                                      |
| AOC, mg/100g                | 0.06±0.01                               | 2.05±0.08                                       | 5.3±0.2                                                                        |
| Flavonoids, mg/100g         | not found                               | 4.48±0.12                                       | 20.3±0.2                                                                       |

The bitter taste of IR-dried rowanberry powder limits its addition into food production formulations to the amount of 2%. This amount doesn’t provide the production with useful properties. Therefore, the IR-dried rowanberry powder can’t be used as a functional ingredient. Encapsulation of the powder allowed to introduce into the formulation 7 times more useful substances and provide the required content of biologically active substances in the production. However, 14% of encapsulated powder in ratio of powder and polysaccharides 1:1 lead to worsening of dessert sample consistency, and with 9% of encapsulated powder in ratio of powder and polysaccharides 2:1 accordingly the dessert consistency...
is better. The second dessert sample contains antioxidants, vitamin C, β-carotene and biologically active flavonoids in more than 15% of daily norm per serving according to norms of the Russian methodical recommendations MR 2.3.1.1915-04 “The recommended levels of nutritional and biologically active substances consumption”. Thus, it can be considered as a functional product.

4. Conclusion
The technology of obtaining of encapsulated rowanberry powders by extracting functional ingredients from raw material by fine grinding is developed. This method is first applied for rowanberry powder of IR-drying. The use of encapsulation technology allows one to mask the natural bitterness of rowanberry and as a result the taste of food production. The product is with high sensory characteristics without decreasing of nutritional value and total content of biologically active substances.

The developed encapsulated powder can be applied for developing of new formulations of desserts, beverages (juices, teas, dairy production). In a state of dry mixture, it can be used for cakes, biscuits and sponge cakes baking. Furthermore, it can be sold in specialized retail stores as a functional ingredient.

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