Technology of rowanberry encapsulation for optimization of functional food production formulations

I V Matseychik¹, S M Korpacheva¹, A I Shteer¹,², A V Myshelovskaya¹ and I O Lomovsky²

¹ Novosibirsk State Technical University, 20, Prospekt K. Marksa, Novosibirsk, 630073, Russia
² Institute of Solid State Chemistry and Mechanochemistry of SB RAS, 18, Kutateladze, Novosibirsk, 630128, Russia

³ E-mail: a.shteer@bk.ru

Abstract. The paper describes the potential of the use of pectin with a low degree of esterification as a matrix for encapsulation of rowanberry powder. Using pectin with a low degree of esterification allowed to increase the antioxidant activity of the powder on 12.5% and its bioflavonoids content on 27% in comparison to previously obtained results and showed the possibility of improving of nutritional value of curd desserts where the powder can be used as a functional food ingredient in amount of 14%. It is also shown that encapsulated rowanberry powder with PLDE can increase the antioxidant activity, vitamin C and bioflavonoids content of curd desserts enriched with it.

1. Introduction
Creation of new technologies for obtaining food products of functional purpose is one of the priorities in modern nutrition. For their producing, traditional and new kinds of functional ingredients must be used [1].

Rowanberries are promising material for producing functional food ingredients from them, but the main problem is bitter taste because of a significant number of polyphenols in them. Rowanberries also contain polyphenol oligomers, which give dry feeling in the mouth [2]. Thus, rowanberry practically is not eaten in its natural form.

2. Purpose and objectives
The research purpose is the study of rowanberry powder encapsulation with pectin with a low degree of esterification (PLDE) for improving of their sensory properties.

The research objectives were:

• to justify the use of rowanberry powder as a functional food ingredient;
• to choose methods of drying of rowanberries and encapsulation of powder obtained from them;
• to substantiate the functional purpose of obtained encapsulated powder.
3. Experimental research

3.1. Object of the research
The object of the research is rowanberry, which is widespread throughout West and East Siberian region. It is known that rowanberries have got high antioxidant activity and contain a whole complex of biologically active substances (BAS), such as vitamin C, β-carotene and flavonoids [3].

Infrared (IR) drying process of rowanberries was carried out at 40…50 °C until the moisture amount was 5.5…5.7%. This temperature allows to evaporate the maximum amount of moisture from the product, while keeping its color and flavor [4]. Besides, its cell walls are not disintegrated while drying, so vitamins, amino acids, macro- and microelements are preserved [5].

Further, the dried material was finely ground into the powder, which had the color of terracotta and its particle size was about 50 μm.

While the BAS content in rowanberry powder of IR-drying decreased by 15…20% in relation to fresh berries. At the same time, the antioxidant activity (AOA) of rowanberry powders had its maximum value, which is related to cell walls destruction during grinding process. Such destruction allows to obtain more water-soluble substances in contact with the working solution [6]. So, it can be concluded, that rowanberry powder of IR-drying can be used in the complex food supplements after fine grinding.

3.2. Encapsulation of rowanberry powder
There were previously carried out research on rowanberry powder encapsulation, where konjac and guar gums were used as materials for encapsulation matrixes, and the encapsulation process was carried out by spray drying and freeze-drying (lyophilization, cryodesiccation) methods [7]. These gums had high costs, less solubility and low tensile strength. In turn, the disadvantages of spray drying method is high energy consumption and low volumetric weight of dried powder [8].

In current research, for the encapsulation process optimization for the first time was used PLDE (the esterification degree is below 50%) as an encapsulation matrix. This substance is well soluble in water, has a low cost and high structural and mechanical properties. It does not form viscous solutions, so it contributes to faster freezing. At 30 °C pectin is finely crystallized, which increases the dispersion degree and yield of the powder. This kind of pectin is often used in dairy products and mixtures of low-solid content [9].

For encapsulation, there was used lyophilization method, which is more rational than spray drying method. It is used for drying of products with high water content, which are previously frozen and kept at –20 °C. The ice contained in the products is converted directly to vapor at –30 °C, which is removed from the camera by low vacuum pump [10]. Lyophilized products keep they sensory properties, have high solubility, low weight and prolonged shelf life.

While the rowanberry extract was being prepared for the encapsulation, its water-soluble substances content was evaluated. The output of water-soluble substances was measured after first (sample 1) and fifth extraction (sample 2). The results are presented in table 1.

| Rowanberry extract samples | Water-soluble substances content, % | Total water-soluble substances content, % | Considering the moisture content in fresh rowanberries, % |
|---------------------------|------------------------------------|-------------------------------------------|-------------------------------------------------|
| Sample 1 (after 1st extraction) | 1.63 ± 0.05 81.51 ± 0.36 | 81.76 ± 0.28 | 76.06 ± 0.04 |
| Sample 2 (after 5th extraction) | 1.71 ± 0.05 82.02 ± 0.36 | | |

10 g of PLDE were dissolved using a magnetic stirrer in 250 ml of distilled water at 40 °C. The solutions of rowanberry powder of IR-drying and PLDE were mixed in the SMC-3000 ultrasound bath,
then they were centrifuged for sediment separation. For a better result, the obtained solution was filtered through Büchner funnel [11].

In the end, there was obtained the light beige colored powder with a faint rowanberry scent. Change in color and scent in the powder indicated that the encapsulation process had been successfully carried out [12].

The figure 1 shows the dependence of relative humidity of rowanberry on its drying time.

![Figure 1. Dependence of relative humidity of rowanberry on its drying time.](image)

On the stage I (freezing) the mass practically did not change. On the stage II (cryodesiccation) about 60% of moisture was removed. On the stage III, it is notably that during additional drying process the relative moisture was removed. In the end of drying process drying speed dropped, which indicated that almost all moisture had been removed from the product [13].

3.3. Functional properties of rowanberry powder with PLDE used as an encapsulating matrix

There were carried out the studies on confirmation of functional properties of obtained powder.

Determination of AOA was carried out according to technique № 20706-05 from “Measurement Techniques for Water Soluble Antioxidants № 31-07 from 04-05-2007” using Yauza Color-01-AA device (Russia).

Considering the dilution of rowanberry powder and PLDE 1:1, the AOA and total content of flavonoids in encapsulated powder is kept approximately at the same level. Herewith, the total AOA values for the powder with PLDE is higher than for the powder with gums [7, 14].

Flavonoid activity was determined by the method of spectrophotometric analysis of flavonoid complexes of with metal ions (aluminum chloride). When bioflavonoids interact with aluminum (III) chloride, flavonols (rutin, quercetin, kaempferol) form yellow-green colored complexes, and flavanones (dihydroflavones) form brown colored complexes [15]. This complex was chosen due to its high expressiveness and the use of equipment available for the laboratory.

Vitamin C content determination was carried out according to Russian national standard GOST 24556-89 “Products of fruits and vegetables processing. Methods for determination of vitamin С” [16].

β-carotene content determination was carried out according to Russian national standard GOST 54058-2010 “Functional foods and foods for special dietary uses. Method for determination of carotenoids”. [17].

The results of studies are shown in table 2.
Table 2. Evaluation of functional properties of encapsulated rowanberry powder sample with PLDE.

| Characteristics                                      | Values   |
|------------------------------------------------------|----------|
| AOA, mg of quercetin per 1 g of product              | 2.8 ± 0.12 |
| Flavonoids, mg per 1 g of product                    | 1.87 ± 0.04 |
| Vitamin C, mg per 1 g of product                     | 2.55 ± 0.05 |
| β-carotene, mg per 1 g of product                    | 0.16 ± 0.05 |

Comparing with our previous results [7], it can be concluded that the antioxidant activity of encapsulated rowanberry powder with PLDE increased on 12.5% and its bioflavonoids content increased on 27%.

4. Results and discussion

4.1. Development of curd desserts with encapsulated rowanberry powder

Fruit and berry raw materials can be a valuable source of several BAS, such as vitamins, ferments, macro- and microelements, antioxidants, carbohydrates, etc. Without them, the human organism cannot develop normally, especially in modern extreme environmental conditions.

Beneficial properties of rowanberry powder of IR-drying and encapsulated rowanberry powder of freeze-drying allowed to develop new technologies and formulations of curd desserts. The development of new formulations and research on them were carried out at the Technology and Organization of Food Industries Department of NSTU. Following up on previous research [7], the formulation of curd dessert with 14% of encapsulated lyophilized rowanberry powder was developed. The content value of the powder was determined using mathematical modeling by solving linear programming problems in Matlab software environment.

It was estimated that using 14% of encapsulated rowanberry powder in curd dessert formulation provided its functionality by vitamin C, carotenoids and flavonoids.

Physico-chemical evaluation of curd dessert samples

Results of physico-chemical evaluation of curd dessert samples with encapsulated lyophilized rowanberry powder are presented in table 3.

Table 3. Physico-chemical characteristics of curd dessert with encapsulated rowanberry powder with PLDE encapsulation matrix.

| Characteristics               | Values   |
|-------------------------------|----------|
| Dry matters content, g/100 g  | 31.03± 0.04 |
| Acidity, °Т                   | 61 ± 0.5  |
| Crude ash, g/100 g            | 2.4 ± 0.1 |
| Sugars, %                     | 2.4 ± 0.1 |
| Vitamin C, mg/100 g           | 22.45 ± 0.2 |
| β-carotene, mg/100 g          | 0.85 ± 0.04 |
| AOA, mg/100 g                 | 6.6 ± 0.1  |
| Flavonoids, mg/100 g          | 25.3 ± 0.3 |

According to obtained characteristics and comparing them with our previous results [7], we can conclude that obtained desserts samples, where PLDE is used as an encapsulating matrix had high values by AOA and content of bioflavonoids and vitamin C.
4.2. Sensory evaluation of curd dessert samples

Sensory evaluation of obtained curd desserts sample in comparison with previously obtained samples [7] was carried out according to the method described in Russian national standard GOST 31986-2012 “Public catering service. Method of sensory evaluation of catering products”.

The results of evaluation are shown in figure 2.

![Sensory evaluation of curd dessert samples](image)

**Figure 2.** Sensory evaluation of curd dessert samples.

It can be noted that the obtained powder sample had the highest points on its sensory characteristics.

5. Conclusions

The encapsulated rowanberry powder with the use of pectin with a low degree of esterification as an encapsulation matrix was developed. For rowanberries, lyophilization method is preferrable. The use of PLDE contributes to more effective result because of encapsulation time reduction, increasing sensory and physico-chemical properties of obtained functional dessert. Although the powder consumption increases, it has lower price, and total cost of the powder is lowered. The use of encapsulation technology allows to level the bitterness of rowanberries. Thereby, it can be recommended for baby, dietary, gerontological and preventive nutrition because of high contents of vitamin C and β-carotene and high antioxidant activity.

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