Intensification of water extraction of non-fruit parts of sea buckthorn (Hippóphaë rhamnóides)

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Annotation. The healing properties of extracts from sea buckthorn fruits have been confirmed by numerous studies, however, the infertile parts remaining after harvesting or after pruning young trees also contain valuable components. Leaves, bark, shoots and woody parts of sea buckthorn are very promising raw materials for the extraction of biologically active substances. The introduction of non-waste technologies, issues of resource conservation, the search for rational ways to isolate valuable components from the non-fruit part of sea buckthorn determined the relevance of this study. The choice of the optimal method for the extraction of non-fruit parts of sea buckthorn is aimed at accelerating heat and mass transfer processes and increasing the rate of diffusion extraction of biologically active substances. The paper reflects the results of experimental studies of traditional aqueous extraction of non-fruit parts of sea buckthorn, namely leaves, bark, shoots and wood, and the results of intensification of extraction by preliminary freezing of the feedstock. The influence of the raw material freezing rate on the size of the formed ice crystals is analyzed. It has been established that at a freezing rate of 0.1-1 cm/ h, large ice crystals form in the intercellular space of plant raw materials, causing mechanical damage to cellular structures and contributing to better leaching of biologically active substances, which is confirmed by experimental studies.

1 Introduction

In a changing climate, special attention is paid to plants that are resistant to the environment and have a useful complex of substances to maintain human and animal health [1]. One such plant is sea buckthorn (Hippóphaë rhamnóides), which is native to Europe and Asia but is now widely grown throughout the world. Basically, this culture is valued for berries, the healing properties of which are reflected in many studies of scientists. However, it is known that the non-fruiting part of sea buckthorn (bark, leaves, shoots and woody part) is rich in a wide range of biologically active substances [2]. Extracts of non-fruit parts of sea buckthorn can be used in pharmaceutical, nutraceutical, cosmetic, food and feed applications [3-6]. Sea buckthorn branches are pruned when picking berries due to the specific attachment of fruits. Since the leaves, bark, shoots and woody part of sea buckthorn are also very promising raw materials, it is necessary to promote waste-free technologies [7]. In this regard, the issues of finding rational ways to isolate valuable components from the non-fruit part of sea buckthorn

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and obtaining an additional amount of valuable substances are undoubtedly relevant today [8].

To extract biologically active substances from the non-fruiting part of sea buckthorn, almost any known extraction method can be used, for example, classical maceration. At the same time, preliminary freezing of raw materials can increase the yield of biologically active substances. In the literature, this method of preparing raw materials for further extraction is not covered.

The main process that takes place during the freezing of plant materials is the crystallization of moisture in cells and intercellular spaces [9]. The rate of crystallization directly determines changes in the structure of plant cells [10]. As you know, the slower the freezing occurs, the more damaged the cellular structure [11]. When evaluating the changes that occur in plant materials during the freezing process, special attention is paid to the size of ice crystals that cause mechanical damage to the material [12]. With slow freezing, the crystal sizes range from 200 to 800 micrometers. The average size of a plant cell does not exceed 15 micrometers, therefore, more than 90% of the cells are pierced by ice crystals. One crystal can destroy up to 10 cells. With rapid freezing of vegetable raw materials, the size of the crystals is 11x25x30 micrometers, which significantly reduces the number of mechanically damaged cells.

Figure 1 shows curves that characterize the processes occurring at different rates of freezing of plant materials.

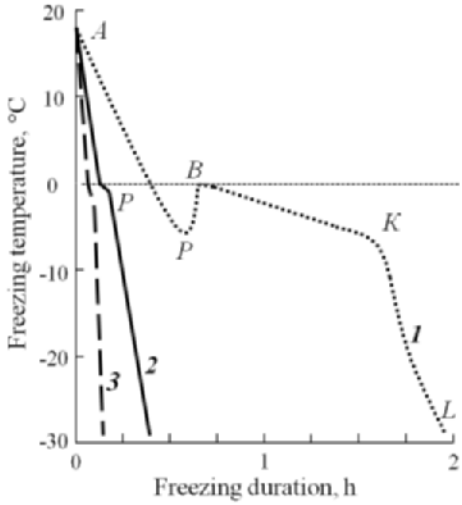

Fig. 1. Graph of the rate of freezing of vegetable raw materials.

The nature of the freezing process depends on many factors, the main of which are temperature and freezing speed [13]. For the process of slow (curve 1), fast (curve 2) and ultrafast freezing (curve 3) there are common patterns. During the freezing process, three temperature ranges can be distinguished in the center of the raw material: from + 20 to 0°C; from 0 to -5°C; from -5 to -18°C.

Graph 1 shows the main segments corresponding to different phases of freezing. Segment A-P corresponds to the period of cooling of the raw material to near-cryoscopic temperatures. At the first stage, the raw material is cooled from +20 to 0°C. The decrease in the temperature of the product here is proportional to the amount of heat extraction work.

Point P corresponds to the subcooling of the raw material. At point P, freezing occurs, crystallization of water begins. The release of the heat of crystallization causes an increase in the temperature of the raw material to point B. The segment B-K corresponds to the length of time at which the bulk of the moisture freezes. With slow freezing, the temperature of the

raw material practically does not decrease; during this period, approximately 70% of the liquid fraction of the raw material crystallizes. With a further decrease in temperature (segment K-L), little moisture freezes, little heat of phase transformation is released, and the temperature of the raw material drops sharply. At this stage, freezing occurs at temperatures of raw materials from -5 to -18°C. The decrease in temperature again goes in proportion to the refrigeration work performed.

The speed of the front of the freezing area during fast freezing of raw materials is 5-20 cm/h, with normal (medium) - 1-5 cm/h, with slow - 0.1-1 cm/h. With cryogenic ultra-fast freezing, which is carried out in cryogenic liquids (liquid nitrogen, liquid CO2, freon) by irrigation or immersion methods, the freezing rate is 100 cm/h. With ultrafast freezing, the formation of ice crystals does not occur, the effect of vitrification of water in the protoplasm of cells is observed.

Thus, in order to intensify extraction by pre-freezing plant materials, a freezer with a slow freezing rate (0.1-1 cm/h) is required. In this case, large ice crystals will form in the intercellular space in the plant material, which will cause serious mechanical damage to the membranes of cells. Such destruction of plant cells will contribute to a better leaching of biologically active substances from the studied raw materials.

The purpose of this work is to study the effect of preliminary freezing of non-fruiting parts of sea buckthorn (bark, wood, leaves and shoots) on the yield of water-soluble substances during aqueous extraction.

2 Materials and methods

Classical maceration with an average temperature of 60°C was chosen as the extraction method. For experimental studies, samples of various parts of sea buckthorn (bark, wood, leaves and shoots) ground in an electric mill were prepared. Freezing of raw materials took place in a freezer with a temperature of -18°C. Distilled water was used as an extractant in the ratio "raw material - solvent" 1:10.

he barren part of sea buckthorn, crushed to 3.0 millimeters, weighing 5±1 grams, was loaded into the extraction tank, where the extractant was poured in a volume of 50 grams at a temperature of 60°C. The infusion process was carried out for 40 minutes. After extraction, the resulting mixtures were successively filtered through a gauze filter and a "white tape" filter. The powdered water-soluble extract was obtained in a drying chamber. The experiments were repeated three times to ensure the reliability of the results of studies to determine the concentration of water-soluble substances in the material.

3 Results and discussion

The following are the results of studies to determine the maximum yield of extractives from various non-fruit parts of sea buckthorn.

Figure 2 shows the kinetic dependence of the change in the concentration of water-soluble substances in sea buckthorn leaves without freezing and with preliminary freezing of raw materials.

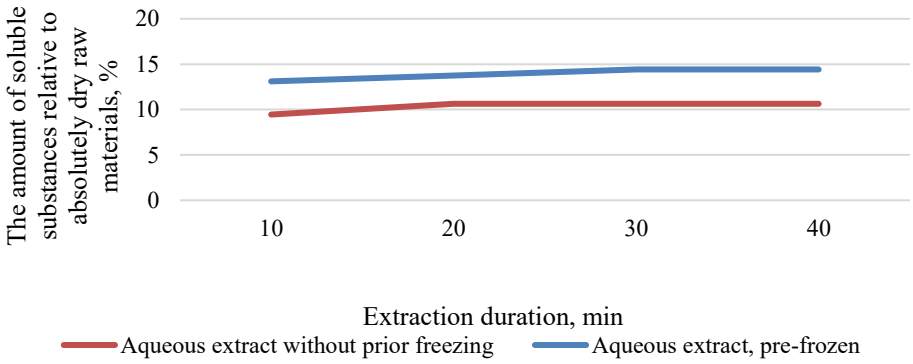

Fig. 2. Effect of pre-freezing on the yield of extractives from sea buckthorn leaves.

According to the obtained results, preliminary freezing of sea buckthorn leaves improves the yield of extractives, regardless of the duration of extraction. During aqueous extraction with preliminary freezing, 38.66% more extractive substances were released in 10 minutes than without freezing.

The results of sea buckthorn bark extraction without freezing and with preliminary freezing of raw materials are shown in Figure 3.

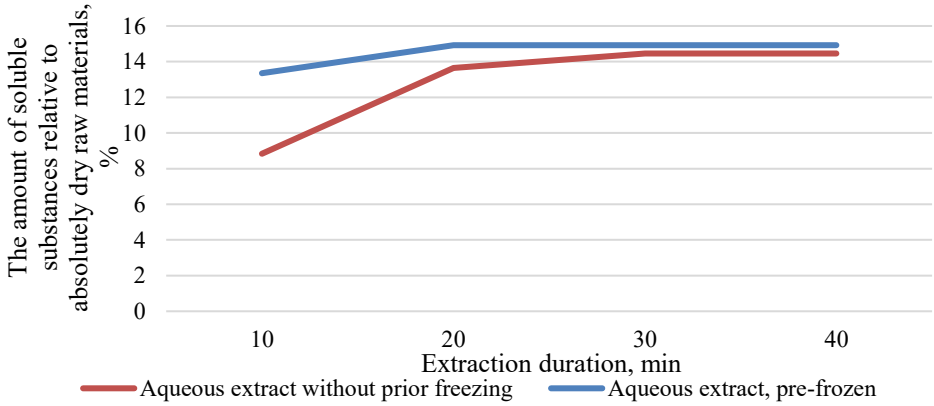

Fig. 3. Effect of pre-freezing on the yield of extractives from sea buckthorn bark.

The research results showed that the preliminary freezing of sea buckthorn bark increases the yield of extractives, regardless of the duration of extraction. During aqueous extraction with preliminary freezing, 51.12% more extractive substances were released in 10 minutes than without freezing.

The results of the extraction of sea buckthorn shoots without freezing and with preliminary freezing of raw materials are shown in Figure 4.

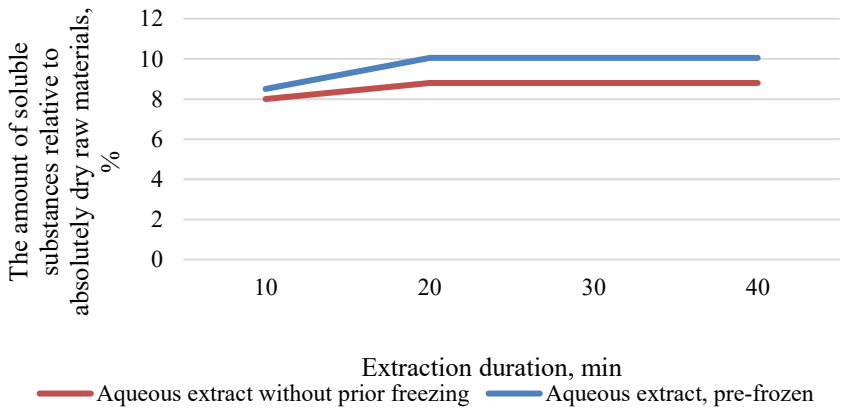

Fig. 4. Effect of pre-freezing on the yield of extractives from sea buckthorn shoots

The results obtained showed that the preliminary freezing of sea buckthorn shoots increases the yield of extractives for any duration of extraction. During water extraction with preliminary freezing, 14.21% more extractive substances were released after 20, 30 and 40, than without freezing.

The results of the extraction of the woody part of sea buckthorn without freezing and with preliminary freezing of raw materials are shown in Figure 5.

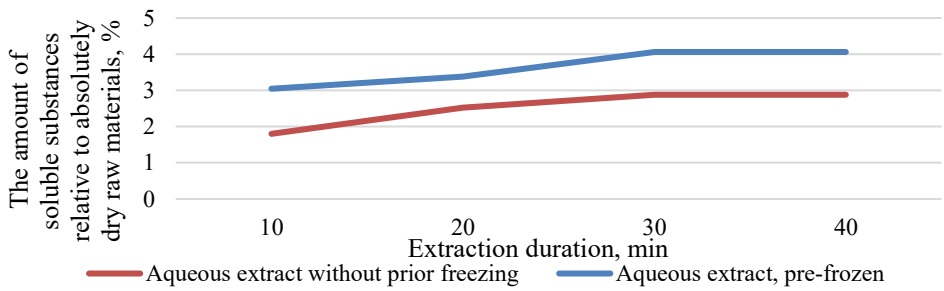

Fig. 5. Effect of pre-freezing on the yield of extractives from the woody part of sea buckthorn

As can be seen from the graph, preliminary freezing of the woody part of sea buckthorn significantly improves the yield of extractives for any duration. During aqueous extraction with preliminary freezing, 69.29% more extractive substances were released in 10 minutes than without freezing.

4. Conclusion

The conducted studies allowed us to conclude that the preliminary freezing of the initial raw material increases the yield of extractives from the non-fruiting parts of sea buckthorn (Hippóphaë rhamnóides). It was found that the yield of water-soluble substances significantly increases both in sea buckthorn leaves (by 38.66% in 10 minutes of extraction), and in sea buckthorn bark (by 51.12% in 10 minutes), in sea buckthorn shoots (by 14.21% in 20 minutes) and in the woody part of sea buckthorn (by 69.29% in 10 minutes). The slow rate of freezing of raw materials (0.1-1 cm/h) promotes the formation of large ice crystals, which in turn damage the cell walls of the material. Such preliminary preparation of plant materials has a beneficial effect on the extraction process even with traditional extraction methods.

Due to the fact that traditional methods are mainly used in the industrial production of extracts, this method will help to increase the amount of extracts obtained without replacing the extraction equipment available in the production. Further research in the field of this method of intensifying extraction processes and considering the possibility of its application in production are topical issues of improving the quality, quantity and range of extractive substances with the lowest raw material and energy costs.

Acknowledgments

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