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Effect of Mechanical Activation of Biocomplexes Based on Lichen Fronds on the Extractability of Essential Microelements in Model Environments

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Abstract

Gastrointestinal extraction of essential microelements from biocomplexes based on the fronds of lichens and medicinal plants, prepared by solid-phase mechanical treatment, was studied. It was established that mechanical activation of these biocomplexes in the presence of sodium bicarbonate leads to the increased extraction of essential microelements in model environments.

Key words: biocomplexes, microelements, lichens, mechanochemical biotechnologies

INTRODUCTION

Traditional production of the physiologically active compounds (PAC) from plant material includes an obligatory stage – extraction with solvents of different polarity. The conventional PAC extraction technology has the following disadvantages: the use of toxic and flammable organic solvents, low extraction extent for one-step processing and, as a result, the multiple repetitions of extraction, increased production costs and environmental pollution. One of the promising directions of processing plant raw materials is the use of solvent-free processes, that is, solid mechanochemical treatment without solvents in one technological stage. Shock abrading impact with the addition of solid-phase chemical reactants (*e. g.*, salts) is accompanied, in addition to the destruction of the cell wall, by the changes of the chemical composition of plant raw material components due to the rupture of a number of chemical bonds and occurrence of chemical reactions [1]. The rate of bond rupture is determined by the rigidity of the structure. An indicator of the efficiency of mechanochemical treatment of biological raw material can be the increasing amount of biogenic water-soluble microelements in the product. This contributes to a more efficient absorption of these elements, because there is a general trend of low digestibility of the vast majority of vitamin and microelement complexes, of food and forage complexes, which is connected with the problems in their intestinal absorption.

Preliminary data obtained previously demonstrate that intense mechanoactivation of plant raw material increasing the degree of dispersion is accompanied by an increase in the yield of water-soluble compounds [2, 3], and also their activation [4–7].

It is known that plants growing in Yakutia under extreme climatic conditions are distinguished not only by increased PAC content but also by significantly higher structural diversity [8–11]. For example, the biological material of lichens is a source of natural PAC, including lichen acids, vitamins, microelements, polysaccharides. The main active components of *Rhodiola rosea* are phenolic compounds: phenolic alcohols and their glycosides, flavonoids and tannins of pyrogallol group. Phenol *p*-oxyphenylethanol (tyrosol) is present in the raw material mainly as salidroside glycoside (Fig. 1, *a*).

The leaves of *Rhododendron aureum* contain about 4 % of the most widespread glycoside of aromatic nature – arbutin (see Fig. 1, *b*).

The use of the mechanochemical stage in the technological cycle of biological products from lichen thalli at the stage of the treatment of dry material allows one to increase the water-soluble fraction by converting flavonoids into the phenolate form, thereby increasing the extractability of a more complete PAC group [4, 6].

The aim of this work is to study the possibility to intensify the extraction of microelements in a model gastrointestinal media from biological complexes obtained on the basis of lichen material through solid-phase mechanochemical processing

EXPERIMENTAL

We studied the solid-state complexes of biological material based on lichen (reindeer moss) and medicinal plants: the roots and rhizomes of *Rhodiola rosea* (Crassulaceae family) and aerial organs of *Rhododendron aureum* (Ericaceae family), with a mass ratio moss/Rhodiola and moss/rhododendron equal to 10 : 1.

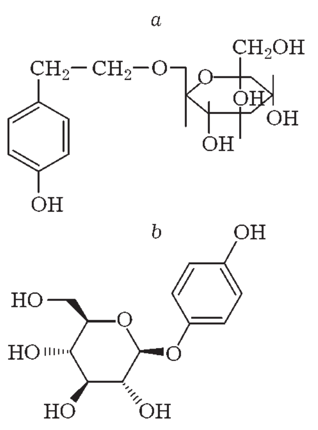

Fig. 1. Examples of phenolic glycosides: *a* – salidroside, *b* – arbutin.

The experimental samples of biological products were subjected to mechanochemical activation in the air environment in the planetary activator mill AGO-2. In preliminary experiments the optimal processing time was found to be 1–2 min. The treatment of biological complexes was carried out with the addition of solid $NaHCO_3$ (mass fraction of 0.5 %).

The solubility of the samples of biopreparations was studied in the model experiment under the conditions close to gastrointestinal ones. The gastric medium was created by adding HCl in the concentration of 30 mM, extraction conditions were: T = 37 °C, duration 4 h. The enteral medium was modelled by alkalization with $NaHCO_3$ to pH 8; extraction conditions: T = 37 °C, duration 2 h. The ratio of additive mass to the volume of model media was 1 g : 1 L. As a control, we examined the composition of identical biopreparations obtained by coarse grinding in a domestic mill without mechanical activation; the extracts were studied using elemental analysis on a Thermo Electron iCAP 6500 Duo atomic emission spectrometer according to the standard procedure.

RESULTS AND DISCUSSION

The powders of biological complexes obtained by solid-phase mechanochemical activation of reindeer moss and medicinal plants with the addition of $NaHCO_3$ in one step without solvents were investigated by elemental analysis. It was established that the concentrations of metals incorporated into milling bodies varies within the experimental error in the reference and experimental samples. Therefore, no interaction between the plant organic substances and the material of mechanical activator occurs (Table 1, exp. Nos. 1 and 4).

Figure 2 presents the data on the content of microelements in the extracts of mechanically activated biocomplex ($C_{m/a}$) with respect to their content in the extracts of reference samples (C_{ref}). The general tendency of changes in the chemical composition of gastrointestinal extracts of biocomplexes with and without mechanical treatment is that the extraction with a model environment practically does

TABLE 1

Changes of the water-soluble composition (microelement part) of biocomplexes under mechanochemical activation

Experiment No.	Structure of biocomposite, method of activation	Content, mg/g dry initial mass							
		Cr	Cu	Fe	Mn	Ni	Zn	Sr	Mg
1	Reindeer moss/Rhodiola + 0.5 % $NaHCO_3$, m/a	0.117	0.961	35.27	14.455	0.234	1.107	0.479	50.40
2	The same, extraction with gastric medium	0.0195	0.344	5.35	14.004	0.114	0.301	0.267	39.99
3	The same, extraction with intestinal medium	0.065	0.310	11.5	0.30	0.113	0.91	0.36	40.10
4	Reindeer moss/Rhodiola + 0.5 % $NaHCO_3$, coarse grinding	0.111	0.980	33.43	13.252	0.202	1.1207	0.448	53.60
5	The same, extraction with gastric medium	0.013	0.348	4.35	2.23	0.0994	0.163	0.268	21.89
6	The same, extraction with intestinal medium	0.013	0.21	1.80	0.2	0.106	0.6	0.32	32.66
7	Reindeer moss/rhododendron + 0.5 % $NaHCO_3$, m/a	0.393	0.756	89.01	13.13	0.291	0.879	0.482	40.23
8	The same, extraction with gastric medium	0.065	0.68	39.64	10.39	0.284	0.602	0.470	36.32
9	The same, extraction with intestinal medium	0.0325	0.20	7.80	0.61	0.149	0.40	0.1277	34.80
10	Reindeer moss/rhododendron + 0.5 % $NaHCO_3$, coarse grinding	0.364	0.736	88.02	12.76	0.256	0.854	0.482	39.29
11	The same, extraction with gastric medium	0.065	0.48	31.95	2.50	0.092	0.19	0.45	31.70
12	The same, extraction with intestinal medium	0.0256	0.40	4.70	0.20	0.064	0.12	0.125	28.66

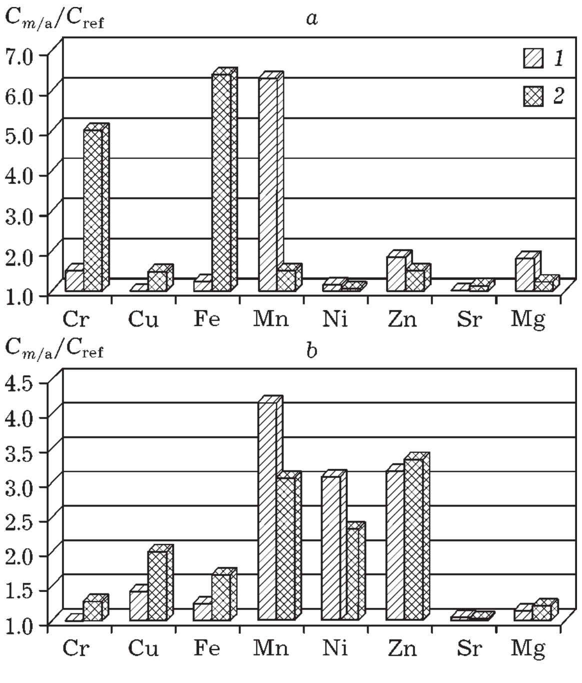

Fig. 2. Effect of mechanical activation of biocomposites reindeer moss/Rhodiola (*a*) and reindeer moss/rhododendron (*b*) in the gastrointestinal extraction of microelements: *1* – gastric media, *2* – intestinal media. $C_{m/a}$ and C_{ref} are concentrations of microelements in extracts of mechanical activated biocomposites, respectively.

not recover non-biogenic Sr, and this is a very important fact. The transition of microelements in water-soluble form is observed mostly for mechanically activated samples in contrast to the biocomplexes of coarse grinding. Elements Mn, Ni, Zn, Cu are actively extracted from a biocomplex of reindeer moss with rhododendron, and Cr, Fe, Mn, Mg, Zn are actively extracted from the biocomposite of reindeer moss with Rhodiola (see Fig. 2 and Table 1).

Perhaps this is explained by an interesting and still controversial mechanism of the provision of water solubility of mechanically activated biological complexes. The specific feature of plant material is that it contains water. Although the mechanochemical techniques use dry raw material, moisture content may be up to 10 %. According to one of the possible models, high-pressure zones and the zones of local heating can arise during intensive mechanical treatment. Water contained in the pores can pass into the state close to the supercritical, acquire increased solubility and provide transport of solutes [12].

CONCLUSION

Thus, the application of mechanochemical technology in the processing of biological complexes based on lichen material and medicinal plants with $NaHCO_3$ can increase the output of microelements in the gastric and enteric extractions.

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