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Agricultural waste as a source of biologically active substances

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Abstract. Agro-industrial waste at all stages of agricultural production, processing and consumption increases annually and reaches an enormous level. Agricultural waste is often rich in valuable biologically active substances, therefore, it is important to consider methods of its efficientprocessing. Waste recycling is required to reduce the negative impact on the environment, minimize waste and increase the efficiency of the use of raw materials. The paper presents the results of chemical analysis of phytogenic waste: potato and carrot tops. Potato and carrot top wastes are considered the agricultural waste. The sown areas of these crops are huge. All this was the reason for choosing the aboveground part of potatoes and carrots as objects of study in order to obtain a sufficient amount of biologically active substances. Lipids were extracted from potato and carrottops by hexane extraction, washed, and the unsaponifiable substancesweresplit by column chromatography on silica gel. The fraction composition was determined by physicochemical methods. The results of the experimental study showed that potato and carrot tops contain a significant amount of biologically active components, among which triterpene compounds present a particular interest. Triterpene compounds have properties that can help to fight against oncology and viral diseases: prevent inflammation, inhibit the active division of cells and the growth of pathogenic neoplasms, activate programmed cell death, which makes it possible to recommend the aboveground part of potatoes and carrots as a cheap source of biologically active substances for the pharmaceutical and perfumery industry.

1 Introduction

A lot of solid waste is generated in the growth and harvesting, processing, packaging, storageof agricultural products, as well as in their preparation for sale. The amount of waste at all stages of agricultural production, processing and consumption increases annually and reaches an enormous level. Thus, the amount of wheat bran is 650 million tons, wheat straw – more than 350 million tons, rice straw – about 700 million tons. All types of straw are most often burned, which negatively affects the environment. Huge amounts of manure from farm animals and bird droppings also pose an environmental problem. The UN study on food production and losses conducted in 152 countries showed that the losses make 47% of root crops, 44% – fruits and vegetables, 28% – cereals, 23% – oilseeds and legumes, 12% – dairy products. At the same time, there is not enough food in the world. Soils are depleted. There is a shortage of energy resources. Waste disposal can be accompanied by the production of liquid and gaseous biofuels, the production of biohumus and preparations that increase the yield of crops and food products. Therefore, the rational use of natural resources and the efficient integrated use of grown raw materials require the introduction of innovative scientific measures aimed at maximizing the effective extraction of useful substances from agricultural waste [1–6].

2 Problem Statement

Agro-industrial waste at all stages of agricultural production, processing and consumption increases annually and reaches an enormous level. Agricultural waste is often rich in valuable biologically active substances, therefore, it is important to consider methods of its efficient processing.

Food industry, which processes multicomponent raw materials, mainly of agricultural origin, usually extracts one component only: sugar from sugar beets, starch from potatoes and grains, vegetable oil from sunflower seeds. For the production of basic products raw materials are used only by 15–30%, the rest remains in waste. Almost all these wastes are secondary raw materials, as they contain significant amounts of valuable substances – vitamins, fiber, protein, microelements and other components. However, the solids content in the secondary raw materials of the food industry is only 5–10%, they are very unstable during storage, quickly fermented thus losing their valuable components and polluting the environment.

This study was carried out in order to reduce the negative impact on the environment, minimize and dispose agricultural waste and find cheap biologically active substances that could be used as medicines and bio-additives for food.

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Phytogenic waste of potato and carrot tops are agricultural waste, the sown areas of these crops are huge. Therefore, the aboveground part of potatoes and carrots was selected for the study to obtain a sufficient amount of biologically active substances [7, 8].

It was concluded that the composition of triterpenes and sterols of potato and carrots is close to that of sea buckthorn oil, which is one of the most valuable sources of vitamins and biologically active substances [9].

3 Materials and Methods

Lipids were extracted from potato and carrot tops by hexane extraction, washed, and the unsaponifiable substances were split by column chromatography on silica gel into 12 fractions, which composition was identified by physicochemical methods [10].

The yield of unsaponifiable substances was 0.6% of potato tops and 0.4% of carrot tops.

4 Results and Discussion

Table 1 shows the results of the analysis. According to nuclear magnetic resonance and mass spectra, fraction 1 is hydrocarbons. The composition of hydrocarbons is as follows (GLC,% of the total): C_{19} – 0.4; C_{20} – 0.4; C_{21} – 0.4; C_{22} – 0.5; C_{23} – 0.8; C_{24} – 0.9; C_{25} – 1.1; C_{26} – 1.0; C_{27} – 6.2; C_{28} – 1.0; C_{29}– 15.3; C_{30} – 1.9; C_{31} – 59.0; C_{32} – 3.6; C_{33} – 37.5. The main component is hentriacontane. According to mass spectrum,fraction 2 was identified as an isoprenoid polyene squalene. According to its behavior in a thin layer, characteristic staining, and UV absorption,fraction 3 was attributed to carotenoids. The content of carotenoids in the total of unsaponifiable substances is quite high (0.9%; 2.8%). The main component of the sum of carotenoids is β-caratin. Esters of triterpenes and high-molecular alcohols (fraction 4) are contained in unsaponifiable substances in noticeable amounts (14.1%; 12.1%). It is known from literature that these components have biological activity, so the presence of them in unsaponifiablesubstances from potato and carrot tops is very important. The fraction of esters of sterols, triterpenes and high-molecular alcohols was subjected to strong hydrolysis with a 20% KOH methanol solution, fatty acids (FA) and alcohols were separated. According to mass spectra, the qualitative composition of alcohols and sterols was similar to free alcohols and sterols to be discussed below.

The composition of fatty acids obtained by saponification is given in Table 2.

As can be seen, the main fatty acids of the esters of sterols, triterpenols and high-molecular alcohols are linolic and linolenic acids. According to mass spectrum, fraction 5 containsα-tocopherol (M^+430), dimers of α-tocopherol (M^+858) and SFA. The quantitative content of tocopherols in the amount of unsaponifiablesubstances of potato and carrot tops was determined by mass spectrometry of multi-peaked monitoring and amounted to 0.53% and 2.1%, respectively. The mass spectrum of fraction 6 confirmed the presence of α-tocopherol and the dimer of α-tocopherol. Along with α-tocopherol, fraction 7 containsβ- and γ-tocopherol (M^+416), as well as plastoquinone-9 (M^+748). The mass spectrum of fraction 8 contains ion peaks with m/z 766 (M^+) and 748 (M^+-18); 698 (M^+) and 680 (M^+-18); 630 (M^+) and 612 (M^+-18), which corresponds to the following isoprenoid alcohols: undecaprenol, dodecaprenol and solanesol, respectively. Polyprenols have various physiological activities, including against ulceration.

They are found in the green parts of many plants. The presence of potatoes and carrots of this class of compounds in unsaponifiablesubstances will possibly increase the activity of the preparation. Besides, isoprenoid alcohols C_{20} and C_{25} were found in sea buckthorn oil. This fact emphasizes the need for the presence of isoprenoid alcohols in the substitute for sea buckthorn oil.The molecular and fragmented peaks of the mass spectrum show the presence of aliphatic alcohols C_{20} – C_{32} in fraction 9, where C_{24}, C_{26}, C_{28} are the maximum among this group of peaks of ions of the even series. Fraction 10 consists of aliphatic and triterpene alcohols, as well as isoprenoid alcohol – solanesol. Triterpene alcohols were repeatedly purified from TLC impurities on silica gel. In the mass spectrum of triterpene alcohols, along with molecular ions (M^+426, 440), there are fragment ions with m/z 411, 393, 218 of almost equal intensity with ions 426. This intensity ratio, according to the mass spectra of triterpene alcohols, indicates that at least four compounds with m/z 426 – α- and β-amyrins, cycloartenol and lanosterine are present in the mixture. At the same time, the presence of M^+440 and fragment ions with m/z 425, 422, 407, 315 and 300 indicates the presence of 24-methylencycloartenol in the mixture. According to the mass spectrum and GLC analysis, sterols (fraction 11) have the following composition: campesterol– 2.8%, stigmasterin– 13.0%, sitosterol– 84.2%. Fraction 12 contains several chromatographically difficult to separate components. This fraction containsmethylsterins, triterpene diols and aldehydes, oxidized pigments and unidentified substances.

As indicated in literature, triterpene diols and aldehydes have biological activity, and their presence in a significant amount can increase the activity of the preparation [7, 8]. Triterpene derivatives have properties that can help to fight against oncology and viral diseases: they prevent inflammation, inhibit active cell division and the growth of pathogenic neoplasms, and activate programmed cell death. Triterpenic acids exhibit antimicrobial, anti-inflammatory and other types of bioactivity. In general, all triterpene derivatives have hormone-like effects and contribute to physiological processes that help fight oncology or prevent cancer.

Table 1. Composition of unsaponifiablesubstances of hexane extract of potato tops, carrot tops and sea buckthorn oil

Lipid class	Content of unsaponifiable substances in potato tops, % of the total	Content of unsaponifiable substances in sea buckthorn oil[9], % of the total	Content of unsaponifiable substances in carrot tops, % of the total
Hydrocarbons Squalene	6.0 0.1	3.0 N/A	5.0 N/A
Carotinoids	0.9	10.2	2.8
Esters of sterols,triterpenes, high-molecular alcohols and FA	14.1	18.2	12.1
β-tocopherol+ FA	3.7	3.4	4.1
β-tocopherol+ polyprenols	7.2	N/A	8.3
α-, β-, γ- tocopherols + plastoquinone Isoprenoid alcohols			
Aliphaticalcohols			
Triterpenealcohols	37.8	25.5	33.5
Sterols	6.2	21.6	7.1
Oxidized pigments, methylsterins, triterpene diols, unidentified substances	24.0	18.1	27.1

Table 2. Fatty acid composition of esters of sterols, triterpenes, high-molecular alcohols

Fatty acids	Weight fraction of fatty acids in esters of sterols, triterpenes, high-molecular alcohols, %	
	From unsaponifiable substances of potato tops	From unsaponifiable substances of carrot tops
Capric C 8:0	0.1	0.1
Caprinic C 10:0	0.3	0.2
Lauric C 12:0	0.1	0.3
Myristic C 14:0	0.7	0.5
Palmitic C 16:0	8.7	9.1
Palmitoleic C 16:1	2.7	2.4
Stearic C 18:0	1.6	2.0
Oleic C 18:1	2.9	3.1
Linolic C 18:2	44.2	47.2
Linolenic C 18:3	38.6	35.0
Arachic C 20:0	0.1	0.1

5 Conclusion

The analysis of the obtained results of the experimental study shows that potato and carrot tops contain a significant amount of biologically active components: esters of triterpenes and high-molecular alcohols, α-tocopherol, isoprenoid alcohols (undecaprenol, dodecaprenol and solanesol), α- and β-amyrins, cycloartenol, lanosterol, 24-methylencycloartenol.Polyprenols have various physiological activity, prevent ulceration. Triterpene derivatives have properties that can help to fight against oncology and viral diseases: they prevent inflammation, inhibit active cell division and the growth of pathogenic neoplasms, and activate programmed cell death. This makes it possible to recommend the aboveground part of potatoes and carrots as a cheap source of biologically active substances for pharmaceutical and perfumery industries.

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