DETERMINATION OF TECHNOLOGICAL PARAMETERS OF OBTAINING STEVIA EXTRACT

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Abstract

The prospects for the use of a plant raw material – stevia as a natural sweetener for obtaining sweet extracts have been substantiated. Literary research has been conducted on the expediency of carrying out preparatory operations of stevia-raw material in order to intensify mass exchange processes during extraction; their necessity has been theoretically justified.

A number of studies have been conducted with the aim of intensifying the process of extracting the dry mass of stevia leaves. Preliminary preparation of stevia was carried out – crushing (using a laboratory crusher – A1-DM2R) and subsequent sieving to the average size of the leaf fraction – 3.9±0.1 mm.

It is proposed to use whey from the production of sour milk cheese to obtain sweet extracts of stevia for their further use in the food industry.

It has been established, that the highest efficiency of the extraction process of the prepared dry stevia leaf mass is achieved with a hydromodule – 1:15. Carrying out the process under these conditions allows to achieve the highest degree of extraction of extractive substances – 29.9.

The results of the experimental studies, obtained and presented in the article, can be used to carry out further physicochemical analyzes of the quality of the obtained stevia extracts and the possibility of combining them with a milk base to obtain a dietary range of food products.

Keywords: stevia, extract, milk whey, hydromodule, extractive substances, mass fraction of dry substances.

DOI: 10.21303/2504-5695.2022.002584

1. Introduction

The use of stevia extracts is of scientific and economic interest due to its therapeutic and nutritional benefits due to the phytochemical substances in the sweet herb leaves (vitamins, minerals, polyphenols, amino acids, fiber) [1]. Steviol glycosides are widely used for the production of confectionery, chocolate, bakery products, yogurts, ice cream, gums, sauces, jams, dairy products, and beverages [2]. Such a wide range of industrial applications of sweet stevia extracts is due to its safety and the absence of side effects from its use, in contrast to synthetic sugar substitutes (saccharin, aspartame, acesulfame, etc.), which are widely used today [3]. In particular, the European Food Safety Agency (EFSA) in accordance with EC Commission Regulation No. 1131/2011 allowed the use of steviol glycosides as sweeteners and developed a specification for stevia extracts with a total content of steviol glycosides ≥ 95 % [4].

Plant extracts of stevia can be used in food technology as an additive that provides health benefits, as well as a food additive capable of slowing down or preventing food spoilage [5, 6]. These effects are directly related to hypotensive, antimicrobial, antihyperglycemic and immunoregulatory effects [7]. Therefore, works [8, 9] are known, in which stevia extract has already found its successful application in the technology of dietary food products.

To date, a wide range of extractants are used to extract extractive substances (ES) from the stevia leaf mass to obtain ethanol, demethanol, methyl acetate, isobutanol, and water extracts [10]. However, the specificity of the selected extractants leads to a significant limitation of the possible range of use of these extracts in the food industry. Therefore, the authors of the article suggested using whey from the production of sour milk cheese as a natural and safe food extractant.

The process of ES extraction from stevia leaves is carried out in accordance with Fick's law. The rate of diffusion of molecules of biologically valuable substances depends on: process temperature, surface area, thickness of the raw material layer, duration, as well as the ratio of raw materials and extractant. Extraction is carried out in two stages: internal – the transition of substances to the boundary layer of raw materials – and external diffusion of stevia components – the transition of substances from the boundary layer of raw materials into the solution, which will directly affect the speed of the process.

In general, the process of extracting stevia has a rather complex physico-chemical nature in the "solid-liquid" system. It consists not only in the washing of raw materials, but also necessarily proceeds with the destruction of existing connections and the subsequent formation of new ones. And at the stage of dissolution of ES, the formation of a concentrated solution and the balancing of concentrations, the direction will depend on the aggregate state of ES – dissolved or solid.

Due to the fact that the sweet substances of stevia (stevioside, steviolbioside, duliobioside, rebaudioside) in the dry leaf mass are in the solid phase, the onset of equilibrium in the process of its dissolution is possible under the condition that the concentration in the main mass of the solvent reaches the saturation concentration. That is why the determination of the ratio of raw materials and extractant (hydromodule) is an important and specific factor for each individual plant material, which will directly affect the degree of extraction of extractive substances [11, 12].

Scientists from many countries of the world are already studying all technological aspects and optimal conditions for obtaining stevia extracts [13]. However, the existing stevia processing technologies need to be improved, because they are mostly focused on application in a specific segment of the food market. Therefore, there are still a number of unsolved questions, related to the technological features of obtaining extracts from the dry mass of stevia leaves.

2. Research aim and tasks

The aim of the research is to improve the process of extracting dry stevia leaves under the condition of carrying out preparatory operations of raw materials and selecting a rational hydromodule. This will make it possible to increase the degree of extraction of extractive substances to obtain high-quality sweet extracts of stevia, which can be used in the food industry in the future.

To realize the set goal, the following tasks were solved:

– on the basis of the conducted theoretical research, prepare raw stevia for cleaning from impurities and maximizing the extraction of dry substances from the leaf mass;

– to investigate the effect of a variable ratio of raw materials: extractant (hydromodule) on the degree of extraction of extractive substances in model samples of sweet extracts.

3. Materials and Methods

Experimental studies of physico-chemical parameters of model samples of stevia extracts were carried out in the problem-based scientific research laboratory (NUFT) within the scope of the research project "Implementation of resource-saving methods of modifying the functional and technological characteristics of whey in the technologies of food products for special purposes" (state registration number 0120U100868), Ukraine.

Shredding of the leaf part of stevia was carried out during T=15±2 s using a hammer laboratory crusher A1-DM2R (**Fig. 1**) with a rotation frequency of 1500 rpm, a power of 200 kW and a sieve of the fourth (Ø-6.5), third (Ø5), and the second (Ø-3) group.

Fig. 1. Appearance of hammer crusher A1-DM2R

When evaluating the degree of pulverization of dry stevia leaves, the indicator of the average particle diameter was used, determined manually or mechanically using a set of sieves with dimensions of 0.5; 1.0; 2.0; 3.0 mm.

The formula was used to calculate the degree of grinding:

$$D_{av} = M_d \times d_1 + M_d \times d_2, \tag{1}$$

where M_d – mass fraction of the weight, which was removed during sieving through a sieve with the corresponding diameter, %; d – sieve diameter, mm [14].

For experiments, we used: whey from the production of sour milk cheese, which fully meets the requirements of DSTU 7515:2014 "Milk whey. Specifications"; dry stevia leaves of the coarse fraction of the TM "Steviasun" brand (TU U 551/46.163331590.001-97).

All model samples of stevia extracts were prepared with a variable hydromodule in the range from 1:10 to 1:16, by the maceration method, under the following conditions of the mass transfer process: the frequency of rotation of the stirrer – 20 rpm, the temperature – 85±2 °C, the duration – 20 min. The aqueous extract was filtered through a paper filter. The obtained extract samples were used for further research.

The mass fraction of dry substances in model samples was determined by the generally accepted refractometric method (DSTU 8402:2015). This method involves determining the mass fraction of dry substances of the test liquid on the scale of a refractometer, at a temperature of 20 °C, after carrying out a complete inversion in the product sample.

The accuracy of the obtained results was ensured by repeating the experiments 3–5 times. The obtained and presented results take into account the standard deviation; graphical presentation of experimental data was performed using standard statistical processing programs – Microsoft Excel 2010.

4. Results

Preliminary grinding of dry stevia leaves is appropriate, given its anisotropic porous body structure, for additional intensification of the process of mass exchange and ES output. The content of stevia stems in the dried leaf mass provokes a deterioration of extraction conditions, because they contain 0.1 % of diterpene glycosides (DG) substances (mature leaves – more than 70 %). Getting the stems on the machine can reduce the output of the concentrate and the content of DG in it by 8–13 %; provoke the deterioration of the organoleptic characteristics of the extract. Therefore, the use of stems in obtaining stevia extracts is impractical [15].

The obtained results of the dispersion analysis of particles of crushed dry stevia leaves are shown in **Fig. 2**.

According to **Fig. 2**, the largest output from the sieve is 67 %, typical for the diameter of the holes – 3.55 mm, with the average diameter of the particles of crushed leaves – 3.9±0.1 mm. A fraction of this average particle size will be used in further scientific research.

The hydromodule is one of the main factors, affecting the transition process of sweet glycosides from stevia leaves into the solution. Moreover, the excessive proportion of water, used in the preparation of extracts, leads to a decrease in their quality as a result of a certain oxidation of biologically active compounds, a slowdown in the extraction process, an increase in the economic cost and a deterioration of the organoleptic indicators of the finished product [8].

In this regard, a number of experimental studies were conducted to select the most rational hydromodule for obtaining sweet stevia extracts. The quantitative ratio of solid and liquid phases of hydraulic modules is presented in **Table 1**.

The efficiency of the extraction process was determined by the dry matter content of model extract samples. The obtained results are shown in **Fig. 3**.

According to the obtained results (**Fig. 3**), we observe a correlation dependence between the mass fraction of dry substances of model samples of extracts from the ratio of raw materials and extractant. The obtained results are in good agreement with the laws of mass transfer of matter between phases, therefore, when the hydromodule of processing increases, the gradient between water and stevia increases, which leads to a decrease in the yield of dry product.

In order to determine in more detail the sufficient amount of extractant (to dissolve water-soluble substances and transfer their mass by diffusion to the boundary layer with subsequent distribution throughout the mass of the solution) to obtain high-quality stevia extracts, the change in the degree of extraction of extractive substances from the mass of the obtained model samples of extracts was studied. The results of the research are presented in **Fig. 4**.

The results, shown in **Fig. 4**, confirm the expediency of using hydromodule 1:15 for obtaining sweet extracts of stevia using whey from the production of sour milk cheese. After all, for this indicator of the hydromodule, the highest degree of extraction of extractive substances is observed – 29.9.

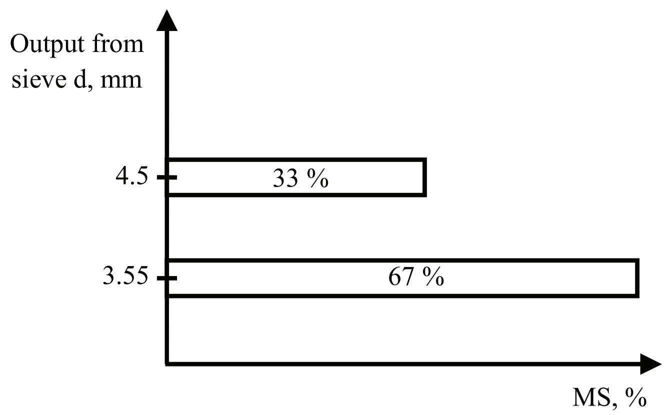

Fig. 2. Size distribution of the crushed dry stevia mass

A further increase of the hydromodulus to 1:16 does not affect the intensity (internal diffusion coefficient) of the transition of ES to the extract (indicates the achievement of equilibrium concentrations between the raw material and the extractant), but provokes an increase in the mass of its output. Excess moisture in the extract will lead to a decrease in quality as a result of certain oxidation of biologically active compounds. Such an extract will have impaired organoleptic properties and cause an increase in the cost of the product. Accordingly, carrying out the extraction process when the hydromodule is increased to 1:16 is irrational.

Table 1
Quantitative ratio of components of solid and liquid phases for a variable hydromodule

Component	Hydromodule value						
	1:10	1:11	1:12	1:13	1:14	1:15	1:16
	Mass, g:						
Dry stevia leaves	9.1	8.3	7.7	7.1	6.7	6.3	5.8
Whey from the production of sour milk cheese	90.9	91.7	92.3	92.9	93.3	93.7	94.2

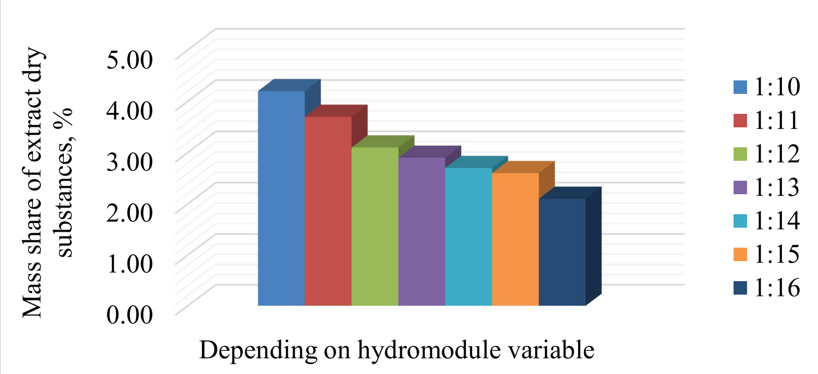

Fig. 3. Dependence of the mass fraction of dry substances on the hydromodule index of model samples of stevia extracts

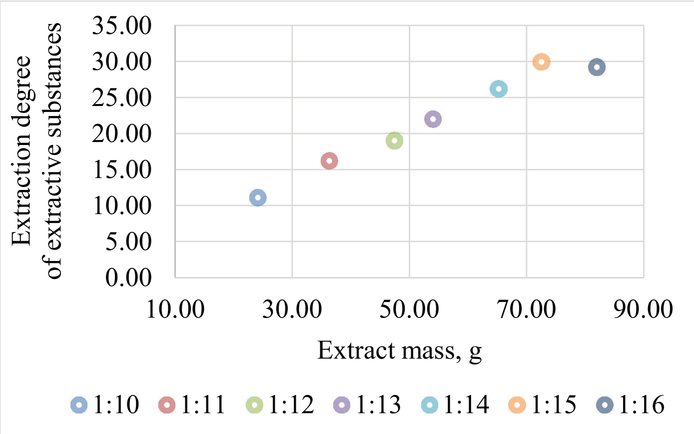

Fig. 4. Efficiency of the extraction process for a variable hydromodule

5. Conclusions

It has been established, that to obtain sweet extracts of stevia, it is advisable to carry out preliminary preparation of dry leaf mass, namely: grinding and subsequent sieving to the average diameter of leaf particles – 3.9±0.1 mm. Carrying out these preparatory operations allows you to maximize the extraction of dry substances from stevia.

According to the results of scientific research, it has been established, that the maximum degree of extraction of extractive substances (29.9) from the prepared stevia leaf mass (extractant – whey from the production of sour milk cheese) is possible with a hydromodule – 1:15. This extractant:substance ratio is sufficient for the penetration of the extractant into the pores of the crushed stevia leaves, the subsequent dissolution of water-soluble substances and their diffusion into the boundary layer (from the inner region of the leaf particle through the boundary) with subsequent distribution throughout the entire mass of the solution.

Conflict of interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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Received date 16.03.2022
Accepted date 04.05.2022
Published date 31.05.2022

How to cite: *Belemets, T., Kuzmyk, U., Gryshchenko, R., Osmak, T. (2022). Determination of technological parameters of obtaining stevia extract. EUREKA: Life Sciences, 3, 15–20. https://doi.org/10.21303/2504-5695.2022.002584*