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POWDERS FROM DERIVATIVES OF WILD PLANT FRUIT PROCESSING

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INTRODUCTION

In Ukraine, about 300 thousand tons of various fruit and vegetable products are spoiled annually, so it is quite important to develop and implement waste-free technologies for the integrated processing of berries, vegetables and fruits[1].

Fruit and vegetable processing products such as powders, purees, and dietary fiber concentrates can be used in the food industry as dyes, flavors, and natural preservatives, as well as used to replace the composition of food products to improve their nutritional properties. Unfortunately, fruits and vegetables have a short shelf life when fresh[2]. Drying is the most rational way of preserving, as microbiological processes slow down in dried products, and the composition of nutrients and biologically valuable substances remains close to natural. During drying, moisture is removed from the raw materials, the concentration of substances in the cell sap increases, and the osmotic pressure increases, which prevents the development of microorganisms. Dried fruits, vegetables and berries contain a large amount of carbohydrates, vitamins, pectin and minerals, and organic acids[3].

Food powders make up a significant share of the total volume of processed food in the world. This is due to several reasons, such as low weight, ease of storage, transportation and a variety of applications[4].

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Traditional methods of processing plant material usually involve processing modes that lead to a partial loss of its biological value. That is why scientists are actively searching for rational ways to process raw materials comprehensively to produce natural food ingredients with additional functional properties.

1. Background and problem statement

The development of new generation products from environmentally safe and biologically valuable plant materials is an urgent area of food industry development.

This includes wild-growing raw materials. It is known that the fruits of wild plants contain a balanced complex of vitamins, minerals, proteins, lipids and have high nutritional, flavour and therapeutic and preventive properties.

Blueberries are considered a source of biologically active compounds, but their industrial use is limited due to their low stability. The technology for producing blueberry powder by freeze-drying has already been developed[5, 6].

The technology for powders rich in antioxidants and pigments from two wild berries – Chilean grape berry (Aristotelia chilensis) and Mediterranean blackberry (Rubus ulmifolius) – has been developed[7].

The use of acacia (Ardisia compressa Kunt) powder in fruit snacks was investigated. Acachula gives food products taste, colour and helps to increase their antioxidant properties[8].

The use of elderberry powders for the preparation of the hot drink "Elderberry" (FITNE, Germany) is proposed. This drink is positioned in the

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pharmaceutical market as a multivitamin for vitamin C deficiency, for the prevention and maintenance of viral and infectious diseases, overwork, and increased physical activity. Frozen elderberry powder is also available (Freeze Dried Elderberry Powder, Wilderness Poets, iHerb). It contains antioxidants, polyphenols, and is used to support a healthy immune system in its form.

The Ukrainian market has virtually no food products made from wild berry raw materials.

Among the products processed from wild berries, supplements in the form of pastes and purees occupy a special place. They are a source of natural dietary supplements, colouring agents, and structuring agents used in the production of fortified foods[9]. Berries are considered superfruits due to their high content of vitamins, minerals, phytochemicals and dietary fibre[10].

Under the leadership of R. Pavliuk, a technology for producing cryopowders from wild berries (black elderberry, viburnum, sea buckthorn) was developed[11]. The essence of the cryogenic technology is instantaneous deep freezing of raw materials in liquid nitrogen (the temperature of the medium is minus 160°C) in a continuous cycle. Such technologies increase the biological value of the products obtained, as they destroy enzymes that prevent the absorption of vitamins and thiamine-like substances. The frozen raw materials are dried in special vacuum-controlled facilities and finely ground to a pulverised state using special machines. This technology is currently being used to develop cryo-supplements from calendula, nettle, currant, apple, chokeberry, citrus, tropical fruit, etc.

A method for preparing a powdered product based on rowan and rose hips has been developed. The method involves drying in a microwave field

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with vacuum at a temperature of 400C for 4–6 hours to a residual moisture content of 14–16 %, the dried product is ground into powder[12].

The subject of our research was the berries of viburnum (Viburnum opulus), mountain ash (Sorbus), sea buckthorn (Hippophae) and black elderberry (Sambucus nigra).

Viburnum opulus is a valuable ornamental, medicinal and food plant known as a natural source of various compounds with antioxidant properties, such as ascorbic acid (vitamin C), α-tocopherol (vitamin E), carotenoids, chlorophylls and phenolic compounds.

In Ukraine, despite their tart-bitter-sour taste, red fruits are used in traditional cuisine as an additional ingredient in marmalades, jams, liqueurs, Kalynnyk pies, and herbal teas[13]. Viburnum berries are highly acidic due to their high content of organic acids – citric, tartaric, malic, quinic, and other acids[14]. Viburnum fruits also contain sugars such as fructose, glucose and sucrose[15]. Viburnum berries contain 27 minerals (Al, Mg, Na, Ba, Ca, Ni, Cd, P, Cr, Pb, S, Cu, Se, Fe, K, Sr, Li, Z, V, Ag, Bi, Co, Mn, B, Ga, In, Ti). Most of all – potassium, magnesium, phosphorus[16].

Viburnum berries have a characteristic smell and specific bitterness, which, unfortunately, consumers do not like. However, the amount of bitterness is significantly reduced during heat treatment. The volatile components found in the fruit belong to the following classes of organic compounds: alcohols, terpenoids, phenols, ketones, aldehydes, esters, branched-chain fatty acids and acids[17].

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The antimicrobial effects of viburnum fruits on 15 cultures of microorganisms have been established[18].

Rowan ***(Sorbus aucuparia***) has been traditionally used in the European diet in various processed products, such as jams, jellies and drinks, which have high nutritional and health potential[19, 20]. Scientific research has proven anti-inflammatory[21], antioxidant[22], anti-diabetic effects due[23] to the unique composition of biologically active compounds – a significant amount of ascorbic acid, phenolic compounds, carotenoids, as well as organic acids and sugars. Ascorbic acid, carotenoids, flavonoids, anthocyanins and especially phenolic acids contribute significantly to antioxidant activity[24].

Rowan fruits also contain tannins (0.5 %) and pectin (0.5 %), sorbitol and sorbose, amino acids, essential oils, potassium, calcium, magnesium, and sodium salts. The presence of vitamin P puts mountain ash in one of the first places among other fruit plants. Rowan fruits are also rich in vitamin C (up to 160 mg%) and β-carotene (up to 5.6 mg%)[25].

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Rowan fruit preparations reduce the amount of fat in the liver and cholesterol in the blood, and rowan fruit powder increases the resistance of blood vessels. In scientific medicine, the fruits of mountain ash are used as a multivitamin, diuretic and haemostatic agent[26].

Sea buckthorn (***Hippophae rhamnoides L.***) is a natural source of vitamins and a number of other bioactive compounds, such as carotenoids and flavonoids, which are claimed to lower cholesterol, blood pressure and blood sugar levels[27].

Sea buckthorn berries are the richest in essential nutrients, such as polyunsaturated fatty acids, provitamins A, C, PP[28], B_1, B_2, K, amino acids, phytosterols and flavonoids, pigments and lipoproteins.

Mineral elements are represented (mg/100 g): potassium – 180–220, calcium – 9–16, magnesium – 7–12, phosphorus – 12–17, iron – 6–14, as well as zinc, manganese, aluminium, titanium, silicon[29].

Sea buckthorn oil is usually produced from sea buckthorn, which contains glycerides of oleic, linoleic, stearic and palmitic acids, vitamin E (160 mg/100 g), carotene and other carotenoids (314 to 2139 mg/100 g)[30]. Sea buckthorn fruits contain a large amount of organic acids, mainly malic and quinic acids[31], and other carotenoids (314 to 2139 mg/100 g)[32]. Sea

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buckthorn fruits contain a large amount of organic acids, mainly malic and quinic acids[33].

Sea buckthorn berries are used as a multivitamin product for hypo- and avitaminosis of vitamins A and C. They are consumed fresh, and are used to make jam, juice and jelly.

Berries of black elderberry (***Sambucus nigra L.***) are a source of important and valuable compounds. The value of these berries lies in the presence of a large amount of low molecular weight phenolic compounds and polyphenols (5960 mg/%), most of them anthocyanins. The fruits contain 18.2 % dry matter, including 5.2…7.4 % sugars, 1 % pectin, and 1.3 % acids. It should be noted that the sugars of elderberry fruits growing in Ukraine are represented only by glucose[34].

Elderberry is rich in carbohydrates (18 %) (mainly simple sugars)[35], fibre (7 %), proteins (3 %) and lipids (0.35 %)[36]. Lipids contain about 80 % polyunsaturated fatty acids and 10 % saturated fatty acids, the content of essential fatty acids is very high[37]. Linoleic and linelenic acids are the main essential fatty acids in elderberries, accounting for 38–39 % of the total fatty acids[38].

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Elderberries contain a significant amount of minerals and vitamins C, α-tocopherol, β-carotene, E[39], B_2, B_3, B_5, B_6, B_9[40] and antioxidants. There are results that elderberry seed powder is a source of α-tocopherol, which has the highest biological activity of vitamin E, as well as γ-tocopherol, which shows better antioxidant potential[41].

Among the main polyphenols in elderberries, the antioxidant properties of this fruit are mainly determined by anthocyanins, as well as flavonols and phenolic acids[42].

Elderberries and their products are potential colourants and antioxidants that can be used in the food industry. However, despite its excellent colouring properties due to its high anthocyanin content and high antioxidant capacity (polyphenols, vitamins, etc.), this product is underutilised[43].

Thus, mountain ash, elderberry, sea buckthorn and viburnum are characterised by a high content of biologically active substances, especially phenolic compounds. Berries are characterised by therapeutic and prophylactic properties, so they can be the basis for the creation of functional powders.

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2. Analysis of existing methods of solving the problem and formulation of the task for optimal solution

It is known that processed products, such as jams, jellies, purees and juices, have a significantly reduced content of minerals, vitamins, phenolic and anthocyanin compounds compared to fresh berries[44].

We have developed a new technology that involves processing wild berry derivatives into functional powders[45].

Plant powders from berry derivatives are produced from high-quality fruit and berry raw materials that are not damaged by diseases and pests. Wild berries were harvested in August – October – November 2022 in Sumy region, Ukraine. The fruits of wild plants are thoroughly washed, disinfected and sorted. The washed fruits are pre-frozen at (−18±2) °C and defrosted at (4±2) °C immediately before processing to improve their taste. The dehydrator is first fed with granulated sugar and drinking water in a ratio of 7:10. The mixture is thoroughly mixed and heated until the sugar crystals are completely dissolved. The mass fraction of sucrose in the sugar solution should be at least 70.0 %. The resulting sugar solution is pasteurised at a temperature of (65±1) °C for 10 minutes, after which the berries are added to it. The fruits are kept in a sugar solution with a mass fraction of sucrose of 70.0 % at a temperature of (50±1) °C for 1 hour.

A special feature of the developed technology for the production of powders from wild fruits is the use of osmotic dehydration. The dehydration process is based on increasing the osmotic pressure in cells by increasing the concentration of solids. This ensures the partial transfer of water from the fruit cells to the sugar solution and, as a result, the inactivation of enzymes. The partially dehydrated fruit is separated from the osmotic solution and sent for drying in an infrared dryer at a temperature of (50±1) °C for 1 hour. Drying at a temperature not exceeding (50±1) °C is based on the fact that a significant amount of moisture is removed from the product and unfavourable conditions for the development of microorganisms are created, while the biological value of the fruit is preserved. The dried material is ground to a powdered structure using a laboratory disc mill LZM-1 and sieved using a set of brass sieves No. 045, No. 035 and No. 016. The smaller fraction can be used as natural colouring

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and flavouring agents. The coarser fraction can be used as an additive to increase the dietary fibre content of food products.

Store herbal powders from berry derivatives at a temperature of 0–10°C and a relative humidity of 60–65 %. The shelf life of plant powders from berry processing derivatives is 12 months.

The proposed technology is completely waste-free and has a number of advantages:

– Efficient use of resources, with osmotic dehydration reducing the drying time by almost 2 hours, and thus reducing energy consumption;

– preliminary freezing of berries allows processing throughout the year, as usually the processing of raw materials is seasonal (summer and autumn);

– the environmental impact is significantly reduced, as there is no need for waste processing and disposal;

– the introduction of this technology will increase the number of employed people in rural areas, as wild berries mainly grow there and it is advisable to process them at the place of collection.

Fig. 1. Powders from berry processing derivatives:
1 – Sorbus aucuparia, 2 – Hippophae rhamnoides, 3 – Viburnum opulus, 4 – Sambucus nigra

The presented samples of functional powders with a powder dispersion of up to 0.5 mm show that the appearance and consistency of the powdered mixture is homogeneous, without impurities; the colour and taste are typical of this dried raw material (Fig. 1).

Plant powders can be used as additives to create functional foods (Fig. 2). In addition to vitamins and minerals, the powders obtained contain a small amount of sugar, which makes it possible to use them as natural sweeteners. This technological solution will not only expand the range of functional food additives, but also solve the problem of reducing waste through the integrated use of raw materials.

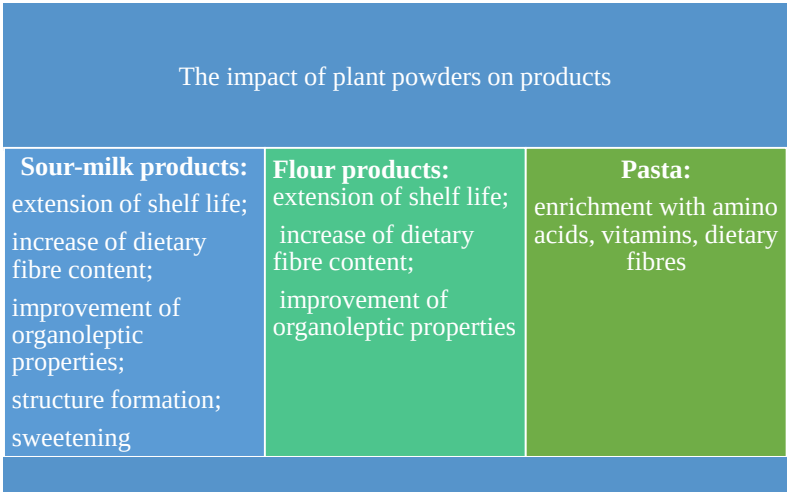

Fig. 2. Effect of plant powders on food products

The organoleptic characteristics of plant powders from fruit processing derivatives (viburnum, elderberry, sea buckthorn, mountain ash) correspond to those presented in Table 1.

Table 1

Organoleptic characteristics of plant powders

Name of indicators	Indicator value			
	Hippophae rhamnoides L.	**Viburnum opulus**	**Sambucus nigra**	**Sorbus aucuparia**
Appearance and consistency	Homogeneous, fine powder, without lumps. Foreign impurities and impurities of vegetable origin are prohibited. Consistency is dry.			
Colour	Homogeneous throughout, typical of the raw materials used, after heat treatment. Slight darkening of the finished product is allowed.			
Taste and smell	The taste is sweet-sour or sour-sweet. Taste and smell are well defined, typical of the raw materials used, after heat treatment. No off-flavours and odours allowed off-flavours and odours allowed			

An important indicator of the quality of plant powders is the mass fraction of moisture, as it affects their shelf life[46]. The mass fraction of total sugar in powders made from wild berry derivatives affects their nutritional value and the nutritional value of products made from them. Sucrose is a kind of preservative and gives the powders the properties of sweeteners.

The results of the study of the physicochemical parameters of powders from fruit processing derivatives (viburnum, elderberry, sea buckthorn, mountain ash) are presented in Table 2.

Table 2

Physicochemical quality indicators of plant powders

Name of indicators	Indicator value			
	Hippophae rhamnoides L.	**Viburnum opulus**	**Sambucus nigra**	**Sorbus aucuparia**
Mass fraction of moisture, %, not more than	8	8	8	8
Dispersibility, mm	<0,5	<0,5	<0,5	<0,5
Active acidity, pH unit	4,1–4,5	4,2–4,5	4,6–4,8	4,6–4,8
Titrated acidity (in terms of citric acid), %.	0,5–0,6	0,4–0,5	0,3–0,4	0,2–0,3
Titratable acidity (in terms of malic acid), %.	0,5	0,5	0,5	0,5
Soluble solids, %, not less than	77,0	77,0	79,0	79,0
Mass fraction of reducing sugars, %, not more than	29,0	37,0	50,0	38,0
Vitamin C content, mg/100 g	3–4	8–9	3–4	1–2

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Amino acids are an essential building block of plant and animal proteins with a characteristic protective effect. Free amino acids largely determine the organoleptic characteristics of food products. Fig. 3 shows a comparison of the amino acid profile of powders made from derivatives of the processing of wild berries Hippophae rhamnoides L., Viburnum opulus, Sambucus nigra and Sorbus aucuparia. Berry powders contain the vast majority of essential amino acids (Fig. 3), including almost all essential ones, except tryptophan. This indicates that the powders are biologically complete.

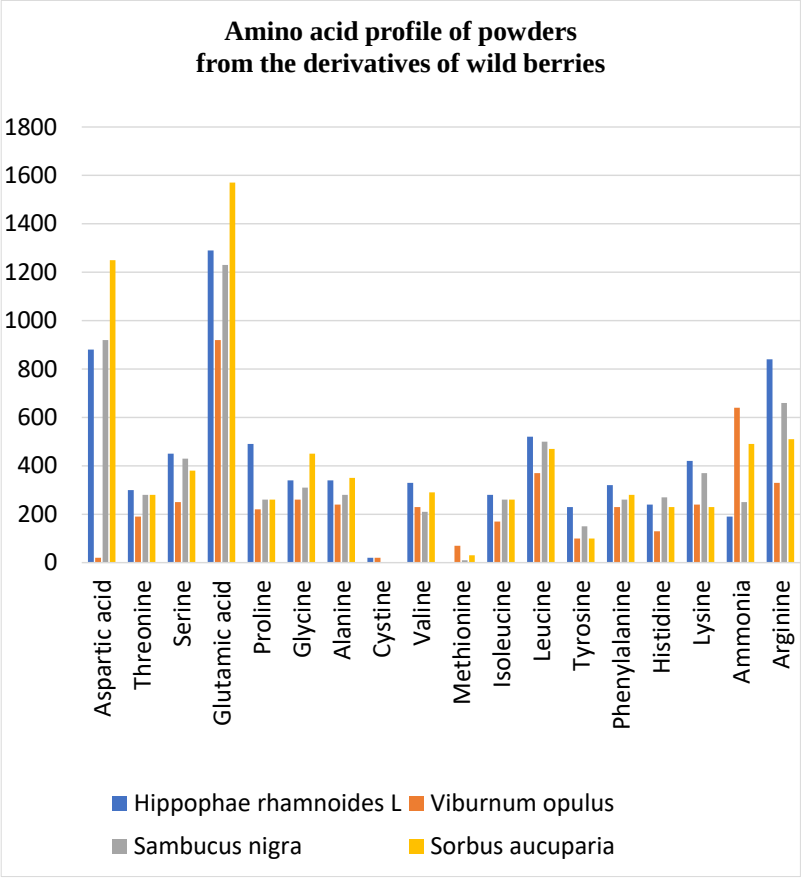

Fig. 3. Amino acid profile of powders from the derivatives of wild berries *Hippophae rhamnoides L., Viburnum opulus, Sambucus nigra* and *Sorbus aucuparia*

The powder from the derivatives of sea buckthorn processing *Hippophae rhamnoides L*. contains 17 amino acids in the amount of 7.48 g/100 g, of which 2.17 g/100 g are essential amino acids, such as leucine (0.52 g/100 g), isoleucine (0.28 g/100 g), lysine (0.42 g/100 g), and valine (0.33 g/100 g), threonine (0.3 g/100 g), phenylalanine (0.32 g/100 g). The following amino acids found in sea buckthorn derivatives are especially useful for children and the elderly: arginine (0.84 g/100 g), histidine (0.24 g/100 g). Arginine is involved in liver cleansing and regulation of muscle growth. Histidine affects the production of white and red blood cells, as well as muscle growth, and is the basis for the production of histamine, which is necessary for regulating sleep and wakefulness cycles, sexual function and the production of the myelin sheath of nerve cells.

Viburnum opulus powder contains 18 amino acids in the amount of 4.63 g/100 g, of which 1.63 g/100 g of essential amino acids were found (isoleucine – 0.17; leucine – 0.37; lysine – 0.24; methionine – 0.07; phenylalanine – 0.23; threonine – 0.19; valine – 0.23). It is worth noting that the concentration of some amino acids in viburnum powder was significantly lower than in elderberry and sea buckthorn powders, respectively: aspartic acid (by 0.9 and 0.86 g/100 g), serine (by 0.23 and 0.2 g/100 g). The same concentration of cystine was found in viburnum and sea buckthorn powders (0.02 g/100 g). In addition, the essential amino acid methionine (0.07 g/100g) was found in viburnum powder. It has a good effect on the kidneys, reduces the toxicity of many toxic substances and helps to restore liver function.

The total amount of amino acids in *Sambucus nigra* elderberry powder is 6.65 g/100 g, of which 2.16 g/100 g are essential (isoleucine – 0.26; leucine – 0.50; lysine – 0.37; methionine – 0.01; phenylalanine – 0.26; threonine – 0.28; valine – 0.21). The highest levels of glutamic acid (1.23 g/100g) and aspartic acid (0.92 g/100g) were found in elderberry powders. Aspartic acid stimulates protein synthesis, reduces ammonia levels in the blood, and normalises liver function. The smallest amount of methionine is 0.01 g/100 g.

In the powder of mountain ash *Sorbus aucuparia*, 7 essential amino acids were found, g/100g: valine (0.29), leucine (0.47), isoleucine (0.26), lysine (0.23), methionine (0.03), threonine (0.28), phenylalanine (0.28). The highest concentration of all amino acids was glutamic acid (1.57 g/100 g). As a result of enzymatic conversion, glutamic acid is converted into γ-aminobutyric acid, which is the most important mediator of inhibition in brain neurons, under the action of the enzyme glutamate decarboxylase. In addition, glutamic acid enhances taste sensations,

creating a “feeling of satisfaction”. The bitter taste is especially enhanced. Glutamic acid derivatives have a stabilising effect on food during storage. It is used as an additive E620 in canned food, food concentrates, and culinary products to enhance their flavour and in fats to extend shelf life.

The analysis of the mass content of trace elements in the studied samples was carried out using a SEM and EDS detector based on an SEO-SEM Inspect S50-B microscope: an AZtecOne microscope with a dispersive spectrometer with an X-MaxN20 detector is presented in Table 3.

Table 3

Analysis of the mass content of trace elements in powders from wild berry processing derivatives

Name of the trace element	Indicator value			
	Hippophae rhamnoides L.	Viburnum opulus	Sambucus nigra	Sorbus aucuparia
Potassium	0,30	5,74	0,61	0,86
Calcium	0,7	0,4		0,11
Phosphorus	0,4	0,14	0,45	0,05
Aluminium	0,05	0,02	-	0,86
Magnesium			0,75	
Sulphur	0,07		0,06	

Potassium, calcium, sulphur, carbon, aluminium, phosphorus, chlorine were detected in powders from sea buckthorn berries Hippophae rhamnoides L., with the highest levels of Ca-0.7 % and P-0.4 %.

Potassium, calcium and phosphorus were detected in powders from viburnum fruit derivatives. The highest amount of K was found in the samples – 5.74 %. The content of Ca was 0.4 %, and P – 0.14 %.

Black elderberry powder Sambucus nigra contains magnesium, sulphur, phosphorus and potassium, with the highest amount of K – 0.61 %.

Rowan powders contain the following minerals, mg per 100 g: potassium – 860, calcium – 110, phosphorus – 50 and aluminium – 40.

Vitamin C stimulates the launch of immune processes and also has antioxidant properties, so its content in powders made from the derivatives of wild berries Hippophae rhamnoides L., Viburnum opulus, Sambucus nigra and Sorbus aucuparia was studied (Table 4).

A large number of studies have confirmed the important role of dietary fibre in human nutrition, health promotion and prevention of lifestyle-

related non-communicable diseases[47]. It has been shown that dietary fibre has a moisture-retaining ability, prevents bread from staling, and extends the shelf life of the product[48].

Table 4

Vitamin C content in samples of powders from wild berry processing derivatives

Name	Indicator value, mg/100 g			
	Hippophae rhamnoides L.	**Viburnum opulus**	**Sambucus nigra**	**Sorbus aucuparia**
Vitamin C	3,81	8,29	3,05	1,72

Vegetable powders from berry processing derivatives are intended for use in bakery and confectionery production as acid- and sugar-containing raw materials rich in pectin, vitamins and minerals.

A formulation of pasta (noodles) with the addition of powders from the processing of wild berries *Sambucus nigra, Viburnum opulus, Hippophae rhamnoides* L. has been developed[49].

There are already studies on the use of sea buckthorn derivatives in the production of buns[50], elderberry – in the production of yoghurts[51], rowan – in the production of bread[52].

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CONCLUSIONS

The natural resource base of Ukraine includes about a thousand different species and varieties of fruit and berry plants, such as sea buckthorn, viburnum, black and red currants, blueberries, raspberries, mountain ash, rose hips, etc. The most promising method of their technological processing is the manufacture of powders.

Powders made from non-traditional plant materials have great potential for use in the production of various food groups, which makes it possible to significantly improve their nutritional and biological value, organoleptic characteristics, extend the shelf life of finished products, increase the efficiency of the technological process and reduce production costs.

The technological scheme for the integrated processing of wild berries developed by us is waste-free and versatile. Our proposed heat treatment modes allow us to maximise the biological value of all berry products.

The optimal mode of drying wild berry derivatives in infrared dryers has been established, namely: drying temperature 50°C, duration 2.5 hours.

The production of powdered supplements by this method makes it possible not only to preserve the biologically active components of the raw materials to the fullest extent possible, but also to increase the amount of vitamins and phenolic compounds with P-vitamin activity. The mass fraction of moisture in the powders obtained using our technology and drying regime does not exceed the level at which mould development is observed (≤8 %). The mass fraction of sugar is, taking into account the approximate amount of powders added in the manufacture of food products, will not significantly increase the amount of sugar in the finished product.

The analysis of the amino acid composition and physicochemical composition of the derivatives of wild berries processing showed that they are extremely promising raw materials for the production of food functional additives

SUMMARY

The paper proposes a waste-free technology for processing wild raw materials Hippophae rhamnoides, Viburnum opulus, Sambucus nigra and Sorbus aucuparia into powders. The moisture removal regime, which involves preliminary dehydration for 1 hour by osmotic dehydration and subsequent drying in infrared dryers, reduces the process time. In this case, the dried materials have a final moisture content that allows grinding the dried material into powders ≤0.45 mm.

In addition to reducing the drying time, osmotic dehydration ensures that the flavour and aroma properties of wild berry derivatives and their

natural colour are preserved. This makes it possible to use the powders as natural food additives in various food industries.

The proposed heat treatment regime reduces the energy consumption of the process and reduces the drying time to 2–2.5 hours.

The analysis of the amino acid composition of powders made from wild berry processing derivatives has shown that they have high biological value and can be used to create functional food products.

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