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Substantiation of wild plants used as functional ingredients in the technology of crisp grain bread

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ABSTRACT

Research on the nutritional content of wild plant fruits in Kazakhstan, including Hawthorn fruit (*Crataegus laevigata*), rosehip fruit (*Rose canina* L. variety), sea buckthorn fruit (*Hippophae rhamnoides* - Altai variety), and black chokeberry fruit (*Aronia melanocarpa*), has determined that these fruits possess a combination of properties essential for maintaining human health, attributed to the presence of bioactive substances (BAS) and other components. The technological process for obtaining extracts and concentrates from wild-growing raw material fruit has developed. The following extraction modes were proposed: ultrasonic wave frequency 40 kHz, extraction time 30 minutes, temperature 500C, and concentration of the obtained extracts was carried out by vacuum evaporation method, using IKA RV-10 apparatus at 40-50°C and pressure 800 mbar.

Found that extracts and concentrates have a higher concentration of nutritional substances when compared to the fruits themselves. Thus, the vitamin C content in hawthorn fruits was 27.8 mg, while in the extract, it was 47.84 mg, and in the concentrate – 62.19 mg. The vitamin C content in rosehip fruits, extracts, and concentrates was 578.01 mg, 811.8 mg, and 1101.3 mg, respectively. The vitamin C content in sea buckthorn fruits, extracts, and concentrates was 285.05 mg, 518.8 mg, and 640.9 mg, respectively. The vitamin C content in black chokeberry fruits, extracts, and concentrates was 86.2 mg, 128.8 mg, and 160.5 mg, respectively. A similar increase was observed for the content of vitamin E and other components.

Furthermore, the obtained concentrates meet the safety parameters required by regulatory documents. A technology for producing grain crispbread using the extrusion method has developed, incorporating whole grains, groats, flavouring additives, and concentrates derived from wild fruits such as hawthorn, rosehip, sea buckthorn, and black chokeberry into the recipe.

Keywords: wild plants, extracts, concentrates, chemical composition, food safety, functional foods

INTRODUCTION

Ready-to-eat breakfast cereals dominate the entire market due to the convenient solution they provide for consumers. The market is primarily propelled by individuals with active lifestyles, as these products are processed cereal formulations suitable for consumption without further preparation. Ready-to-eat giants find millennials and the younger generation are the most accessible targets, as they allocate a significant portion of their income to such food products. Consequently, the high level of convenience associated with these products contributes to the overall growth of the market **[1]**.

Accumulated data in the field of nutritional science testify that in contemporary conditions of human life, it is challenging to adequately meet the body's needs for all necessary nutrients and minor biologically active components solely through traditional nutrition. Worldwide, there is a growing emphasis on seeking safer alternative sources, including wild plants characterised by an increased content of biologically active substances known for their ecological purity and high efficiency. Wild plants serve as abundant sources of essential nutrients such as vitamins, carbohydrates, fats, proteins, organic acids (citric, malic, and so on), aromatic substances, and antioxidants, fulfilling crucial needs for the human body **[1]**, **[2]**, **[3]**.

In connection with the above, research aimed at solving significant problems associated with creating qualitatively new food products enriched with biologically active components isolated from environmentally safe wild plants is relevant.

As non-traditional sources of plant raw materials in the production of breakfast cereals, fruits of various wild fruit and berry plants are used. These plants serve as a direct food source and technological raw material for processing traditional food products, resulting in unique flavours and maximising benefits **[4]**. Thus, utilising raw materials from wild plants can improve the flavour range of products and enrich them with biologically active substances. Among wild fruit plants, the fruits of rosehip, hawthorn, sea buckthorn, and mountain ash are particularly noteworthy, as they not only exhibit high taste properties but also offer a diverse range of physiological benefits attributed to a rich set of biologically active substances, including those with antioxidant properties.

Rosehip (*Rosa L.*) is widely used as a medicinal and food component and is represented by approximately 200 wild species worldwide **[5]**. Rosehip (*Rosa canina L.*) is a fruit member of the Rosaceae family that contains high amounts of phenolic compounds, carotenoids, tocopherols, flavonoids, and vitamin C.

Due to its rich bioactive compounds, rosehip generally prevents and treats diseases such as colds, cardiovascular diseases, gastrointestinal disorders, infections, and diabetes **[6]**. It is also recommended as a general tonic **[7]**.

According to the content of vitamin C (4.8% in seeds and up to 8.5% in pulp), it stands unrivalled among fruit and berry crops. Additionally, rose hips contain P-active compounds (up to 9%), vitamin E (6-10 mg/100 g), B_1, B_2, B_9, carotene, tannins, pectin, nitrogen compounds, flavonoids, sugar, organic acids, fats, and various trace elements crucial for hematopoiesis such as Fe, Mg, Ca, K, Cu, Zn. The seeds also comprise up to 12% of fatty acids, rubixanthin, gazaniaxanthin, β-cryptoxanthin, zeaxanthin, and phenolic compounds such as quercetin, ellagic acid, quercetin glycosides, hydroxycinnamic acids, proanthocyanidin, and aglycones **[8]**.

Rosehip fruits and seeds contain a substantial amount of crucial dietary antioxidants. The increased antioxidant activity is primarily due to ascorbic acid, and the content in rosehip fruits ranges from 6.0 to 8.2 mg g-1 in fresh weight (FW) **[9]**. Phytochemical studies have shown that Rosa species contain a wide range of chemical compounds, including quercetin, kaempferol, catechin, citronellol, limonene, lycopene, carvacrol, thymol, rosmarinic acid, etc. **[10]**. With antiviral and antitumor effects, rosehip preparations can inhibit the proliferation of cancer cells **[11]**.

One promising source of biologically active substances is a unique plant - sea buckthorn. Various bioactive substances are present in all parts of sea buckthorn, and these are used traditionally as raw materials for health foods and as nutritional supplements **[12]**, **[13]**, **[14]**. Research has identified 24 compounds in the seeds and 16 compounds in the pomace, including phenolic acids, flavonoids, and tannins. Sea buckthorn extracts demonstrated in vitro antidiabetic and anti-obesity potential by inhibiting α-glucosidase enzymes (71.52-99.31%) and pancreatic lipase (15.80-35.61%), respectively **[15]**. Additionally, the extracts showed antibacterial activity against *S. aureus*, *B. cereus*, and *P. aeruginosa* **[16]**.

The chemical composition of sea buckthorn fruit represents the lower sugars at 3.5-6.0 % (glucose and fructose), organic acids (oxalic, tartaric, malic, citric and caffeic acids), including fatty acids **[17]**.

The four sea buckthorn varieties (Klara, Dora, Kora, Mara) cultivated in the Republic of Moldova had varying contents of organic acids (malic acid 5.8–13.4 mg/100 g, citric acid 0.08–0.321 mg/100 g, succinic acid 0.03–1.1 mg/100 g), titratable acidity (2.15–8.76%), and pH values (2.73–3.00) **[18]**. The content of phenolic-type antioxidants (phenolic compounds, flavonoids, phenolic acids) and vitamin C was studied. The greatest variability of water-soluble antioxidants in sea buckthorn is associated with vitamin C content, ranging from 82 to 297 mg/100 g, depending on the botanical variety. The total phenolic compounds content was 600-795 mg/100 g, while flavonoids and phenolic acids were 265-346 and 105-170 mg/100 g, respectively. The content of fat-soluble antioxidants in sea buckthorn fruits of different varieties, including vitamin E and carotenoids, was also studied, which amounted to 6.9-8.3 and 10.7-14.9 mg/100 g, respectively **[19]**, **[20]**.

Hawthorn belongs to the genus Crataegus and is widely distributed in the northern temperate zone of the world, counting about 280 species. It has long been used in folk medicine to treat diseases such as heart (cardiovascular disorders), central nervous system, immune system, eyes, reproductive system, liver, kidneys and others. The multifunctional therapeutic role of hawthorn extracts in treating various chronic and degenerative diseases is emphasized, primarily focusing on flavonoids **[21]**. Treatment with hawthorn extracts may be associated with improvements in the complex pathogenesis of various liver and cardiovascular diseases **[22]**. Polysaccharides of *Crataegus pinnatifida* possess diverse biological activities, including antitumor, immunomodulatory, hypoglycemic, cardioprotective, and antioxidant activities etc. **[23]**. Furthermore, assessments have demonstrated that hawthorn is non-toxic **[24]**.

The carbohydrates in hawthorn fruits consist of sugars, starch, pectin substances, and other compounds. So the content of glucose is 2.02 mg/g, fructose - 2.21 mg/g, sucrose - 0.23 mg/g, arabinose - 1.82 mg/g, xylose - 3.88 mg/g, mannose - 4.25 mg/g, galactose - 1.31 mg/g. Seeds contain from 27.5 to 39.2% fat. The content of organic matter in hawthorn fruits varies widely. Of the organic acids in hawthorn, fruits contain citric acid, oleic acid, ursolic acid, crotegus acid, caffeic acid, and chlorogenic acid **[25]**, **[26]**.

Black chokeberry is a source of many bioactive compounds with a broad spectrum of health-promoting properties. Its ripe and ripe berries are a vibrant source of polyphenolic compounds. Polyphenols are biofactors that determine the high bioactivity of chokeberries, some of the richest sources of polyphenols, which include anthocyanins, proanthocyanidins, flavonols, flavanols, proanthocyanidins, and phenolic acids **[27]**, **[28]**. A total of 27 polyphenolic compounds, comprising seven anthocyanins, 11 flavonols, five phenolic acids, three flavan-3-ols, and one flavanone, were identified in the fruits **[29]**. The highest content of total polyphenols (up to 20 g/100 g dry weight), procyanidins (10-15 g/100 g dry weight), and flavonoids (7-11 g/100 g dry weight), as well as the highest antioxidant activity (up to 100 mmol Trolox/100 g dry weight), was observed in unripe fruits. The content of procyanidins increased at later stages of ripening **[30]**. Proanthocyanidins contribute the most to the antioxidant activity of black chokeberry, being the most potent antimicrobial compound in these fruits **[31]**. Chokeberry fruit stands out as a promising food component due to its exceptionally high levels of antioxidants **[32]**, **[33]**.

It should also be emphasised that berries are rich in biologically active components such as polyphenolic compounds, vitamins (vitamin C and vitamin E), mineral elements (potassium, calcium, and magnesium), carotenoids, pectins, organic acids, and carbohydrates, which are present in smaller quantities **[34]**.

The overall content of key ingredients, polyphenolic compounds, influences many well-documented effects of chokeberry, such as antioxidant, anti-inflammatory, hypotensive, antiviral, anti-aggregatory, anti-diabetic, and anti-atherosclerotic activities, respectively **[35]**. It is possible to classify black chokeberry as a natural medicine. Chokeberry has positive effects in treating cardiovascular and gastrointestinal diseases due to its high antioxidant activity **[36]**. It should be noted that consuming chokeberry products may prevent oxidative-antioxidant imbalance induced by cadmium **[37]**, **[38]**. Black chokeberry can potentially inhibit the development of various types of cancers, including leukaemia, breast and intestinal cancer, and cancer stem cells **[39]**, **[40]**.

Wild plants like rosehip, sea buckthorn, hawthorn and chokeberry contain a diverse set of biologically active substances, including natural antioxidants and other valuable micro-ingredients, which have high antioxidant activity, which gives reason to evaluate them as promising ingredients of food products that can increase the nutritional value and expand the range of healthy food products.

Depending on growing conditions and other factors, more scientific information is needed regarding wild-harvested raw materials' chemical composition and functional-technological properties. Therefore, research on local wild plants' quality, chemical composition, and safety is relevant and in demand. This research aims to expand the raw material base and explore its application in producing functional dry breakfasts (such as crispbreads, snacks, slices, and chips).

Scientific Hypothesis

Extracts extend the raw material base and could be applied to the technology of functional breakfast cereals, particularly bread.

MATERIAL AND METHODOLOGY

Samples

The following wild plants of Kazakhstan have been selected for experimental research: Hawthorn fruit (*Crataegus laevigata*), rosehip fruit (*Rose canina* L. variety), sea buckthorn fruit (*Hippophae rhamnoides* - Altai variety), and black chokeberry fruit (*Aronia melanocarpa*). Extracts are products obtained from their processing (Figure 1).

Hawthorn fruit (*Crataegus laevigata*)	Rosehip fruit (Rose *canina* L. variety)	Sea buckthorn fruit (*Hippophae rhamnoides* - Altai variety)	Black chokeberry fruit (*Aronia melanocarpa*)

Figure 1 Photos of wild plant fruit samples for experimental research.

Raw materials (rose hips, sea buckthorn, black chokeberry, hawthorn) were purchased for experimental studies in a research project. Wild plants (rosehip, sea buckthorn, mountain ash, hawthorn) were collected according to norms approved by local maslikhats, ensuring the preservation of their populations, communities, and growth habitats.

The addition of concentrate from wild fruits (rosehip, sea buckthorn, chokeberry, hawthorn) in the recipe of grain bread carried out by the technical regulation of the Customs Union “Safety requirements for food additives, flavourings and technological auxiliaries” (TR CU 029/2012).

Chemicals

All reagents were of analytical grade and purchased from Laborfarm (Kazakhstan)and Sigma Aldrich (USA).

Animals and biological material

This research did not use animal or biological materials.

Instruments

Obtaining processing products—extracts and concentrates. Extracts from hawthorn, sea buckthorn, rosehip, and black chokeberry fruits were obtained by ultrasonic method. The obtained extracts were concentrated by vacuum evaporation using the IKA RV-10 apparatus.

Ultrasonic extraction (ultrasonic extraction) extracts bioactive compounds from different sources, including plants, fruits and vegetables, by applying ultrasonic waves to the extraction medium. The mechanism of ultrasonic extraction involves the generation of acoustic cavitation, which creates microbubbles in the extraction medium. These microbubbles then collapse, creating shock waves and micro-jets that increase the mass transfer between the sample and solvent, resulting in increased extraction efficiency. Ultrasonic extraction can use extraction methods, including solid-liquid extraction, liquid-liquid extraction, and supercritical fluid extraction.

Laboratory Methods

Determination of quality indicators of plant raw materials was carried out according to the following methods: protein content by the Kjeldahl method, carbohydrate content - by the permanganatometric method, mass fraction of fat - by the Soxhlet method, the content of organic acids - according to GOST 32771-2014, dietary fibres - according to GOST 34844-2022, mass fraction of ash - according to GOST 25555.4-91, the content of vitamin A - according to GOST R 54635-2011, vitamin B5 - according to GOST 32040-2012, vitamin C - according to GOST 24556-89, vitamin E - according to GOST EN 12822-2014, β-carotene - according to GOST EN 12823-2-2014, the content of minerals Mn, Cu, Si, Mo, K, Fe, Zn was determined according to GOST 56372-2015, Se - according to GOST 31707-2012.

The colourimetric method determined the content of heavy metals (cadmium, lead, arsenic, mercury) according to GOST 26927-86.

Aflatoxin B_1 content1 was determined by GOST 33780-2016.

The content of pesticides (α, β и γ-HCH, DDT and its metabolites, heptachlor) was determined by gas-liquid chromatography according to GOST 32689.2-2014.

The quantity of mesophilic aerobic and facultative anaerobic microorganisms was determined according to GOST 10444.15-94. Determination of the number of bacteria in the Escherichia coli group (coliform bacteria) was carried out according to GOST 31747-2012.

Description of the Experiment

The research aims to justify the choice (rosehip, sea buckthorn, hawthorn, mountain ash) based on the study of quality, chemical composition, and safety. It also aims to expand the raw material base and the possibility of using them in the technology of functional breakfast cereals and exceptionally crisp bread.

The following tasks were set to attain the intended aims:

- to substantiate the choice of wild plants of Kazakhstan (rosehip, sea buckthorn, hawthorn, black chokeberry) based on the study of quality and chemical composition;
- to obtain products by processing wild-growing raw materials, providing minimal losses of biologically active substances;
- to carry out a comprehensive assessment of quality (physicochemical parameters, food and biological value, safety indicators) of wild plants of Kazakhstan, extracts and concentrates from them;
- to develop the technology of crisp bread using products that process wild-growing raw materials.

Number of samples analyzed: We analyzed three crisp bread samples.

Number of repeated analyses: All tests were performed in triplicate.

Number of experiment replications: Experiments were carried out in two repetitions

Design of the experiment:

At the beginning of the experiment, work was carried out to prepare fruits of rosehip (variety *Rose Canina* L.), sea buckthorn (variety *Altai*), hawthorn (*Crataeguslaevigata*), and black mountain ash for laboratory analysis. The content of proteins, fats, carbohydrates, organic acids, dietary fibre, vitamins and minerals was determined in the fruits. Subsequently, extracts and concentrates from the fruits were obtained, and a regression model was constructed to evaluate the degree and nature of the relationship between the yield of extractive substances from hawthorn fruits and the effects; the qualitative characteristics of extracts and concentrates were determined. The technology of grain bread by extrusion method was developed, the recipe of which includes whole grains, groats, flavouring additives, and concentrate from wild fruits (hawthorn, rosehip, sea buckthorn and mountain ash).

Statistical Analysis

The experimental data were processed using STATISTICA 13 (TIBCO Software, Palo Alto, CA, USA) and Microsoft Excel 2019 (Microsoft, Lemoyne Township, PA, USA) application programmes.

A General Discriminant Analysis (GDA) model was applied in the mathematical processing of the research experiment analysis, specifically the hypothesis decomposition - Sigma-constrained parameterization. The Sigma-constrained model uses limited sigma-coding to represent the effects of categorical predictor variables in general and generalized linear models. In this method, discriminant functions are considered as a general multidimensional linear model, where the categorical dependent variable (extract yield, %) is represented by vectors with codes indicating different groups (such as high, medium, and low extract yield).

In the GDA method, these values are encoded as vectors (1,0,0), (0,1,0), (0,0,1). Independent quantitative predictor variables used include: the amount of extractant and the duration of extraction.

RESULTS AND DISCUSSION

Determination of the quality of wild plants

The chemical composition of wild fruits depends on genetic and ecological factors. Water composition, soil structure, the range of mineral substances present, the diversity of microorganism species, and climatic conditions condition the latter. Therefore, indicators of chemical composition are not absolute but can serve as a source of preliminary information for researchers working on creating functional food products **[41]**, **[42]**.

This research established the scatter of values in the chemical composition of mountain ash fruits depending on the harvest and variety of cultivars **[43]**.

The fruits of Crataegus oxyacantha L. (prickly hawthorn) have been studied. They collected in areas with low anthropogenic load (landscape-recreational zones). It found that under minimal exposure to factors of anthropogenic origin, C. oxyacantha fruits can accumulate phenolic compounds (up to 15.9 mg/g), leucoanthocyanins (up to 1.5 mg/g), tannins (up to 6.5 mg/g), catechins (up to 4.1 mg/g), flavonoids (up to 6. 0 mg/g), fructose (up to 14.1%), pectin substances (up to 11.6%), organic acids (1.45%), ascorbic acid (up to 49.3 mg%,), macronutrient calcium (up to 12.12 mg/g), trace element zinc (up to 39.12 mg/kg), have higher antioxidant activity (up to 9.7 mg/g) **[44]**.

Scientific research on the chemical composition of rose hips from the genus Rosa L. has shown that rosehip biomass has potential as a source of biologically active substances. It has been established that rosehips contain vitamins such as C, P, K, and B1 and organic acids, pectin, polysaccharides, tannins, saponins, amino acids, and macro- and microelements **[45]**.

We have studied the quality of local wild plants: rosehip (Rose CaninaL. variety), sea buckthorn (Altai variety), hawthorn (Crataegus laevigata), and black chokeberry. Data on the content of the leading food substances in wild fruits are shown in Table 1.

Table 1 Quality parameters of fruits of wild plants.

Parameter	Hawthorn berries	Rosehip berries	Sea buckthorn berries	Black chokeberry berries
		Physico-chemical parameters		
Protein (g)	1.5±0.02	4.0±0.2	3.2±0.1	1.85±0.02
Fats (g)	1.85±0.02	1.53±0.02	4.7±0.2	2.46±0.05
Carbohydrates (g)	11.57±0.06	13.46±0.8	1.05±0.2	12.75±0.7
Organic acids (g)	0.29±0.8	2.81±0.05	1.8±0.05	1.98±0.02
Dietary fibre (g)	7.2±0.3	12.28±0.7	2.24±0.05	4.56±0.02
Ash (g)	2.01±0.5	3.02±0.1	1.01±0.02	0.91±0.8
		Vitamins		
A (mg)	-	0.411	0.279	1.708
B_5 (mg)	-	0.91	0.14	-
C (mg)	27.8	578.01	285.05	86.2
E (mg)	7.8	1.8	3.18	1.1
K(mg)	-	0.023	-	-
β-carotene (mg)	9.27	2.7	2.13	6.5
		Minerals		
Mn (mg)	-	0.97	0.47	-
Cu (mg)	-	0.127	0.31	-
Si (mg)	-	-	5.21	-
Mo (mg)	-	-	0.009	-
K (mg)	14.72	26.18	197.18	190.12
Fe (mg)	0.05	1.7	1.14	5.6
Zn (mg)	0.08	0.23	0.004	-

Note: content in 100g.

The Table 1 shows the content of vitamin C in hawthorn fruit: 27.8 mg; rosehip fruit: 578.01 mg; sea buckthorn fruit: 285.05 mg; and black chokeberry fruit: 86.2 mg per 100 g of product. The content of vitamin E is 7.8; 1.8; 3.18, and 1.1 mg; β-carotene: 9.27; 2.7; 2.13, and 6.5 mg; and dietary fibre: 7.2; 12.28; 2.24, and 4.56 g, respectively.

Plants are a significant source of several minerals in an easily digestible form. Cobalt, copper, iron and manganese stimulate natural immunity factors. The combined presence of copper, cobalt and chromium provides P-vitamin activity. They also contribute to the accumulation of flavonoids in the fruit. Potassium maintains water-electrolyte balance and osmotic pressure in the cell **[46]**. Table 1 shows that the potassium content of hawthorn fruit is 14.72 mg, rosehip fruit - 26.18 mg, sea buckthorn fruit - 197.18 mg, and black rowan12 mg per 100 g of product. The iron content is respectively 0.05; 1.7; 1.14, and 5.6 mg, Zn - 0.08; 0.23; 0.004 and 0 mg, etc.

Preparation of extract and concentrate from wild plants fruits

In recent years, ultrasonic extraction has attracted attention due to its ability to increase extraction efficiency, reduce extraction time, and minimise the use of solvents, making this method environmentally friendly and cost-effective. Researchers often focus on extracting phenolic compounds due to their highly diverse pharmacological activity. Recently, ultrasound extraction has gained attention due to its ability to enhance extraction efficiency, reduce extraction time, and minimise solvent usage, making this method environmentally friendly and cost-effective. Researchers often focus on extracting phenolic compounds and antioxidant activity due to their highly diverse pharmacological activities **[47]**, **[48]**. Additionally, recent studies indicate a direct correlation between the antioxidant activity of various plant extracts and their anti-cancer **[49]**, anti-diabetic **[50]**, **[51]**, and antibacterial **[52]** activities.

According to work, UAE was the more effective method to extract the total phenolics (54.4 mg GAE/g), with high antioxidant activity and a 33% time savings compared with MAE **[53]**.

The extraction process of plant material is influenced by several factors that must be considered when selecting extraction conditions: anatomical structure, nature or degree of grinding of plant material, concentration difference, temperature regime and duration of extraction, viscosity and nature of extractant, surfactants and hydrodynamic layer of plant material. Some authors found the influence of parameters such as the nature of the solvent, solvent volume, temperature and time **[54]**. It was proved that the applied techniques allowed for a reduction in solvent consumption and extraction time, and the extraction yield of analyses was equal to or to some higher extent than that of traditional techniques.

In studying the effects of ultrasound extraction parameters on yield and composition, as well as their influence on the antioxidant, anticancer, and antimicrobial properties of phenolic extracts, it was found that higher extraction temperatures above 50°C destroy polyphenols in the extracts, lower frequencies in the ultrasound power range below 40 kHz are most effective; the yield of polyphenols generally increases with increasing power, but there is a threshold beyond which no significant increase is observed; higher ultrasound power leads to the formation of free hydroxyl radicals, which destroy polyphenols, especially in the presence of high water content **[55]**.

The effect of process variables such as extraction temperature (30–50°C), power of ultrasound (20–40 W), extraction time (10–45 min) and solid-liquid ratio (1:10–1:20 g/ml) is studied. Multiple regression analysis was done on the experimental data to develop second-order polynomial models with a high coefficient of determination value ($R^2 > 0.99$). The optimal conditions were determined based on both individual and combinations of all process variables (extraction temperature of 50°C, ultrasound power of 20 W, extraction time of 45 min and solid-liquid ratio of 1:18.6 g/ml) **[56]**. Besides flavonoids, phenolic acids in sea buckthorn are noteworthy. It has been reported that gallic acid exhibits a broad spectrum of biological activity **[57]**, **[58]**.

The results of the biochemical analyses of the extracts showed that extraction by double infusion, given optimal conditions such as ethanol concentration in the extractant, raw material-to-extractant ratio, and the best infusion time selected, ensured an average 55-60% yield of nutrients from the studied fruit raw materials **[59]**.

The optimal composition of extracting mixtures, including the alcohol-to-water ratio of 1:1 by volume and the raw material-to-extractant ratio of 1:7 by mass, was established along with the ideal extraction duration. The fruits of rosehip (*Rosae*), hawthorn (*Crataegus*) and common rowan (*Sorbus aucuparia*) have been used as plant raw materials for obtaining extracts **[60]**.

The sequence and parameters of technological operations of pectin concentrate productions from pumpkin squeeze of the "Karina" variety have been substantiated. As a result of research, the secure storage period of pectin-containing concentrates at a temperature of 25°C is 7 months, and at a temperature of 80°C for 10 months **[61]**.

The technological process of obtaining alcoholic extract and concentrate from fruits consisted of the following stages: preparation of plant raw materials and extractant, grinding and sieving, extraction in an ultrasonic extractor, filtration, purification, concentration, pasteurisation and packaging.

Preparation of raw materials and extractant involves several key steps. The following procedures should be carried out at this stage: identifying the raw material and determining its integrity and compliance with established requirements. Different concentrations of ethanol (30%, 40%, 50%, 60%, 70%, and 96%) were employed as extractants to study their impact on extractive yield. Based on the data obtained, the highest extractive yield was achieved with 40% of ethanol. Based on the obtained data, the highest yield of extractive substances from rosehip fruit was achieved using 40% ethyl alcohol as the extractant, with an extraction duration of 30 minutes. For extracts from hawthorn fruit, the highest yield of extractive substances was achieved using 70% ethyl alcohol as the extractant, with an extraction duration of 45 minutes. When extracts from sea buckthorn and mountain ash fruits were obtained, the yield of extractive substances was with 70 % ethyl alcohol for 45 minutes and 30 % ethyl alcohol for 45 minutes, respectively. Therefore, these concentrations were chosen as the main extractant for further experiments.

Grinding and sieving: Rosehip, sea buckthorn, hawthorn, and black rowan fruits were crushed by using a laboratory mill. The resulting intermediate product was passed through a sieve.

Raw materials should be crushed to facilitate mass exchange in the process of extraction of BAS from wild plants. Because under the action of binding surface layers between the particles of raw materials, the extractant increases the surface layer of mass exchange. However, it is essential to consider that excessive grinding of raw materials can result in the inactivation of BAS and the destruction of cell walls, which leads to the flow into the extract of many accompanying substances that contaminate it. The optimal size for grinding raw materials is as follows: up to 3-5 mm for leaves, flowers, and herbs; up to 1-3 mm for roots, stems, and bark; up to 0.3-0.5 mm for fruits and seeds.

Extraction. Prepared raw materials were placed in a flask, and ethanol was added using a funnel. The obtained solutions were left to wet for 60 minutes. Sample extraction was conducted under the following conditions: ultrasonic wave frequency of 40 kHz, extraction time of 30 minutes, and a temperature of 50ºC. Subsequently, the flask was securely sealed with cork and immersed in the ultrasonic bath.

Filtration. The filtration was held using filter paper and a glass funnel and continued for 60 minutes.

Purification - is a process that removes unwanted impurities or contaminants from an extract.

The obtained extracts were concentrated by vacuum evaporation using the IKA RV-10 apparatus at 40-500 C and 800 mbar pressure.

Pasteurisation. The obtained products were pasteurised at 75°C for 30 minutes.

Packaging. The extract from the raw material was carefully packed in containers that guarantee safe and effective extract storage.

Figure 2 shows the technological scheme for obtaining alcoholic extract and concentrate from rosehip and black rowan fruits by solvent extraction in an ultrasonic extractor.

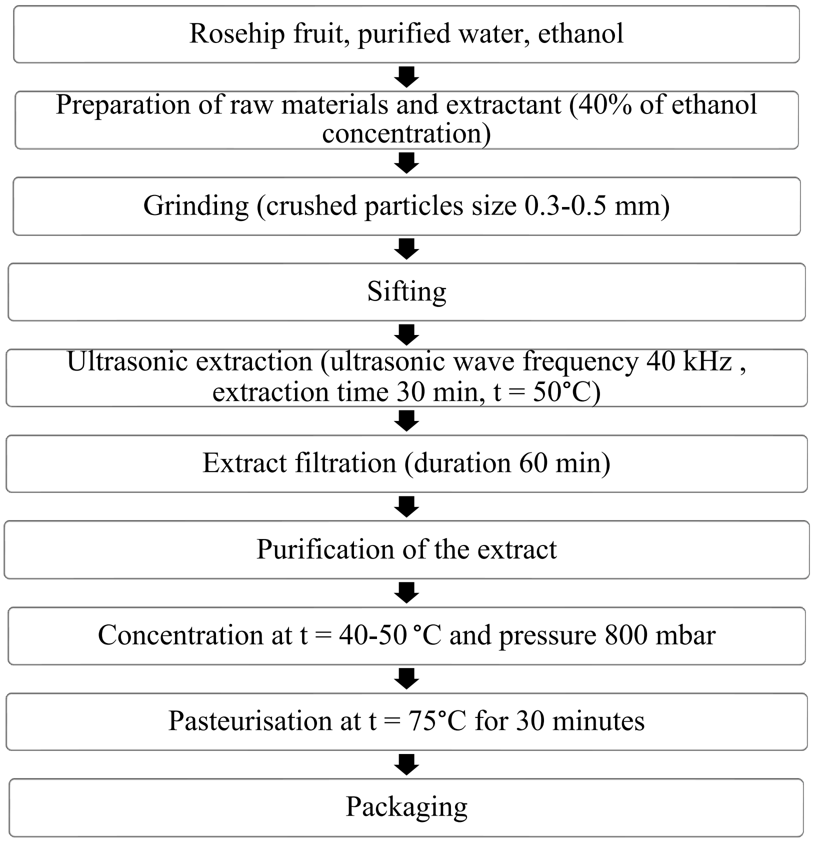

Figure 2 Technological scheme for obtaining extracts and concentrates from rosehip fruit.

To study the degree and nature of the relationship between the extract yield from hawthorn berries and the effects, a regression model was constructed to determine the influence of independent variables (amount of extractant and extraction duration) on the dependent variable (extract yield, %). Table 2 presents the univariate significance criterion for extractive yield,% (experiment) Sigma-limited parameterisation - Hypothesis decomposition used to assess the degree and nature of the relationship between the response (extractive yield, %) and effects (extractant amount and extraction duration) in the regression model.

Table 2 Results of the experiment.

Effect	Univariate significance criterion for yield, % (experience) Sigma-limited parameterisation Hypothesis decomposition				
	SS	**Freedoms degrees**	**MS**	**F**	**p**
St. member	31547.71	1	31547.71	671227.8	0.00
extractant,%	5099.82	6	849.97	18084.5	0.00
Time, min	205.41	4	51.35	1092.6	0.00
extractant,% time, min	38.28	24	1.59	33.9	0.00
Mistake	3.29	70	0.05		

The Table 2 shows that all the effects are statistically significant as the significance levels of Fisher's p criterion are less than 0.05. The effect "Extractant, %" makes the largest contribution to the overall linear model, as the SS statistic of 5099.82 takes the highest value, followed by the effect "time, min", and the combination of effects "Extractant, %*time, min".

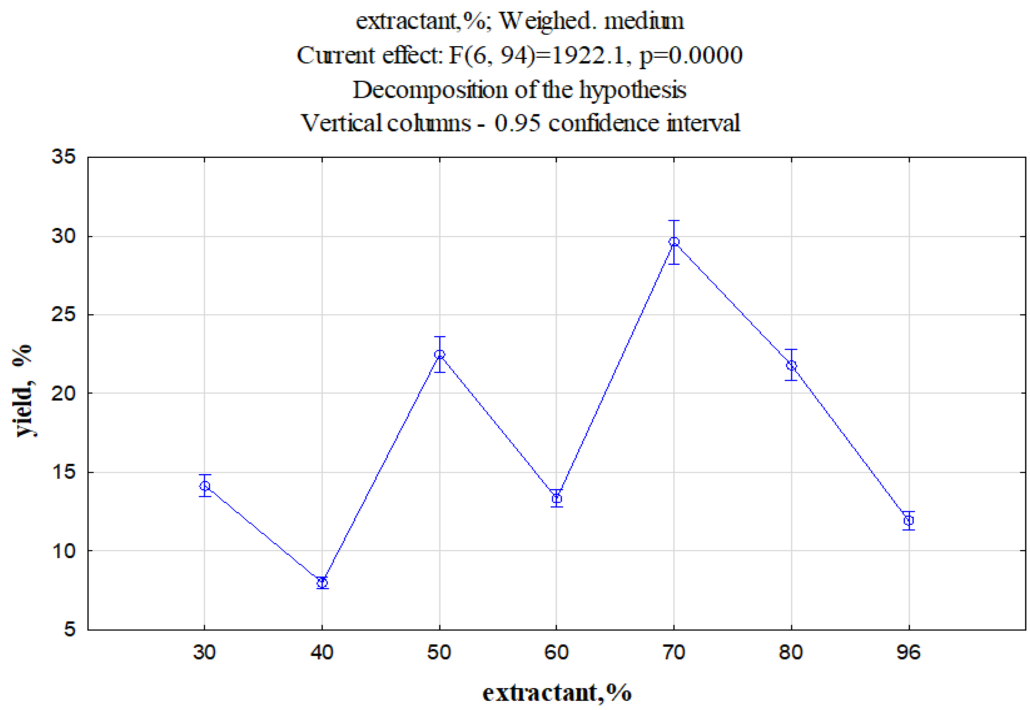

Figure 3 Weighted averages for Y 1 (extractive yield from hawthorn fruit), as a function of the dosage of extractant used.

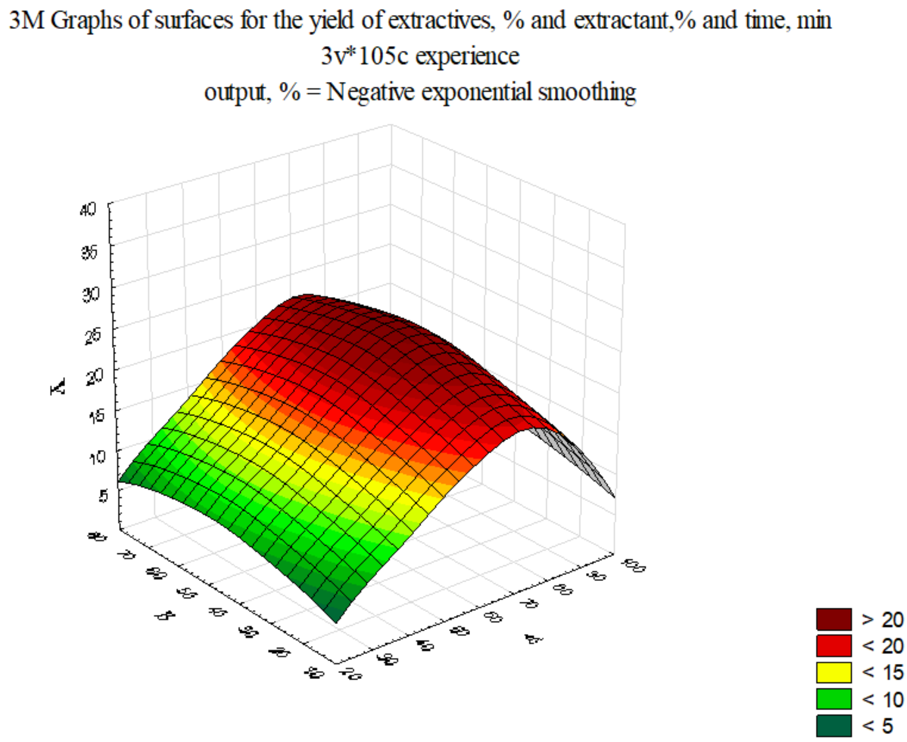

Figure 4 3M surface plot showing the dependence of extractive yield from hawthorn fruit on extractant and extraction duration.

As shown in Figure 4, the highest yield of extractive substances from hawthorn is observed at 70% extractant dosage and 30 minutes of extraction time.

Longest processing and increasing the dosage of extractant are not reasonable, as they hurt the yield of extractive substances and can lead to a significant increase in the cost of the extraction technological process.

A regression model was constructed to evaluate the degree and nature of the relationship between the extractive yield from rosehip fruit and its effects. Table 3 presents the univariate significance criterion for extractive yield, % (experiment). Sigma-limited parameterisation—Hypothesis decomposition was used to assess the degree and nature of the relationship between the response (extractive yield, %) and effects (extractant amount and extraction duration) in the regression model.

Table 3 Results of the experiment.

Effect	**Univariate significance criterion for yield, % (experience) Sigma-limited parameterisation Hypothesis decomposition**				
	SS	**Freedoms degrees**	**MS**	**F**	**p**
St. member	32943.26	1	32943.26	216273.9	0.00
extractant,%	3549.66	6	591.61	3883.9	0.00
Time, min	1333.87	4	333.47	2189.2	0.00
extractant,% time, min	149.85	24	6.24	41.0	0.00
Mistake	10.66	70	0.15		

The table shows that all the effects are statistically significant as the significance levels of Fisher's p criterion are less than, 0.05. The effect "Extractant, %" contributes the most to the overall linear model, as the SS statistic of 3549.66 takes the highest value, followed by the effect "time, min", and the combination of effects "Extractant, %*time, min".

Figure 5 shows the weighted averages for Y_1 (extractive yield from rosehip fruit), depending on the dosage of extractant used.

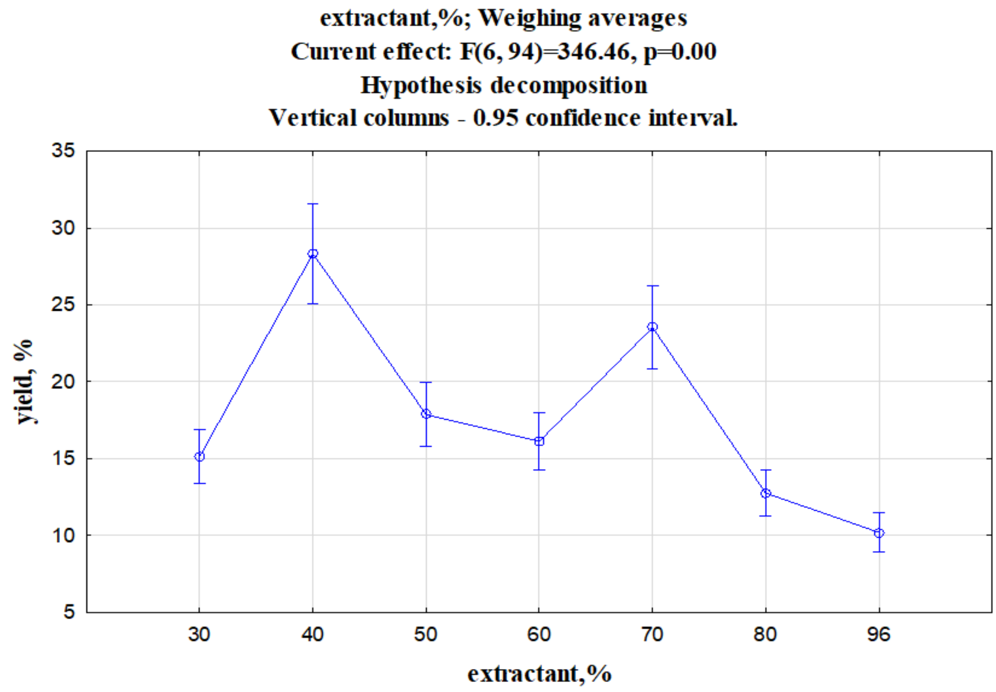

Figure 5 Weighted averages for Y 1 (extractive yield from rosehip fruit), depending on the dosage of extractant used.

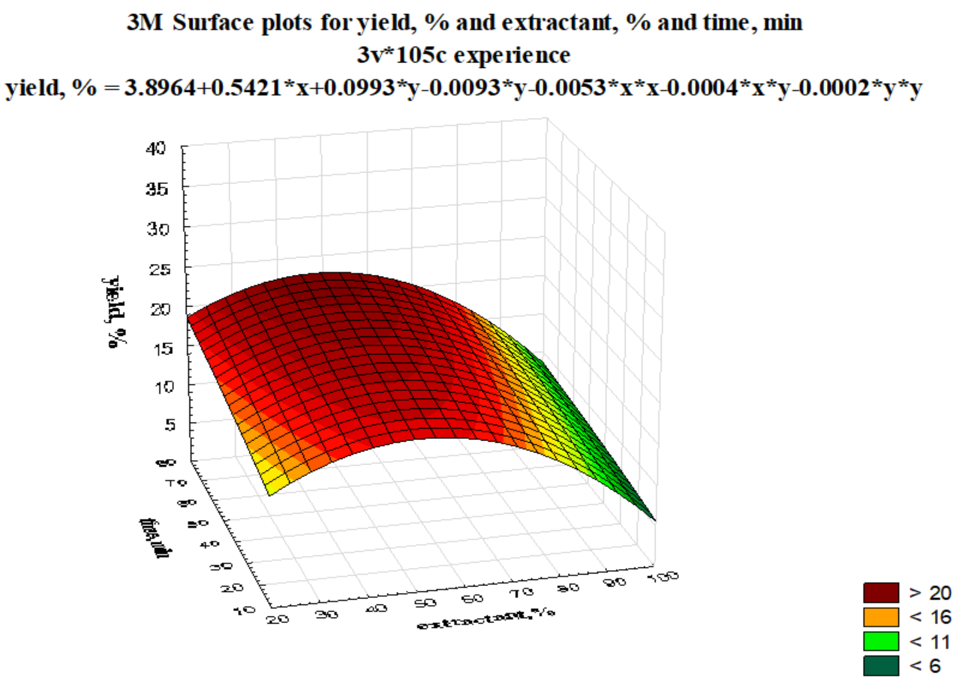

Figure 6 3M surface plot showing the dependence of extractive yield from rosehip fruit on extractant and extraction duration.

As can be seen from Figure 6, the highest yield of extractive substances from rosehip is observed at 40% of the extractant dosage at 45 minutes of extraction time. Longer processing and increasing the dosage of extractant are not reasonable, as they hurt the yield of extractive substances and can lead to a significant increase in the cost of the technological process of extraction.

Quality and safety of obtained extracts and concentrate

A comprehensive evaluation of extracts and concentrates from hawthorn, sea buckthorn, rosehip, and black rowan fruits was carried out, which included determining physicochemical parameters, nutritional value, and safety parameters. The data obtained during the determination are summarised in Table 4 and figures 6, 7, 8, and 9. These results provide a crucial insight into the chemical composition of the extracts and concentrates, highlighting the presence of various nutritional substances that may be relevant for numerous research applications.

Table 4 Chemical composition of extracts and concentrates from fruits of wild plants.

Parameter	hawthorn extract	hawthorn concentrate	rosehip extract	rosehip concentrate	sea buckthorn extract	sea buckthorn concentrate	black rowan extract	black rowan concentrate
				Physico-chemical *parameters*				
Protein (g)	0.87	1.28	0.98	2.11	0.58	1.12	0.68	1.31
Fats (g)	-	-	-	-	0.8	1.2	-	-
Carbohydrates (g)	2.98	5.01	2.76	4.79	0.36	0.62	2.06	3.77
Organic acids (g)	0.48	0.59	4.11	5.08	2.91	3.59	3.31	4.21
Dietary fibre (g)	11.08	14.51	20.9	25.99	4.08	5.51	6.98	8.91
Antioxidants (mg)	24.12	31.98	19.32	26.11	19.08	26.02	21.02	29.21
Ash (g)	3.14	4.08	4.89	5.94	1.58	2.17	1.48	2.01
				Vitamins				
A (mg)	-	-	0.748	0.98	0.72	0.91	2.72	3.99
B_5 (mg)	-	-	1.37	1.81	0.21	0.31	-	-
C (mg)	47.84	62.19	811.8	1101.3	518.8	640.9	128.8	160.5
E (mg)	12.08	15.17	2.12	2.91	5.02	6.48	1.52	2.09
K (mg)	-	-	0.035	0.048	-	-	-	-
				Minerals				
Mn (mg)	-	-	1.05	1.41	0.65	0.82	-	-
Cu (mg)	-	-	0.21	0.29	0.39	0.52	-	-
Si (mg)	-	-	-	-	8.91	11.75	-	-
Mo (mg)	-	-	-	-	0.014	0.02	-	-
K (mg)	22.98	29.41	35.12	47.18	298.5	370.2	248.5	311.25
Fe (mg)	0.09	0.12	2.29	3.01	2.02	2.69	10.09	13.41
Zn (mg)	0.13	0.16	0.29	0.36	0.04	0.09	-	-
Se (mg)	0.012	0.018	-	-	-	-	-	-

Note: content in 100g of extract and concentrate.

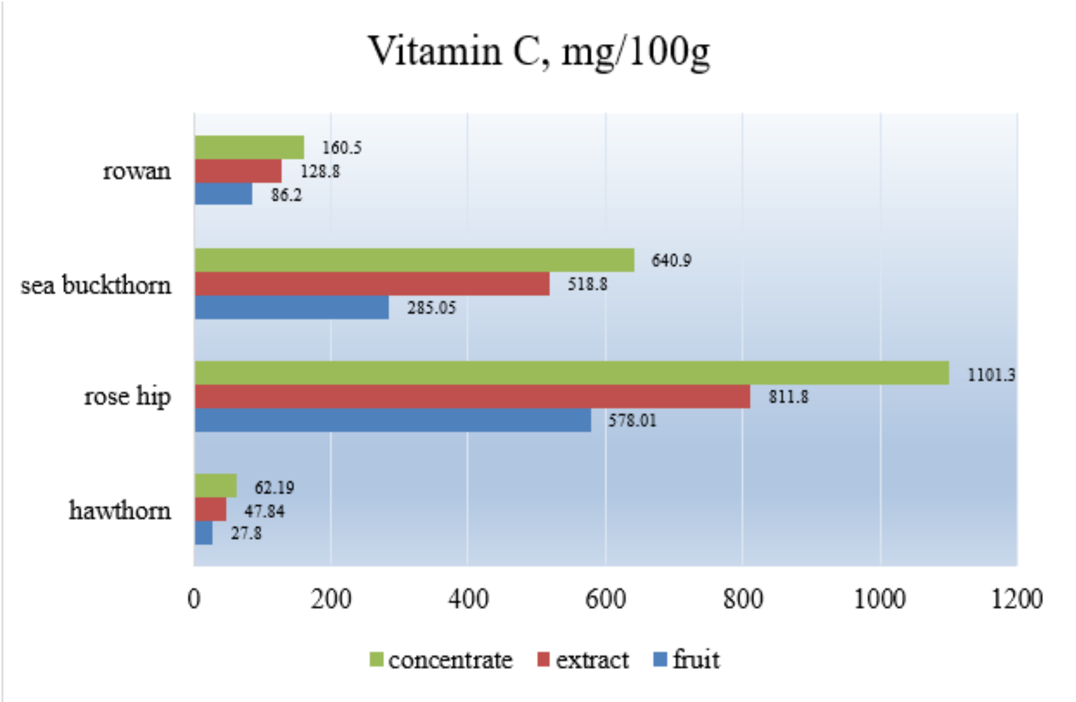

Figure 7 Vitamin C content in fruits and their processed products.

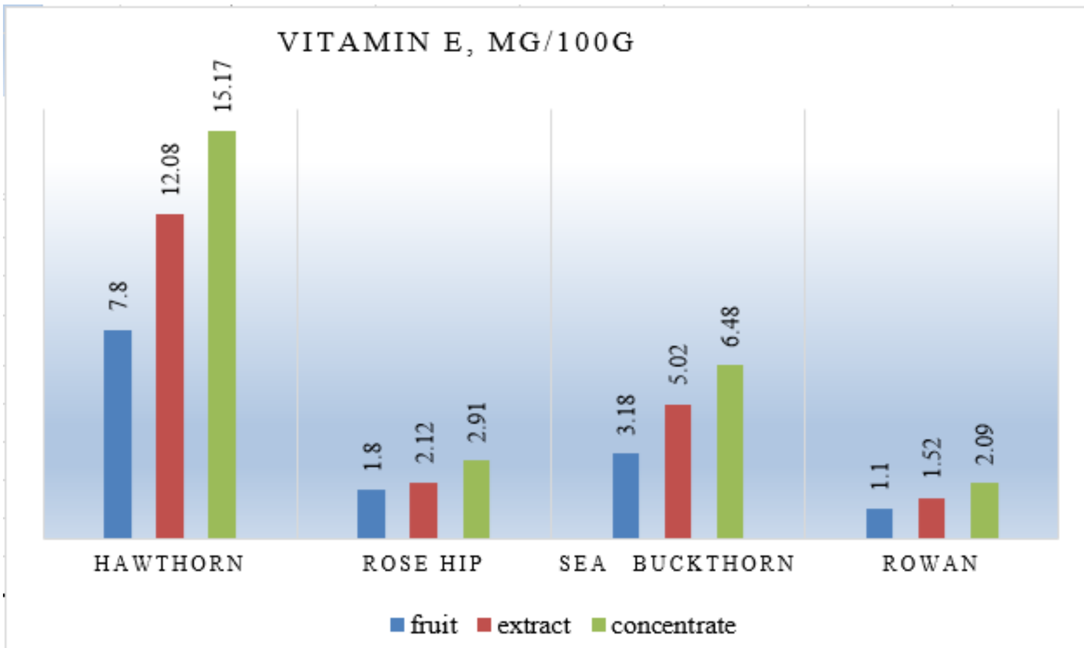

Figure 8 Vitamin E content in fruits and their processed products.

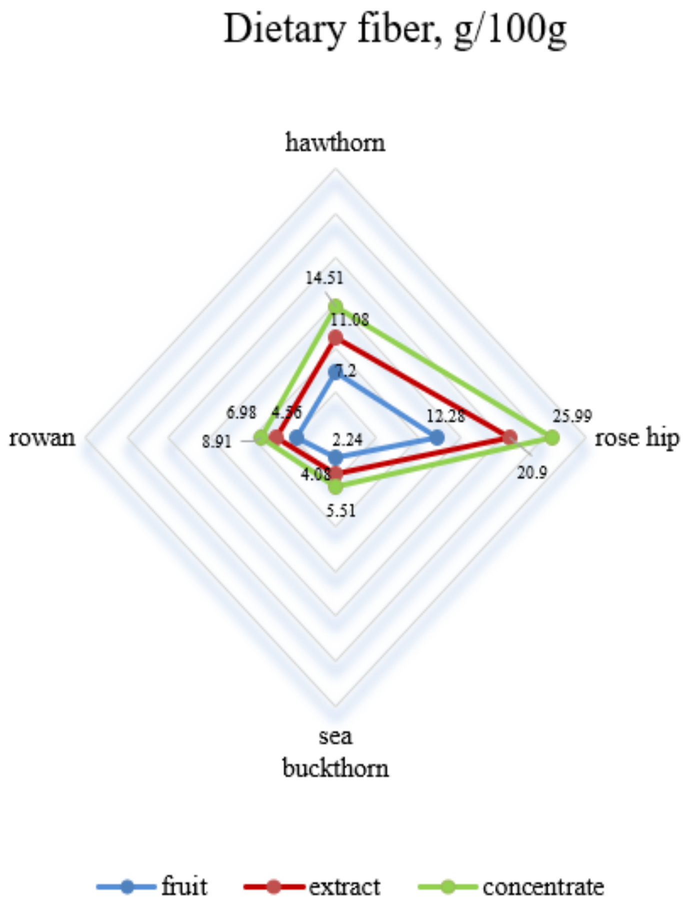

Figure 9 Dietary fibre content in fruits and their processed products.

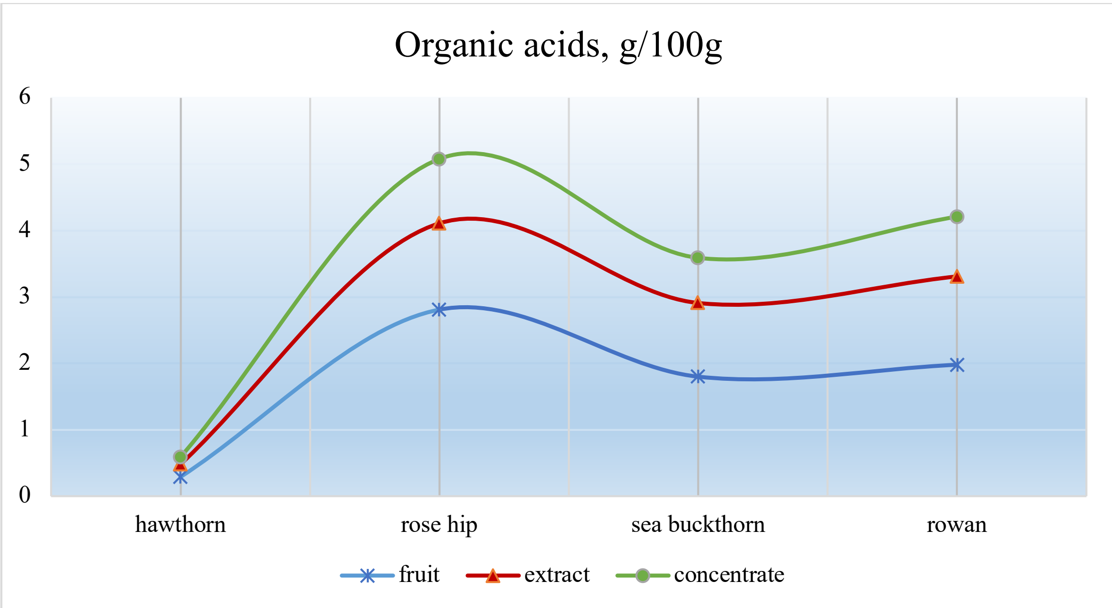

Figure 10 Organic acid content in fruits and their processed products.

From Tables 1, 4, and Figures 7 and 8, it can be seen that the vitamin C content in hawthorn berries was 27.8 mg, whereas in the extract, it was 47.84 mg, and in the concentrate, it was 62.19 mg. For rosehip, the vitamin C content in the fruits, extracts, and concentrates was 578.01 mg, 811.8 mg, and 1101.3 mg, respectively. The vitamin C content in the fruits, extracts, and concentrates for sea buckthorn was 285.05 mg, 518.8 mg, and 640.9 mg, respectively. For black chokeberry, the vitamin C content in the fruits, extracts, and concentrates was 86.2 mg, 128.8 mg, and 160.5 mg, respectively. A similar increase is observed for vitamin E content.

In addition to proteins, fats, carbohydrates, and vitamins, essential components of food include mineral substances. Each mineral element performs a specific function in the body. A comparative analysis of Tables 1 and 4 showed a trend of increased mineral content in extracts and concentrates compared to the fruits.

As shown in Figures 9 and 10, the content of dietary fibre and organic acids was higher in concentrates than in fruits.

We will use concentrates of hawthorn, rosehip, sea buckthorn, and black chokeberry in the future production of snacks, bread, and slices. Therefore, we researched the safety of concentrates from wild plants. Table 5 shows the safety parameters of concentrates from wild fruits.

Table 5 Safety parameters of concentrates from fruits of wild plants.

Parameter	Hawthorn concentrate	Rosehip concentrate	Sea buckthorn concentrate	Black chokeberry concentrate
		Microbiological parameters		
QMAFAnM,CFU/cm^3 (g), notmore	2×10^1	2×10^1	1×10^1	1×10^1
E. coli group g, cm3 in 1.0 g of product	ND	ND	ND	ND
Heavy metals, mg/kg:				
- lead	0.0017±0.0004	0.0027±0.0006	0.0007±0.0003	0.0011±0.0004
- cadmium	0.0009±0.0002	0.0007±0.0001	0.0012±0.0004	0.0002±0.0001
- mercury	ND	ND	ND	ND
- arsenic	ND	ND	ND	ND
		Pesticides, mg/kg		
HCH ($\alpha-, \beta-, \gamma - isomers$)	ND	ND	ND	ND
- Heptachlor	ND	ND	ND	ND
- DDT and its metabolites	ND	ND	ND	ND
		Mycotoxins, mg/kg		
- aflatoxin B_1	ND	ND	ND	ND

The research results on the safety of hawthorn, rosehip, sea buckthorn and black chokeberry concentrates showed their compliance with the requirements of the Technical Regulations of the Customs Union 021/2011 and confirmed their safety.

Development of technology production of crispbreads by extrusion method

From both scientific and technological perspectives, significant efforts are focused on developing new alternative and adapted technological processes for food production. These processes aim to meet consumer sensory and functional requirements while simultaneously addressing the needs of producers for value-added food products from both technological and economic standpoints **[62]**.

Extrusion products have high consumer appeal, good digestibility, low microbial contamination, and increased oxidation resistance, making them suitable for various of populations.

Extrusion is considered one of the most suitable methods for bread production, as the formation of starch rather than gluten causes the formation of textural and consumer properties in extruded products such as breakfast cereals, snacks, and crisp bread.

The primary purpose of the study was the possibility of introducing concentrate from wild plants (*rosehip, hawthorn, mountain ash, sea buckthorn*) in the production of new breads and the influence of its dosage on the technological and consumer properties of finished products.

A technology for cereal crisp bread has been developed. The recipe includes groats, flavouring additives, and concentrate from wild fruits (*hawthorn, rosehip, sea buckthorn and black chokeberry*). The technological process begins with grain mixture preparation by cleaning it of impurities and moistening it with water. Moisture of raw materials brought to 18 - 25%. The prepared grain mixture is fed to the loading hopper, then to the dosing compartment and then to the sintering chamber, which has a rectangular shape (this is the reason for the appearance of crisp bread). The created temperature difference causes the grain and groats to explode due to the instantaneous boiling of the moisture in its composition. As a result, the groats become voluminous and porous and fill the entire space of the chamber. The machine was used to produce grain crisp bread that we purchased for the project (Figure 11).

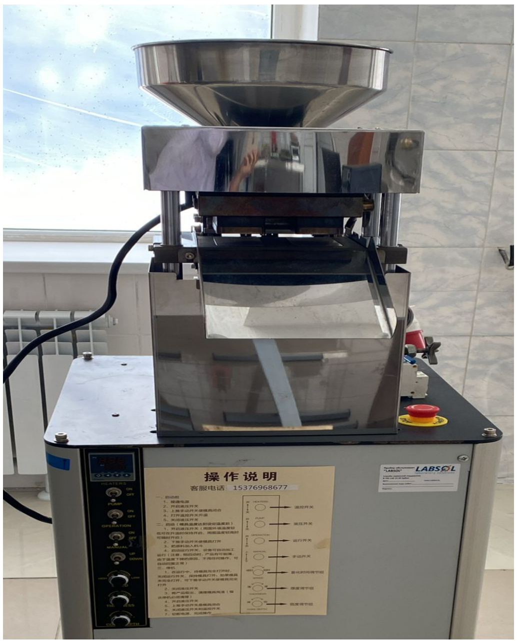

Figure 11 - Machine for the production of grain crisp bread

Crisp bread had a regular shape, and the thickness of the tiles was uniform around the perimeter, without dents, with even edges. The surface of the bread was slightly rough, without bloating, cracks and stains. The colour of the products is uniform light cream with dotted flecks of dark colour. Products are brittle, not stiff, easily breakable with a crunch, well loosened, and porous with a uniform structure. Taste and odour correspond to used raw materials, with the extruded product exhibiting its inherent smell without any extraneous taste or odour.

Thus, developing technologies for grain crisp bread using extracts, contributing to reducing human body weight, is relevant and aimed at improving public health.

CONCLUSION

The analysis of scientific publications on the researched topic has shown that wild plants contain a different set of biologically active substances, and our research confirms this. The study of the chemical composition of fruits of wild plants of Kazakhstan - rose hips (variety Rose Canina L), sea buckthorn (variety Altai), hawthorn (Crataeguslaevigata), black chokeberry has established that they contain a diverse set of biologically active substances, which gives reason to evaluate them as promising components of food products that can increase the nutritional value and expand the range of healthy food products. It has been established that the vitamin C content in hawthorn fruits is 27.8 mg, in rosehip fruits is 578.01 mg, in sea buckthorn fruits is 285.05 mg, and in black chokeberry fruits is 86.2 mg per 100 g of the product. The vitamin E content is 7.8 mg, 1.8 mg, 3.18 mg, and 1.1 mg, respectively. The dietary fibre content is 7.2 g, 12.28 g, 2.24 g, and 4.56 g; potassium content is 14.72 mg, 26.18 mg, 197.18 mg, and 190.12 mg; iron content is 0.05 mg, 1.7 mg, 1.14 mg, and 5.6 mg, Zn content is 0.08 mg, 0.23 mg, 0.004 mg, and 0 mg, respectively, and so on. The technological scheme has been developed to obtain extracts and concentrates from fruits of wild-growing raw materials. The modes of extraction of samples were proposed: ultrasonic wave frequency 40 kHz, extraction time 30 minutes, temperature 500C, and *concentration of* the extracts obtained were carried out by vacuum evaporation, using IKA RV-10 apparatus at 40-50^{0}C and pressure 800 mbar. Compared to other extraction methods, ultrasonic extraction has gained attention for its mild temperature conditions, ability to increase extraction efficiency, shorter extraction times, and reduced solvent use, making it an environmentally friendly and cost-effective method.

The mathematical analysis of the research experiment was conducted using hypothesis decomposition - Sigma-restricted parameterisation.

Based on the analysis of the chemical composition of extracts and concentrates from hawthorn, sea buckthorn, rosehip, and black chokeberry fruits and comparison with the composition of fruits, it was found that the content of nutritional substances in extracts and concentrates is higher compared to fruits. Thus, the vitamin C content in hawthorn fruits was 27.8 mg, while in the extract, it was 47.84 mg, and in the concentrate – 62.19 mg. The vitamin C content in rosehip fruits, extracts, and concentrates was 578.01 mg, 811.8 mg, and 1101.3 mg, respectively. The vitamin C content in sea buckthorn fruits, extracts, and concentrates was 285.05 mg, 518.8 mg, and 640.9 mg, respectively. The vitamin C content in black chokeberry fruits, extracts, and concentrates was 86.2 mg, 128.8 mg, and 160.5 mg, respectively. A similar increase was observed for the content of vitamin E and other components.

The obtained concentrates meet the requirements of TR CU 021/2011 Technical Regulations of the Customs Union "On the safety of food products" regarding safety parameters. The technology of grain bread by extrusion method has been developed, and the recipe includes groats, flavouring additives, and concentrate from wild fruits (hawthorn, rosehip, sea buckthorn, and chokeberry). Extrusion is one of the most important methods for processing plant raw materials into food products. This process increases the digestibility of many components of plant raw materials and reduces the content of anti-nutritional factors. The extrusion process occurs with high temperatures and moisture levels of raw material. However, high values for these parameters can lead to a decrease in valuable nutrient content. Therefore, scientific research should focus on identifying the optimal extrusion parameters to maintain a balance between the desired properties of the extrudate and the preservation of nutrients.

The subject of extruding plant raw materials for food production is promising but requires additional research.

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