THE REPUBLIC OF AZERBAİJAN

In the law of manuscripts

ABSTRACT

of the dissertation submitted for the degree
of Doctor of Sciences

STUDY OF THE BIOCHEMICAL FOUNDATIONS OF INDUSTRIAL PROCESSING OF WILD FRUITS AND BERRIES OF THE REPUBLIC OF AZERBAİJAN

Field of Study:	3309.01 – "Food Technology"
Scientific Field:	Technical Sciences
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Baku – 2025

The dissertation was carried out at the Department of "Engineering and Applied Sciences" of Azerbaijan State Economic University.

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and degree of development. In the modern world, the environmental situation in our country, as well as in many countries around the world, is quite complex, and because of this, great attention is paid to the issue of healthy nutrition for the population. One of the ways to solve this problem is to expand the range of products made from unconventional types of food raw materials that have a high content of biologically active substances.

The concept of "ecological safety" of food products implies the harmlessness of the raw materials used in their production. The biotechnological potential of wild fruits and berries grown in various administrative regions of Azerbaijan is unique.

Wild fruits and berries grow without the use of agrochemical cultivation methods, are easily accessible, and have a significantly lower cost. Wild raw materials can become an alternative source of valuable food ingredients and biologically active substances.

The list of supplied wild plants includes up to 160 species. Among them, 30 species, including rose hips (in some regions of the country referred to as "dergil," "kushburnu"), hawthorn, medlar, sea buckthorn, barberry, and others (including a number of essential oil-bearing plants), make up the bulk of the supplied raw materials. The products of their secondary metabolism, namely small components of food products and phenolic compounds, which can affect the human body in a wide range of physiological processes, including the activity of vitamin P and antioxidant activity, have particular scientific and practical significance.

According to the FAO/WHO international classification, natural bioproducts in the form of extracts, powders, and pasty substances, as well as traditional food products enriched with biological additives, are included in the category of functional foods.

At the same time, among the numerous sources of literature that discuss the physiological activity of natural substances obtained from wild plants through extraction and drying, there is still no unified approach to the study and systematization of these important substances. Further development of methods for identifying the

ingredient composition of bioproducts and quantitative analysis is needed. The practical use of biologically active natural ingredients is complicated by the fact that natural substances are easily affected by various technological factors, which prevents the use of their true forms in the formulations of functional bioproducts that undergo processing and storage. The development of processing technologies for plant raw materials, including wild fruits and berries, as well as the improvement of existing technologies for their use in the production of natural food ingredients and functional foods, is the subject of theoretical and practical research. In this field, significant contributions have been made by scientists from both local and foreign countries, such as M.Maharramov, X.Fataliyev, V.Mikayilov, K.Asadov, N.Qurbanov, A.Ibrahimov, Z.Hasanov, M.Khalilov, G.Hafizov, V.Petrova, A.Tsinkiladze, A.Djaboiva, G.Magomedov, V.Kolubiev, V.Spirichev, L.Telezhenko, T.Tsykanova, A.Kolesnik and others.

Without diminishing the significance of the research results of the aforementioned scientists and specialists, it should be noted that there is insufficient information on the in-depth study of the biochemical foundations of industrial processing of wild fruits and berries. Thus, the development of innovative industrial technologies for processing wild food raw materials with a wide biological activity in both liquid and dry forms to obtain bioingredients that meet the safety and quality requirements for the production of food additives is an urgent scientific and practical task.

In this context, to assess the effectiveness of the applied technological solutions, it is necessary to conduct experimental studies on the kinetics of the processes that limit the duration of technological operations for the processing and storage of wild fruits and berries.

Thus, the development of scientifically grounded technological processes, taking into account the component indicators and biochemical characteristics of raw materials enriched with biologically active substances from wild fruits and berries for the production of bioingredients and functional foods, is relevant and can make an important contribution to ensuring the food security of the country's population.

Aims and objectives of the study. The aim of the work is to scientifically justify and develop innovative technologies for the production of bioadditives and functional food products enriched with biologically active substances from wild fruit and berry raw materials.

To achieve the stated goal, the following scientific and practical tasks are proposed:

- Study the methods of obtaining and stabilizing biologically active substances from wild raw materials, analyze scientific and technical data on their use in food production technologies, and assess the prospects for their targeted application.
- Justification of biochemical principles for obtaining bioingredients from wild fruits and berries, as well as technological modes for producing natural biologically active substances using low-frequency hydroacoustic cavitation, low-temperature drying, and extraction with supercritical carbon dioxide (carbon dioxide in a supercritical state).
- Analyze the chemical composition of wild raw materials, determine the properties of biologically active substances in the bioproducts obtained from wild raw materials using innovative technological processes and supercritical carbon dioxide.
- Investigate the main qualitative and safety indicators of functional foods and bioingredients, as well as their medical-biological, antioxidant, and nutritional properties.
- Study the kinetic patterns of supercritical CO_2 extraction of seeds, pits, and pulp from sea buckthorn, barberry, rose hips, medlar, and hawthorn, as well as determine the main physicochemical parameters of the obtained plant oils.
- Develop recipe formulations for the production of jelly products and the technological modess for their production.
- Identify pectin substances in the fruits of wild sea buckthorn, medlar, and hawthorn, determine their quality, safety, and technological properties.
- Develop a technology for drying wild fruits and berries at low temperatures for the production of dry bioadditives.
- Develop technologies for the production of semi-finished

products and fillings for confectionery and desserts using bioingredients from wild fruits and berries with high biological potential.

- Prepare regulatory and technical documentation for the production of functional foods from bioingredients of wild fruits and berries for the treatment of various diseases, test them, and implement them into production.
- Conduct marketing research to study the consumer preferences of the residents of Baku, as well as investigate the population's attitude towards products made from wild fruit and berry raw materials.

Research methods. In the course of the dissertation work, general scientific and experimental research methods were applied. Modern and certified laboratory instruments were used to study the characteristics of raw materials, semi-finished products, and finished food products, as well as special physicochemical, biological-microbiological, organoleptic (sensory), and instrumental research methods.

Main provisions to be defended.

- The justification of scientific and practical criteria for organizing industrial production of biologically active additives and food ingredients for healthy food production, based on the results of the first comprehensive biochemical analysis of wild plant fruits such as rose hips, black chokeberry, sea buckthorn, hawthorn, and black cumin, which are extremely important for the human body.
- Biochemical justification and implementation of innovative technologies for the integrated processing of certain fruits and berries growing wild in the territory of the Republic of Azerbaijan.
- The results of the identification, systematization, and quantitative analysis of natural complexes of biologically active substances and pectin polysaccharides in liquid (aqueous) extracts obtained from the studied wild food raw materials, their safety indicators, as well as the results of studying their medical-biological, antimicrobial, and antioxidant properties.
- Biochemical justification of the technology for producing gel-like products and improving their quality based on a scientific approach to the comprehensive assessment of sea buckthorn, black chokeberry, and rose hip fruits, including the study of technological

and commercial characteristics of raw materials, the formation of quality indicators for functional foods, the identification of patterns, and the development of an algorithm to determine criteria for assessing raw materials based on their technological potential.

- The results of the study on the technology for obtaining encapsulated polyphenolic substances from wild rose hip and wild black cumin fruits for food ingredients and their impact on the quality indicators of finished food products during storage.

Scientific novelty of the research. The methodological principles for studying the biotechnological potential of the fruits and berries of perennial wild plants from the Rosaceae, Elaeagnaceae, and Berberidaceae families, widely distributed across various administrative-territorial regions of Azerbaijan, are scientifically justified. The innovative technological stages of processing these plants for obtaining bioadditives and bioingredients using processes such as low-frequency hydroacoustic extraction, low-temperature (sublimation) drying and supercritical CO_2 extraction are also developed.

The biochemical principles of producing biologically active products from raw materials obtained from wild fruits and berries are justified, taking into account their nutritional, taste, and aromatic characteristics, additional effects, and the balanced combination of predominant and accompanying bioingredients.

The composition of pectin substances obtained from raw materials of plants that grow naturally without the use of special and specialized cultivation methods was experimentally determined. The technological schemes for their production were optimized, and the possibilities of industrial processing were evaluated depending on the type of raw material. Empirical relationships were obtained, characterizing the rate and completeness of flavonol removal during extraction processes. The methods of spectral and chromatographic identification of the component composition of bioingredients obtained by extraction from wild raw materials, as well as methods of quantitative analysis, were improved. The systematization of fatty acids in the experimental oils obtained using the CO_2 extraction method was carried out.

It was established that the extraction technology using low-

frequency hydroacoustic cavitation is more effective for extracting natural forms of phenolic compounds. Additionally, the use of supercritical CO_2 extraction technology is more efficient for extracting terpenoid compounds.

The electronic mechanism of the process of neutralizing oxygen-containing free radicals by antioxidants containing natural polyphenolic compounds has been scientifically justified. The antioxidant activity (AOA) values of the studied bioproducts were determined. It was established that the biological products obtained from wild rose hips, black chokeberry, and sea buckthorn possess high antioxidant activity.

The composition of biologically active substances and encapsulated bioingredients based on CO_2 extraction has been developed, along with the technological modes (technological schemes) for their production for food products.

Theoretical and practical significance of the research. Innovative technologies for the production of single-component (mono) and multi-component (poly) bioingredients from the fruits and berries of perennial wild plants of the Rosaceae, Elaeagnaceae, and Berberidaceae families have been developed.

In order to produce a variety of functional food products with a rich nutritional composition, the technological modes for the extraction of pectin substances and flavonoids have been optimized to obtain multifunctional ingredients.

The technology for obtaining multi-component liquid products from wild fruits has been tested and implemented at the production facilities of the Limited Liability Companies (LLC) "MƏRƏNDİ," the Closed Joint-Stock Company (CJSC) "AZNAR," the LLC "AZGRANATA," and the LLC "Biyan Products" (Appendix 4 - 23). For the production of the product "Jam from Wild Fruits (Cherry)", certain technological calculations were made, Normative and Technical Documents (NTD) were developed, and based on the obtained experimental data, the standard AZS 957:2024 was created, which was approved by the Azerbaijan Institute of Standardization (Appendix 24).

For the production of food bioingredients, a package of technical

documents was prepared and approved. The technology for encapsulating bioproducts was tested and implemented.

The following developments were made and implemented in production:

- Recipe for the composition of organic products "BİO-Tərkib";
- Technology for the production of jelly-fruit marmalade based on natural rosehip puree and low-ester pectin from sea buckthorn.

A method for the standardization of biologically active substances (BAS) in functional food products and a method for their determination have been developed.

The methodological recommendations and practical issues developed by the author have been applied in organizing scientific research work in the educational process for the specialty 050635 – "Food Engineering" at the bachelor level, 060642 – "Food Engineering" at the master's level, as well as for the specialty 3309.01 – "Food Technology" in the programs "Doctor of Philosophy" and "Doctor of Science." These recommendations were included in the textbook "General Technology of Food Products" [Appendix 1], [Appendix 2], [Appendix 3], [26].

The scientific results obtained through theoretical and experimental research, as well as technical and technological developments, were presented to the "Patent and Trademark Expertise Center of the Intellectual Property Agency of the Republic of Azerbaijan," and their novelty was confirmed by a positive review of the invention and acts of applying the results of the scientific research work (Appendix 1 – 26).

Approval and application of the work. The main provisions of the dissertation were presented and discussed at the following scientific and practical conferences:

– Scientific and practical conference dedicated to the 10th anniversary of the Independence of the Republic of Azerbaijan (Baku, 2002);

– Scientific and practical conference on the results of Budget-Funded Research Conducted at Azerbaijan State University of Economics (Baku, 2006, 2007, 2011);

– Scientific and technical conference on the topic "Technology

and Techniques of Food Production" (Mogilev, Belarus, 2013, 2022, 2023);

– International scientific and practical conference on the topic "Regional Economic Policy and the Development of Cooperative Relations" (Baku, 2014);

– International scientific and practical conference on the topic "Preservation of Cultural Heritage and Biological Diversity in the Context of Urbanization and Industrialization Processes" (Ganja, 2017);

– International scientific and practical conference dedicated to the 100th anniversary of the Azerbaijan Democratic Republic on the topic "Ensuring Food Security in the Independent Azerbaijani State and Enhancing the Competitiveness of the Agricultural Sector" (Baku, 2018);

– International scientific and practical conference on the topic "Current Issues in the Food and Light Industry" (Ganja, 2019);

– III Republican scientific and practical conference on the topic "Prospects for the Development of the Food and Textile Industry in Our Republic and the Tasks Ahead" (Baku, UNEC, 2019, 2020);

– 55th International scientific conference on Economic and Social Development (Baku, 2020);

– First International scientific and practical conference "Recent Scientific Research," organized by Dagens Naeringsliv Publishing House (Oslo, Norway, 2020);

– International scientific and practical conference dedicated to the 50th anniversary of Azerbaijan Technological University on the topic "Key Issues in Ensuring the Quality of University-Industrial Relations" (Ganja, 2020);

– First International scientific and practical conference on the topic "Scientific Theory and Practice: Key Aspects" (Rome, Italy, 2021);

– Republican (online) scientific and practical conference on the topic "New Directions in Agricultural Development and Environmental Protection" (Baku, 2021);

– XII International scientific and practical conference on the

topic "Advances in Technology and Science" (Berlin, Germany, 2021);

– XV International scientific and practical conference on the topic "Modern Science of the World: Problems and Development Prospects" (Paris, France, 2021);

– XIV International scientific and practical European Conference on mathematics, engineering, natural and medical sciences (Estevan, Hungary, 2021);

– 87th International conference of young Scientists, postgraduates, and students on the topic "Youth Scientific Achievements — Solutions to Human Nutrition Problems in the 21st Century" (Kyiv, KTMU, Ukraine, 2021);

– Scientific and practical conference within the framework of the international forum "Caspian 2021: Paths to Sustainable Development" (Astrakhan, 2021);

– 5th International Asian Congress on Modern Sciences (Nakhchivan, 2021);

– International scientific and practical conference on the topic "Key Issues in University Rankings," dedicated to the 98th anniversary of the National Leader Heydar Aliyev's Birth (Ganja, UTECA, 2021);

– 70th International scientific conference on Economic and Social Development (Baku, 2021);

– 3rd International conference on the topic "Food Industry, Agriculture, and Veterinary Science" (Izmir, Turkey, 2021);

– 2nd International scientific and practical conference on the topic "Digital Economy and Knowledge Management: Problems and Development Prospects" (Kirov, Russia, 2021);

– International scientific and practical conference on the topic "Azerbaijan at a New Stage of Development — Food Security and Nutrition Security in the Context of Globalization and the Post-Pandemic World: Current Situation, Challenges, and Prospects" (Lankaran, 2021);

– Republican scientific and technical conference for students and young researchers on the topic "Youth and Scientific Innovations,"

dedicated to the 98th anniversary of the National Leader Heydar Aliyev's Birth (Baku, 2021);

– International scientific and practical conference on the topic "Agriculture and Organic Farming in the Context of the Green Economy Concept" (SDGE, 2021);

– International scientific and practical conference on the topic "Ensuring Sustainable Development: Agriculture, Ecology, and Earth Sciences" (AEES, 2021);

– Scientific conference on the topic "Issues of Multicultural Value Development and Tourism in the Caspian Countries" (Baku, 2022);

– IV International scientific forum on computer and Energy Sciences (WFCES II, Almaty, Kazakhstan, 2022);

– Scientific and practical conference organized by Azerbaijan State University of Economics (Baku, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2011).

The main scientific results of the dissertation, the methodological recommendations developed by the author, and the practical issues have found their application in organizing research work during the educational process in the following areas: at the bachelor's level in the specialty 050635 — "Food Engineering," at the master's level in the specialty 060642 — "Food Product Engineering," as well as in the "PhD" and "Doctor of Sciences" programs in the specialty 3309.01 — "Food Technology." These recommendations were used in the preparation of research papers by students, master's students, PhD candidates, and doctoral researchers, and they were included in the textbook "General Technology of Food Products" [Appendix 1], [Appendix 2], [Appendix 3], [26].

The experimental results obtained from theoretical and experimental research have led to the creation of the AZS 957:2024 standard [Appendix 24], as well as the novelty of the proposed technical-technological developments, which have been submitted as an invention (a 2023 0066) to the "Intellectual Property Agency of the Republic of Azerbaijan, Patent and Trademark Expertise Center." The application of the results of scientific research work is confirmed by the application acts (Appendices 1–26) and the obtained patent (I

2024 0116) (Appendix 27).

Place of dissertation work. The dissertation was conducted at the Department of "Engineering and Applied Sciences" of the Azerbaijan State Economic University (UNEC).

Publications. Based on the materials of the dissertation, 46 scientific papers were published, 1 standard AZS 957:2024 was developed and approved, and copyright was obtained for 1 invention (a 2023 0066). Of the published scientific works, 8 were published in national scientific journals, 5 in international scientific journals, 19 in scientific and practical materials and scientific-practical conferences organized in our country, and 15 in the materials of scientific events held abroad.

The volume of the dissertation, indicating the volume of individual structural sections and the total volume of the work: The dissertation consists of an introduction, 4 chapters, a conclusion, a list of references, and 27 appendices, including 70 tables and 45 figures. The volume of individual structural sections of the dissertation, with the number of pages and characters, is as follows: title page, table of contents, and introduction – 16 pages, 26,383 characters; Chapter One – 46 pages, 80,490 characters; Chapter Two – 22 pages, 28,123 characters; Chapter Three – 134 pages, 171660 characters; Chapter Four – 10 pages, 13,383 characters; Conclusion – 5 pages, 9,214 characters. The total volume of the dissertation is 340 pages of A4 size, written using a computer.

The main text of the dissertation consists of 233 pages, equivalent to 329,253 characters, excluding tables, figures, diagrams, the list of references, and appendices. The references include 304 sources, of which 27 are in Azerbaijani, 220 in Russian, and 57 in foreign (English) languages.

The author expresses deep gratitude to the official reviewers, the head of the "Engineering and Applied Sciences" department of the Faculty of Engineering at Azerbaijan State University of Economics, Doctor of Physical and Mathematical Sciences, Professor R.M. Rzayev; Associate Professor of the "Center for International Master's and Doctoral Studies," Candidate of Technical Sciences N.H. Gurbanov; Director of the Institute of Viticulture and Winemaking of

the Ministry of Agriculture of the Republic of Azerbaijan, Doctor of Agricultural Sciences, Professor V.S. Salimov; Chairman of the Board of "AZGRANATA" C.G. Bakhtiyarli; production directors Y.N. Lazgiyev and P.R. Arzimanov; laboratory assistant H.K. Iskenderov; quality control department staff member N.S. Yolchuzade; Director of the Beylagan Industrial Park R.M. Mammadov; Director of "Biyan Products" LLC A.T. Hasanov; Director of "MƏRƏNDİ" V.Sh. Mikailov; technologist B.M. Bagirov; head of the alcoholic beverages sector V.V. Mikailov; head of the laboratory M.B. Ismailov; Director of "AZNAR" OJSC T.F. Akhmedov; technologist I.A. Bekirov; laboratory manager R.I. Abbasov; head of the "Herbarium" department at the Botanical Institute of the Ministry of Science and Education of the Republic of Azerbaijan, Doctor of Biological Sciences, Associate Professor P.H. Karakhan; and the leading specialist of the Agricultural Research Center of the Ministry of Agriculture of the Republic of Azerbaijan, Candidate of Economic Sciences, Associate Professor E.E. Guliyev, for conducting experimental research, implementing the results of the work, as well as providing consultations and practical assistance in the proper documentation of certain issues.

MAIN CONTENT OF THE WORK

The introduction substantiates the problems of healthy nutrition for the population, associated with the environmental situation in our country and in many other countries worldwide, as well as the ways to solve them. Special attention is given to expanding the range of products made from unconventional food raw materials with high levels of biologically active substances (BAS), the significant role of wild plants in functional nutrition, and the importance of producing bio-ingredients and bio-products. This section highlights the relevance and level of development of the dissertation topic, the goals and objectives of the research, the scientific novelty of the work, the research methods, the main points presented for defense, as well as the theoretical and practical significance of the dissertation. The dissertation describes the approval and application of the work, the location where the dissertation was conducted, the publications,

as well as the overall volume of the dissertation, including the specific lengths of its structural sections. The first chapter, titled *"Informational and Analytical Review,"* analyzes contemporary data presented in various literature sources. It examines the theoretical and practical aspects of using plant materials from wild-growing plants for food production in Azerbaijan, their biologically active substances as raw materials for the production of bio-products, and the role of biologically active substances from wild plants in the treatment of certain nutrition-related diseases [14].

It is shown that wild plants are natural sources of carotenoids, particularly α-carotene, β-carotene, γ-carotene, lycopene, and others. β-carotene, which has higher antioxidant activity, accounts for 40% to 90% of the total carotenoid content.

The nutritional and therapeutic value of wild raw materials from berries and fruits is significantly enhanced by the presence of dietary fibers (cellulose, hemicellulose, and pectic substances) in their composition.[1] Dietary fibers (DF) are considered an essential component of the human diet. They not only serve as a key ingredient in food products but also have the ability to prevent various diseases.[2] The important physiological functions of soluble dietary fibers are due to their role in creating a nourishing environment for the development of normal intestinal microflora, as well as their prebiotic properties, which help maintain the composition of beneficial microflora.

It has been described that, through specific interference in intercellular interaction processes, pectic substances exert multifaceted effects on the human body[3]. It has been established that cancer cells and pectin molecules form a strong complex, thereby

[1] Голубев, В.Н., Губанов, С.Н., Духанина, А.Ф. Внедрение широкого ассортимента продуктов лечебно-профилактического действия как путь к снижению уровня профессиональных заболеваний // Сб. материалов Всесоюзн. конф. «Экстремальная физиология, гигиена и средства индивидуальной защиты человека», – Москва: – 2-3 апреля, –1990. – с. 393-399.

[2] Cicero, A.F., Baggioni A.A. Berberine and its Role in Chronic Disease // Adv. Exp. Medic. Biol., – 2016. vol. 928, – p. 27-45.

[3] Голубев, В.Н. Пектин: химия, технология, применение / В.Н.Голубев, Н.П.Шелухина, – М.: Академия Пресс, – 1995. – 486 с.

inhibiting the development of metastasis processes in the human body. Another important feature of pectic substances is their ability to bind heavy metals and radionuclides, facilitating their removal from the body.[4]

Wild berries and fruits contain a wide range of organic compounds, among which organic acids play a significant role. Their content ranges from 0.6% to 6.0%, depending on the type of raw material. Most often, these are non-volatile acids, such as citric, oxalic, malic, succinic, and tartaric acids, as well as smaller amounts of volatile organic acids, including acetic, formic, valeric, and capronic acids. Among wild berries and fruits, sea buckthorn and barberry stand out due to their higher acidity levels compared to others. During storage, the content of both volatile and non-volatile organic acids in wild fruits and berries undergoes significant changes, which helps improve their aromatic and taste characteristics. Since the amount of nitrogenous substances fluctuates between 0.1% and 0.44%, wild fruits and berries do not have significant value as a source of protein[5].

Wild fruits are not only a source of various organic compounds but also of minerals that play an important role in metabolic processes in the human body. Along with proteins, fats, carbohydrates, and vitamins, they are vital components of functional foods that regulate acid-base balance, water-salt metabolism, and osmotic pressure in the body's cells and intercellular fluid. Many mineral components, such as potassium, magnesium, phosphorus, iodine, and selenium, possess radioprotective effects, which is especially important when developing diets for populations living in areas with elevated radioactive backgrounds. Many fruits of wild plants suitable for food use (rosehip, medlar, sea buckthorn, hawthorn, barberry, and others) contain significant amounts of trace elements, such as iron, manganese, cobalt, molybdenum, and others. These elements contribute to the intensity of bioenergetic processes

[4] Донченко, Л.В., Пектин: основные свойства (Производство и применение) / Л.В.Донченко, Г.Г.Фирсов, – Москва; Дели: Принт, 2007. – 275 с.

[5] Петрова, В.П. Биохимия дикорастущих плодово-ягодных растений / В.П.Петрова. – Киев: Высшая школа, – 1986. – 287 с.

and enhance the protective responses of the human body.

An analytical review of the composition of biologically active substances in plant materials shows that wild plant raw materials are a valuable natural source of nutrients. This opens new opportunities for creating a wide range of functional food products, including bio-products aimed at maintaining the immune status of the human body.[6] In addition, the first chapter explores the role of biologically active substances in wild plant raw materials in the treatment of certain nutrition-related diseases. The issues discussed include the impact of these substances on the functioning of the immune system, fat, carbohydrate, protein, and mineral metabolism, enzyme system activity, as well as the regulation of antioxidant, electrolyte, and acid-base balance, and blood clotting.

The study examines the scientific approach to use wild raw materials in the technologies for producing functional food products. It presents the algorithm for creating functional products and its four directions, as well as modern approaches to the technologies for the integrated processing of raw materials from wild berries and fruits. A review of scientific and practical information from literature and production sources is provided on such important topics as drying plant food raw materials at low temperatures and the agrobiological features of wild plant raw materials.

Based on the results of the literature review, it can be noted that the production, processing, and consumption of wild raw materials are among the most dynamically developing segments of the commodity market, both in our country and abroad. The resources of wild fruits and berries in the Republic of Azerbaijan hold significant industrial value and undoubtedly represent an inexhaustible national wealth. Expanding the range of bio-products and multifunctional ingredients, as well as creating new product groups with distinct functional characteristics, can be effectively and profitably achieved thanks to the unique features of local wild raw material varieties and their chemical composition. Based on the above, there is a need for

[6] Колесник, А.А. Химия плодов и овощей и биохимические основы их хранения [Текст] / А.А.Колесник. – М.: Лесная промышленность, – 1971, – 121 с.

further expansion and acceleration of scientific research aimed at the effective use of natural fruits and berries growing in the wild in Azerbaijan. Thus, the main objective of the presented dissertation is the theoretical and practical justification of the evaluation of biochemical characteristics of wild fruits and berries, as well as the development of innovative technologies for the production of multifunctional bio-additives and food products from wild raw materials in Azerbaijan.

The second chapter discusses the methodology of experimental research, the methods, tasks, and organization of the experiments. Experimental research was conducted in the laboratories of the "QMT" department (now "Engineering and Applied Sciences") at Azerbaijan State University of Economics, the "Fruit Processing and Storage Technology" laboratory of the Research Institute of Horticulture and Tea Industry of the Ministry of Agriculture of Azerbaijan, production laboratories of AzGranata MMC and "Mərəndi" MMC companies, the laboratory of AZNAR OJSC, as well as in the "Biochemical Research and Quality Control" and "Grape Processing Technology and Winemaking" laboratories of the Research Institute of Viticulture and Winemaking of the Ministry of Agriculture of Azerbaijan. The research was also conducted at the research laboratory of the "Public Catering Technology" department of Moscow State University of Food Production (Russian Federation). Industrial testing of product production based on new technological schemes was carried out at the companies "AZNAR" OJSC, AzGranata, "Mərəndi," and "Biyan Products" MMC, and the characteristics and composition of the products were studied on industrial pilot samples.

The sequence of conducting the research is presented in Figure 1. Before carrying out the experimental studies, a systematic review and analysis of numerous data from modern scientific and technical sources, published in different languages, were conducted regarding the nutritional and physiological value of wild fruits and berries, as well as the prospects for using these unique raw materials in the production of functional food products in various regions of the country.

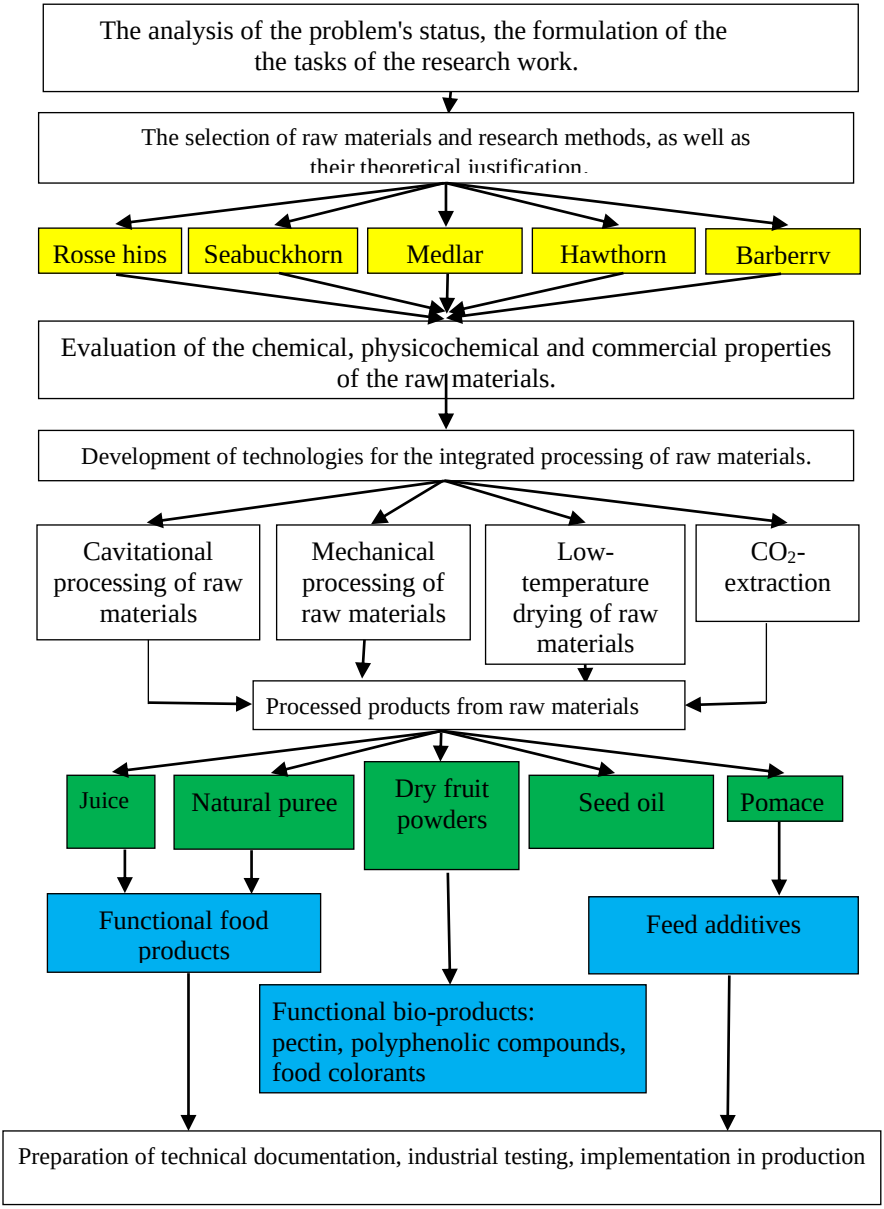

Figure 1. Sequence of conducting research

The following sources of wild raw materials, growing in various

administrative districts of the Republic of Azerbaijan with different soil and climatic conditions, were used as the object of the study: fresh fruits of the Rosaceae L. family—hawthorn (Crataegus orientalis L.), sea buckthorn (Hippophae rhamnoides), medlar (Mespilus germanica L.), rosehip (Rosaceae aciculus L.), and barberry (Berberis vulgaris L.). The fruits used for the study were those that had reached technical maturity, harvested between September and November from 2015 to 2021.

The study also included bio-products derived from natural puree of wild fruits and powder obtained solely from crushed pulp, as well as dried pits and seeds. The research used products necessary for the preparation of gel-like products, juices, and nectars, which meet the medical and biological quality requirements for food raw materials, as well as sanitary and hygienic standards and the requirements of regulatory technical documentation. These products include: granulated sugar (GOST 21-94), citric acid E 330 (GOST 3652-69), and drinking water (GOST R 51232-98).

In the course of the dissertation work, general scientific as well as specialized physical, chemical, physicochemical, biological, microbiological, and organoleptic research methods were used to determine the composition and properties of raw materials, semi-finished products, and finished food products. The following standard methods were applied in the experimental research:

– The sampling was carried out in accordance with the requirements of GOST 26313-84;

– The samples were prepared for analysis in accordance with the requirements of GOST 26671-85;

– The amount of dry matter was determined using a refractometer and the drying method to constant weight in accordance with the requirements of GOST 8756.2-82;

– The moisture (water content) was determined by the thermogravimetric method in accordance with the requirements of GOST 28561-90;

– Titratable acidity (total acidity) was determined by titration according to the requirements of GOST 25555.0-82;

– Active acidity (pH) was determined by potentiometric method

according to the requirements of GOST 26781-85;

– The total nitrogen content was determined by the Kjeldahl method[7];

– The amount of lipids was determined in accordance with the requirements of GOST 5668-68, GOST 5899-85, GOST 8756.21-89. The fatty acid composition of the lipids was determined by gas-liquid chromatography (GLC) in accordance with GOST 30418-96. After extracting oil from the pits and seeds using CO2 (carbon dioxide), the oil characteristics (acid number, iodine number, and others) were determined by well-known methods.[8] The extraction of lipids and their separation was carried out according to the scheme shown in Figure 2.

– Carbohydrates were determined using the Bertrand method[9]; the separation of the carbohydrate complex into fractions was performed according to the scheme shown in Figure 3;

– The amount of pectin substances was determined using the calcium-pectate method in accordance with the requirements of GOST 8756.11-95;

– The amount of starch was determined by the polarimetry method, based on the Evers method;

– The amount of cellulose was determined using the Kushner and Ganak method in the modification of Kogan;

– The amount of vitamin C was determined in accordance with the requirements of GOST 24556-89;

– The levels of vitamins B1, B2, and B6 were studied using the fluorimetric method[10] [11];

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[7] Методы биохимического исследования растений / А.И.Ермаков, В.В.Аросимович, Н.Н.Ярош [и др.]. – Л.: Агропромиздат, – 1987. – 430 с.

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[9] Поздняковский, В.М. Использование ягод барбариса обыкновенного в питании человека / В.М.Поздняковский, О.В.Голуб, Д.Г.Попова [и др.] // ж. Вопросы питания, – Москва: – 2003. №4, – с. 46-49.

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[11] ОФС (общая фармакопейная статья) - 1.2.3.0017.15. Методы количественного определения витаминов. – Москва: Мин. Здрав. РФ / – 2015.

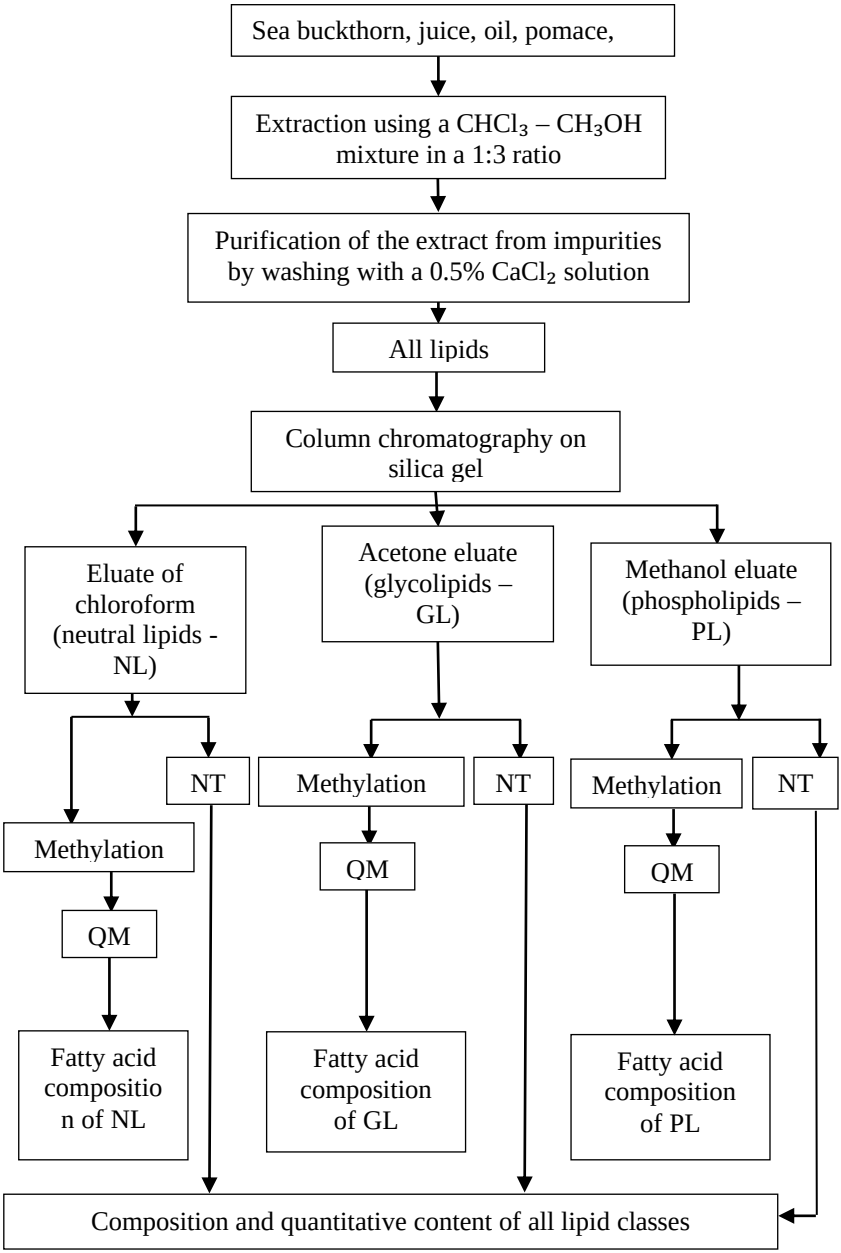

Figure 2. Scheme of extraction and separation of total lipids.

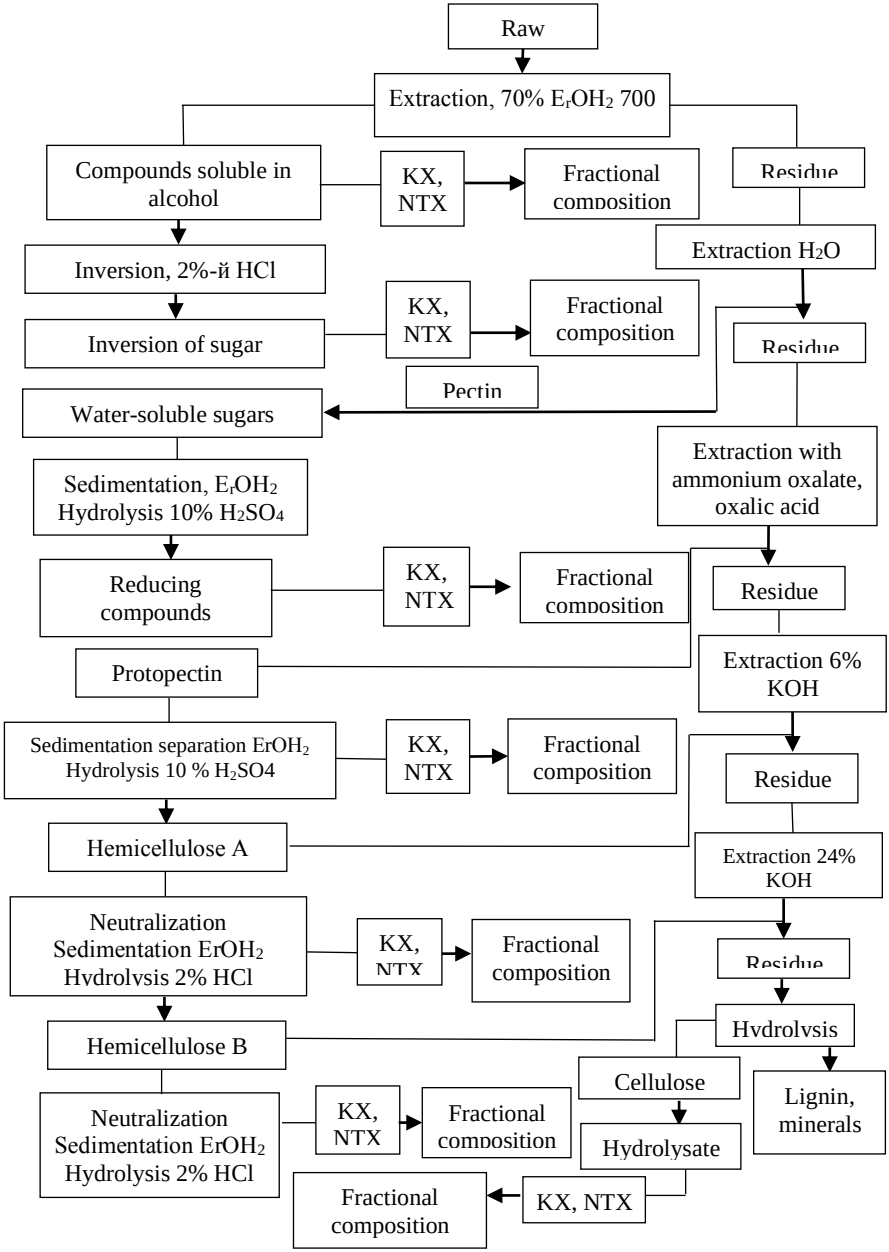

Figure 3. General scheme of carbohydrate complex fractionation.

– Active substances P were determined by the colorimetric method in accordance with the modification of Vigorov;

– The determination of macroelements was performed using the flame photometry method.

– The determination of microelements was performed using the emission spectral analysis method.

– Safety indicators of the raw materials and finished products were determined in accordance with the requirements of the standards GOST R 51301-99, GOST 10444.15-97, GOST 30518-97, GOST 30519-97, for the composition of chemical compounds with potential hazards and microbiological indicators;

The evaluation of organoleptic (sensory) quality characteristics of raw materials and finished products after processing was carried out in accordance with a well-known methodology using the expert method based on a scoring system;

– The structure and rheological properties of the products were determined using a rotational viscometer (Reotest-2 viscometer) and a Structurometer ST-2 device;

– IR spectra were recorded on the "Vertex-70" IR spectrometer with a Fourier transform converter in the frequency range of 400–4000 cm^{-1} using the "compressed drop" method between two monocrystalline silicon plates, followed by processing using the GRAMS 4.32 software;

– NMR spectra – ^{1}H and ^{13}C of pectin samples were recorded on a "Bruker Avantes" device;

– Microstructural studies were carried out using an atomic force microscope Part Nx10 (Park Systems) with the Smart Scan software;

– The total antioxidant activity (AOA) of bioproducts was evaluated using an amperometric method on the device “Tsvet – Yauza – 01 – AA” (Tsvet – Yauza – 01 – AA). The method involves the preparation of analyzed samples and standard substances, their electrochemical oxidation in the amperometric detector cell, amplification of electrical signals, their registration, and calculation of AOA based on a mathematical relationship. Quercetin was used as the standard substance.

To conduct marketing research on consumer motivation in the functional food market based on wild fruits and berries from Azerbaijan, questionnaires were developed to collect primary information through communication with residents: an online survey was conducted via social media (Appendix 24).

To ensure the reliability of the experimental data, subsequent processing of the results was carried out using modern analytical methods. For statistical, mathematical, and graphical processing of the experimental data, computer software packages Excel MS and Statistika 6.0 were used, which allowed for performing analytical tasks.

The third chapter presents the biochemical foundations of the technology for the comprehensive processing of food products derived from wild raw materials.

It is shown that, currently, the focus in healthy nutrition is on the production of multicomponent functional food products. These products include not only macronutrients but also vitamins, minerals, and biologically active substances (BAS). The production of such products is considered a priority because, due to the large number of food ingredients, the human body is supplied with essential nutrients necessary not only for normal functioning but also for reducing the negative impact of harmful environmental factors, boosting immunity, and combating the effects of the COVID-19 virus [12][17].

It has been confirmed that, according to the formula for balanced nutrition, a complete diet should consist of five classes of nutrients: energy sources, essential amino acids, vitamins, essential fatty acids, and mineral elements. It is noted that the concept of functional nutrition began to take shape at the end of the 20th century. The definition of functional food products (FFPs) has been clarified, showing that FFPs are healthy food products that provide the human body not only with beneficial and essential nutrients but also with important biologically active components. These components supply the body not only with energy and building materials but also with

[12] Бобренева, И.В. Функциональные продукты питания и их разработка / И.В.Бобренева. – М.: Лань, – 2019. – 368 с.

ingredients that optimize specific physiological functions, minimize the risk of diseases, and accelerate the recovery process.

Thus, a new approach has been developed towards wild food products as an effective means for the prevention and treatment of so-called "diseases of civilization." It has been shown that specialists designing technological schemes for the production of functional products for healthy and therapeutic-prophylactic nutrition must now ensure the proper planning of nutritional systems. It is justified that when developing new technologies for producing functional food products, the key factors to consider should be the biochemical composition, nutritional value, and biological properties of the raw materials. It has been established that, in the modern era, the approach using artificial neural networks (ANNs) has proven effective in the processing of wild raw materials for the production of functional food products, modeling technological processes, and formulating recipe compositions [25]. It has been substantiated that the application of modeling techniques with ANNs to calculate the dosage of pectin substances in functional bioproducts made from dietary supplements—produced using activated pectin technology from wild raw materials—offers extensive opportunities for the creation of new types of highly effective food products.

It has been shown that the development of new technologies for producing healthy food products based on the efficient use of wild natural food resources can play a significant role in ensuring food security in our country. Despite the fact that the range of wild fruit and berry raw materials in Azerbaijan is relatively limited, it is essential to expand the search for new types of locally adapted raw materials of particular importance. From this perspective, the lack of sufficient scientific and practical data on the phytochemical composition and techno-technological characteristics, as well as the almost non-existent regulatory and technical documentation, has generated significant interest in fresh sea buckthorn berries and their organic products, including medicinal preparations. These unique raw materials have not yet been adequately developed within the country’s processing industry. For this reason, the creation of an integrated comprehensive technology for processing wild sea

buckthorn berries to produce functional food products with high nutritional and biological value is considered one of the key directions for regulating the population's dietary structure.

Comprehensive technology for processing wild sea buckthorn berries. Based on the conducted techno-technological studies and systematic research on phytochemical and biochemical indicators, a universal block-modular technology has been developed for the comprehensive processing of wild sea buckthorn berries in Azerbaijan. The chemical indicators of various parts of wild sea buckthorn berries have been studied, including the content of **carotenoids**, **carbohydrate levels, the composition of fatty acids in lipids**, and the **phospholipid** content. It has been established that the presence of unsaturated fatty acids indicates that the oil derived from wild sea buckthorn berries has very high biological value. Sea buckthorn is considered a rich wild plant belonging to the multivitamin group due to its content of water-soluble vitamin C, rutin-like compounds (flavonoids, coumarins, and others), as well as fat-soluble carotenoids and tocopherols.[13]

The analysis of macro- and microelement content in various parts of wild sea buckthorn berries has shown that these berries are a unique organic raw material for the production of organic food products, traditional preserves, as well as dietary supplements that enrich baked goods. Due to their high vitamin content, processed products from wild sea buckthorn berries have a stronger impact on the human immune system. For this reason, food industry specialists are recommended to include them in the daily diet.

The study of the amino acid composition of wild sea buckthorn berries has shown that they primarily contain essential amino acids, such as tryptophan, phenylalanine, methionine, and others. This indicates the high biological value of these berries. For this reason, using sea buckthorn berries as wild raw material for the production of dietary supplements and functional food products is both effective

[13] Гнусарева, Р.С., Голубев, В.Н. Технология производства продуктов функционального назначения на основе полуфабрикатов из плодов дикорастущей облепихи // Материалы межд. конф. «Функциональные продукты питания», – Краснодар: – 30-31 мая 2001, – с. 71-73.

and practical. Based on the results of experiments, a scheme for the comprehensive technology of processing wild sea buckthorn berries has been developed (Figure 4).

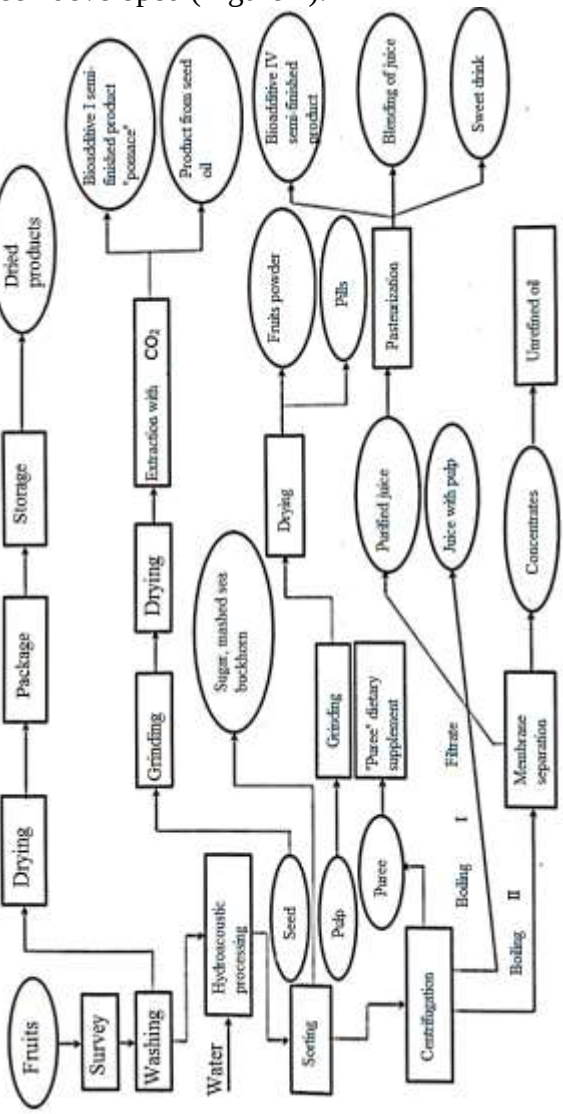

Figure 4. Scheme of comprehensive processing of wild sea buckthorn berries

The proposed technological scheme represents a waste-free production process. It allows for the production of food products such

as dried berries, four types of dietary supplements, purified and enriched extracts, sugar-based beverages, crushed sugar berries, puree for dietary supplements, concentrates, unrefined oil, capsules, and other types of food products.

The dependencies of oil yield from wild sea buckthorn berries using supercritical carbon dioxide (CO_2) at different pressures and over varying time periods have been studied. Additionally, the dependencies of oil yield at different relative flow rates of supercritical CO_2, as well as at various temperatures, and their influence on the extraction process, have been analyzed. The corresponding optimal results have been obtained.

The analysis of the technological and chemical indicators of products derived from the processing of wild sea buckthorn berries has shown that the characteristics of the products obtained through the technological operations conducted according to the proposed scheme for comprehensive berry processing ensure a high content of vitamins, pigments, lipids, and other components. These substances contribute to the high biological value of the final products, which unequivocally confirms the advantages of the technological scheme used.

The techno-chemical indicators of the residues after oil extraction from wild sea buckthorn berries, as well as their amino acid composition, content of macro- and microelements, and pectin substances [37]. (figure 5), were studied. As a result, a number of new scientific data were obtained, which have significant importance for the food industry.

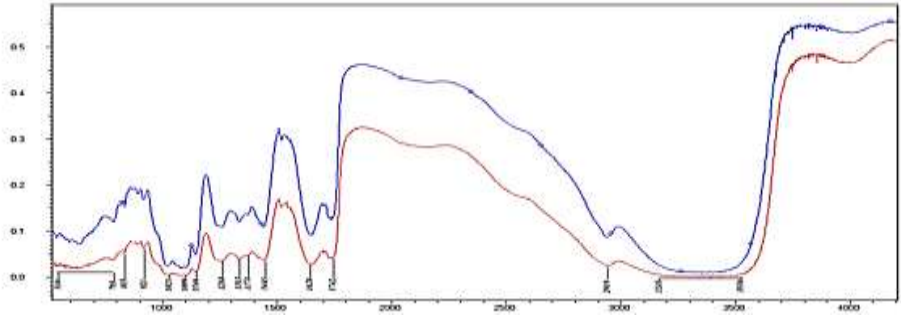

Figure 5. IR Spectra of pectin samples obtained from sea buckthorn berries

Comprehensive technology for processing wild medlar fruit. The technological scheme for the comprehensive processing of wild medlar fruit is presented in figure 6.

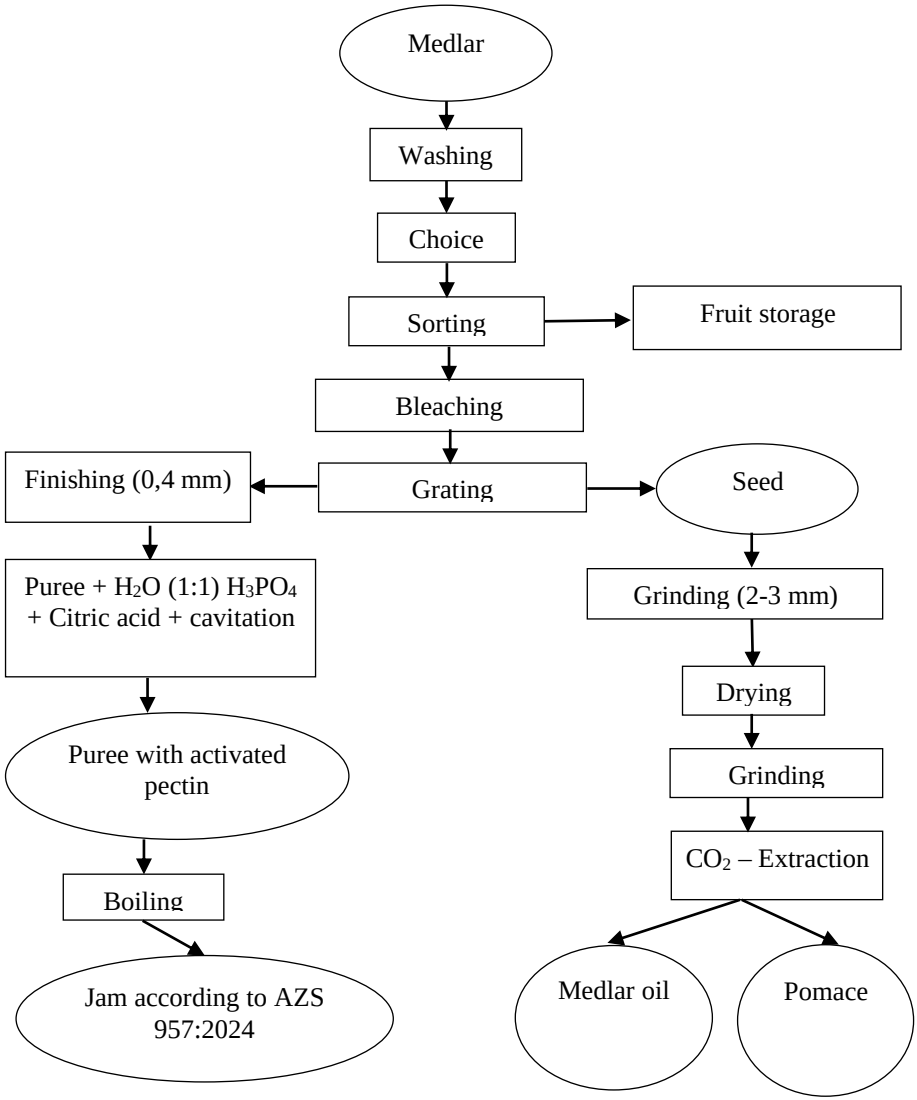

Figure 6. Technological scheme for the comprehensive processing of wild medlar fruit

It has been established that wild fruits and berries have a richer composition of biologically active substances and better quality indicators compared to cultivated species.

It has also been shown that wild plants with favorable biochemical properties include the fruits of wild medlar. According to specialists' calculations, the stock of wild medlar fruits in Azerbaijan for industrial processing purposes amounts to more than 2,000 tons per year.

It has been established that the creation of high-quality beneficial bioproducts largely depends on the biochemical properties of the raw material, including wild medlar. In this context, comprehensive studies were conducted on the main chemical and technological characteristics of fresh wild medlar fruits, as well as the lipids, carbohydrates, minerals, and vitamin complexes in their composition, including the skin, pulp, and seeds. Fatty acid components of seed oil were also identified. As a result, new important scientific data have been obtained.

It has been established that the fruits of wild medlar contain vitamin-like compounds such as inositol and P-active compounds, as well as a wide variety of polyphenolic compounds. These substances are capable of neutralizing free radicals in the human body and stopping the chain reactions of aggressive lipid oxidation, which accompany damage to cell membranes and disruptions in normal biochemical processes.

As follows from the proposed technological scheme, the fruits are sorted by quality before processing on the conveyor. Damaged and partially deformed fruits, as well as foreign impurities, are removed. The fruits are then cleaned, washed, inspected, and undergo fermentation. Since wild medlar fruits have a rather tough skin, the fermentation process is carried out in a continuous mode using a screw device, with the fruit shape being forcibly maintained until the product becomes soft. After that, the product undergoes a grinding process in a machine with a long shaft and rubber sealant.

To extract oil from medlar seeds, the method of supercritical CO_2 extraction was used. The digital indicators of the seed oil samples, the content of carotenoids and tocopherols, as well as the fatty acid

composition, were determined using standard methods.

The ground seed mass was extracted using supercritical carbon dioxide (CO_2) at pressures ranging from 100 to 280 atm and a temperature of 40°C. The dependence of oil yield on time at different pressure levels is shown in figure 7.

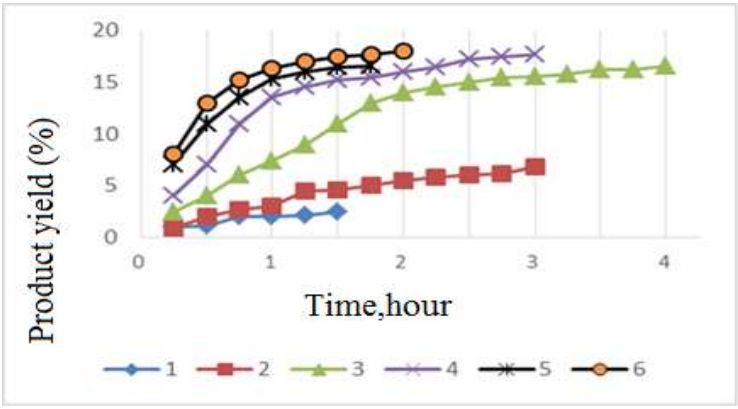

Figure 7. The dependence of oil yield on time at an extraction temperature of 40°C within a pressure range of 100-280 atm: 1 – 100 atm; 2– 120 atm; 3 – 150 atm; 4 – 200 atm; 5 – 250 atm; 6 – 280 atm.

It was found that the oil obtained from the ground seeds of wild medlar growing in our country, using supercritical CO_2 extraction, is almost identical to the corresponding product obtained from wild medlar seeds growing in Turkey. The fatty acid composition is virtually the same, with differences only observed in the higher content of tocopherols and carotenoids.

Experimental results showed that the main components of the oil extracted from ground wild medlar seeds consist of about 70.0% polyunsaturated linoleic acid (omega-6) and about 17.0% monounsaturated oleic acid (omega-9). The composition also includes saturated fatty acids: palmitic acid (about 7.0%) and stearic acid (about 4.0%). The presence of biologically active substances such as tocopherols and carotenoids in the seed oil makes it an indispensable product for the food and pharmaceutical industries. The remaining

wild medlar seeds after supercritical CO_2 extraction are a source of polar biologically active antioxidants, especially polyphenols, and can be used as a valuable food and feed supplement.

The comprehensive technology for processing wild hawthorn. It is shown that the varieties of wild hawthorn growing in the forests of the country have high yields annually and can be used as an indispensable raw material for the production of pharmaceuticals and food products due to their chemical composition [28]. However, the development of production technology requires systematic research of the entire spectrum of bioactive substances (BAS) and the development and implementation of innovative, waste-free, and environmentally clean technologies that ensure the efficient use of natural resources.

It has been confirmed that the creation of valuable functional food products with high-quality indicators largely depends on the quality characteristics of the raw material. Currently, there is a lack of reliable scientific data on the biochemical composition of wild hawthorn varieties in our country. This is why, in 2018-2020, we conducted scientific research to determine the organoleptic, physicochemical, and biochemical parameters of wild hawthorn fruits, as the beneficial properties of this unique fruit species are determined by the indicators of its chemical composition.

The analysis of the data obtained from the research showed that wild hawthorn fruits are an extremely valuable raw material source and have very high nutritional value. The composition of hawthorn fruits contains a large amount of dry matter, biologically active compounds, including vitamins, trace elements, P-active compounds, and other substances. Due to the high content of pectin substances, wild hawthorn fruits can serve as an excellent raw material for creating a wide range of therapeutic and prophylactic bioproducts, as well as for enhancing the physiological value of food products. Furthermore, the balanced content of sugars and organic acids in the fruits and berries gives them an excellent, pleasant, harmonious taste, which is confirmed by the high value of the "sugar-acid balance index."

The composition of wild hawthorn fruits contains a high amount

of pectin substances, with the content of hydropectin exceeding that of protopectin, which makes it possible to obtain bioproducts with therapeutic and prophylactic functions. Therefore, we decided to conduct additional scientific research to study the analytical and technological characteristics of the pectin substances found in wild hawthorn fruits. The results of the scientific studies confirmed the promising potential of using bioproducts derived from wild hawthorn fruits in specialized diets.

It has been established that the mass fraction of nitrogen-containing substances in the composition of wild hawthorn fruits, calculated as protein, averages 1.5%. The major part of nitrogen-containing organic compounds consists of free amino acids. Free amino acids play an important role in the synthesis of biologically active compounds and participate in reactions that lead to the formation of aromatic substances. The obtained scientific data showed that amino acids such as serine, glutamic acid, leucine, lysine, and asparagine occupy a significant place in the composition.

In addition, comprehensive studies of the lipid and vitamin composition of wild hawthorn fruits were conducted.

It was shown that most types of wild fruits are perishable food raw materials, so harvesting at the stage of technical maturity should not exceed 2.5–3.0 months. Therefore, there is an urgent need to develop effective and optimal technologies for the production of semi-finished products, as well as for ensuring year-round production of food products.

One of the widely used methods for processing raw materials from wild fruits and berries is drying and preservation. We have developed a systematic technological approach, including the use of both "cold" technologies and technologies involving supercritical fluids, which yielded very effective results when processing wild rose hips, sea buckthorn, and medlar fruits.

The technological scheme for the comprehensive processing of wild hawthorn fruits for the production of bioproducts is shown in figure 8.

Hawthorn fruits are washed in a vibratory washing machine, inspected on a sorting conveyor, and then blanched for 5-8 minutes

to soften cell membranes. The fruits are then grated in a specialized machine equipped with a device for separating seeds and pulp. The resulting pulp is forwarded for the production of seed oil.

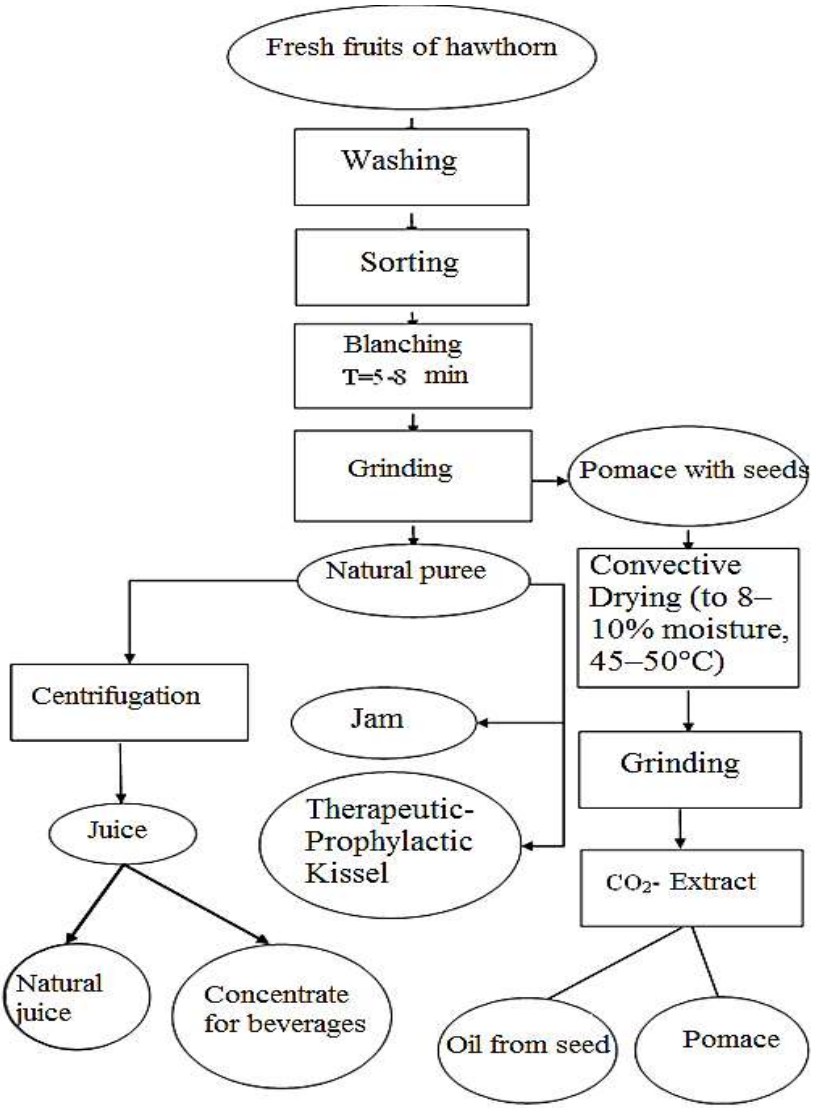

Figure 8. Technological scheme for the production of bioproducts from wild hawthorn fruits

The mass-like consistency of the fruits, resembling puree—referred to as "natural puree"—is a bioproduct that can be used for the production of natural juice, beverage concentrates, jelly, and jam for therapeutic and preventive nutrition. The product yield in the production of "natural puree" is 75-80%. Thus, it has been established that wild hawthorn fruits can serve as raw material for the production of a wide range of functional food products certified as "BIO," "ECO," or "ORGANIC."

Technology for comprehensive processing of wild barberry fruits. It has been established that the chemical composition and nutritional properties of barberry fruits growing in Azerbaijan, as well as the technologies for industrial processing, storage conditions, and the expansion of the range of processed products, require thorough scientific research.

Due to the lack of scientifically grounded recommendations regarding the chemical composition, technological characteristics, and applications in the processing industry, wild barberry fruits have not yet found widespread use in food production. Therefore, our objective was to study the comprehensive commercial and technological characteristics of wild barberry fruits in the country. Based on the results of scientific research conducted from 2019 to 2021 and a review of existing literature, we aimed to identify effective methods for producing food products from barberry raw materials.[14] [15] [16] The results of the general chemical analysis of freshly harvested wild barberry fruits are presented in Table 1.

Studies have shown that wild barberry fruits are a valuable food raw material due to their content of biologically active substances and hold great significance for the production of bioproducts with high physiological activity. Experimental results revealed that the

[14] Ковалевская, И.Н. Товароведческая характеристика ягод барбариса и продуктов его переработки: [Текст] / автореф. дисс. канд. техн. наук / – Кемерово, 2004. – 28 с.

[15] Петрова, В.П. Дикорастущие плоды и ягоды / В.П.Петрова. – М.: Лесная промышленность, – 1989. – 248 с.

[16] Попова, Д.Г. Разработка и товароведческая оценка сушеных полуфабрикатов из ягод барбариса и пищеконцентратов с их использованием: [Текст] / автореф. дисс. канд. техн. наук. / – Кемерово, 2008. – 28 с.

carbohydrate composition of wild barberry fruits includes equal amounts of glucose, fructose, and sucrose, while the pectin substances also exhibit nearly identical proportions. The richness of pectin substances in the berries contributes to their long-term storage. The analysis of the chemical composition of wild barberry fruits highlights the high biological value of the raw material for producing functional food products, including a multicomponent vitamin complex present in the raw material.

Table 1. Chemical Composition of Wild Barberry, %

Indicator Name	Indicator Value
Water	75,00
Dry substances, including:	
Soluble Insoluble	25,00 20,50
Ash substances	1,10
Total carbohydrates:	
– Monosaccharides – Disaccharides – Hydropectin – Protopectin – Cellulose	6,55 2,95 1,48 1,58 2,60
Nitrogenous substances	4,50
Inoculants and coloring substances	1,10
Lipids	4,30
Titrable acidity (as malic acid)	3,95
Sugar-acid index	1,75

It has been confirmed that the nutritional value and physiological activity of wild fruits and berries are linked to the richness of vitamins and vitamin-like compounds in their composition. Experimental results have shown that the vitamins in berries are diverse and present in relatively high amounts, particularly vitamin C (257.0 mg %). All groups of B vitamins were found in wild barberry fruits. The vitamin complex of berries is dominated by flavonols (1700 mg %), and there is also a group of polyphenolic compounds that impart a bitter taste to the raw material, combined with alkaloids. The vitamin complex of wild barberry is presented in the second table.

It has been established that the content of nitrogenous substances in wild barberry fruits, calculated as protein, does not exceed 0.55%, and the main part of these compounds consists of free and bound amino acids. In the total lipids of wild barberry fruits, 14 fatty acids were found, ranging from C12:0 to C18:3. Thus, it is suggested to process barberry seeds for oil production, which could increase the economic efficiency and profitability of barberry fruit processing.

Table 2. Vitamin complex of freshly harvested wild barberry.

Types of vitamins	Amount (mg %)
Vitamin C (Ascorbic acid)	257,00
Vitamin B_1 (Thiamine)	0,048
Vitamin B_2 (Riboflavin)	0,146
Vitamin B_3 (Niacin, Nicotinamide)	0,310
Vitamin B_6 (Pyridoxine)	0,110
Vitamin K_1 (Phylloquinone)	0,820
Vitamin E (Tocopherol)	3,500
Polyphenolic substances, including: - Catechins - Anthocyanins - Leucoanthocyanins - Flavanols	 1270,00 575,00 1210,00 1700,00

It has been shown that wild barberry has been used as a medicinal plant since ancient times [28, pp. 201-203], and its fruits possess healing properties that are used to treat a wide range of diseases, especially gastrointestinal and digestive system disorders. A great deal of data in literary sources regarding the nutritional value of wild barberry fruits in Azerbaijan, volumes of industrial processing and supply, as well as current consumer market requirements, do not provide a complete understanding of rational technological schemes for integrated processing that take into account the requirements for healthy food products. It has been established that during the processing of wild barberry fruits, around 30% of the total mass is generated as waste in the form of pomace and seeds, which contain a large amount of biologically active compounds and lipophilic substances. When creating a technological scheme for low-waste processing of wild barberry fruits, it was taken into account that, in

the production of canned goods, preference is currently given to preparing puree-like food products from a variety of fruits, berries, and vegetables. These products are classified as natural fruit and vegetable preserves, and their composition includes only the pulp of fruits and vegetables, and in some cases, according to technological requirements, water.

Considering that wild barberry fruits are an ecologically clean food product and "organic" raw material, the bioproduct obtained from this raw material will have a "natural puree" and "organic product" certification. This product can be used as an independent food item, as well as a multivitamin supplement and a key component that enhances the taste and aroma of functional products. It can also serve as filler and thickener in preventive, dietary, and children's nutrition. Since the harvesting season for wild barberry fruits is limited, it has been proposed to ensure the supply of dry raw material, i.e., the drying process of fresh berries. This proposal allows for the use of this type of raw material in processing for a longer period. Thus, taking all factors into account, a low-waste industrial processing technology for fresh wild barberry fruits has been proposed (figure 9).

Fresh wild barberry fruits undergo inspection, during which immature, mechanically damaged, and pest-infested fruits, as well as plant impurities, are removed at this stage of the technological process. The prepared batch of fresh raw materials is partially sent to the berry drying line, while the remaining part undergoes blanching at a temperature of 90–100°C for 5–10 minutes until the fruits become soft. It is important to ensure uniform heating of the berries. Immediately after blanching, the berries are crushed in a special machine with a wire mesh with hole diameters of 0.5–0.8 mm.

The quality of the grinding process is monitored by ensuring the absence of crushed seeds, skin, and coarse pulp in the puree-like mass. The average puree yield is 84.00%. The obtained berry seeds are sent to the production line for extracting raw oil from the pomace. To justify the feasibility of producing puree from wild barberry fruits and assess its nutritional value, a comparative analysis was conducted on the chemical composition of the raw material and

the chemical composition of the resulting bio-product, "natural puree." To ensure the year-round production of functional and food bio-products from wild barberry, it is recommended to establish primary reserves of dried wild barberry fruits and dried pomace.

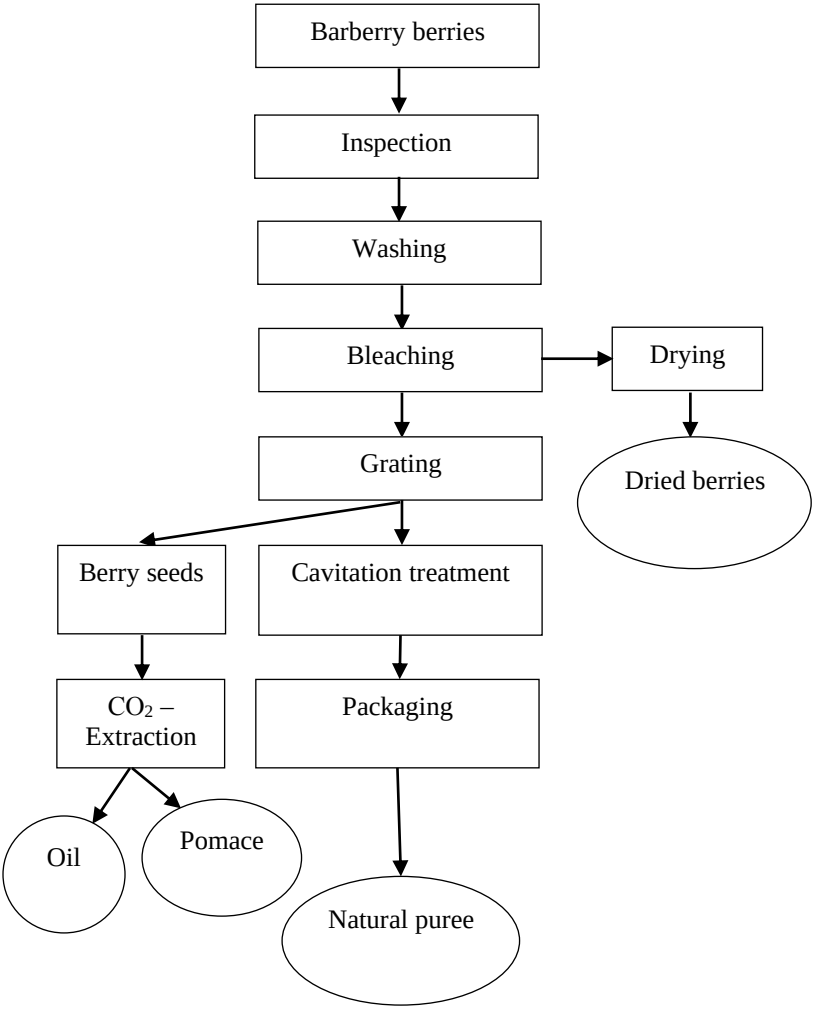

Figure 9. Technological scheme of low-waste integrated processing of fresh wild barberry fruits.

It is asserted that in the modern era, with the gradual depletion of natural food resources, the development of fundamentally new

approaches to the comprehensive processing of plant raw materials should be considered a priority. It has been demonstrated that the creation of innovative technologies can benefit significantly from the extensive use of methods that involve both chemical (regulating the composition of the reaction mixture) and physical (excess pressure, cavitation) impacts on plant raw materials. In this context, the integration of processes conducted under supercritical (high-critical fluid technologies) and subcritical conditions (explosive autohydrolysis) into the schemes for the comprehensive processing of wild plant raw materials in our country has been proposed. These methods are not only environmentally friendly and aligned with the core principles of "green chemistry" but also enable the targeted modification of plant material processing products.

When the temperature and pressure of a substance exceed its critical parameters, such processing is referred to as "high-critical fluid" technology. In this case, the system contains two phases—liquid and gaseous—that transform into a single-phase system. Therefore, extraction using supercritical carbon dioxide (SC-CO_2) from wild barberry seeds is an innovative and promising technology for obtaining biologically active substances from plant material. The drying process of wild barberry can be observed in the thermogram shown in figure 10.

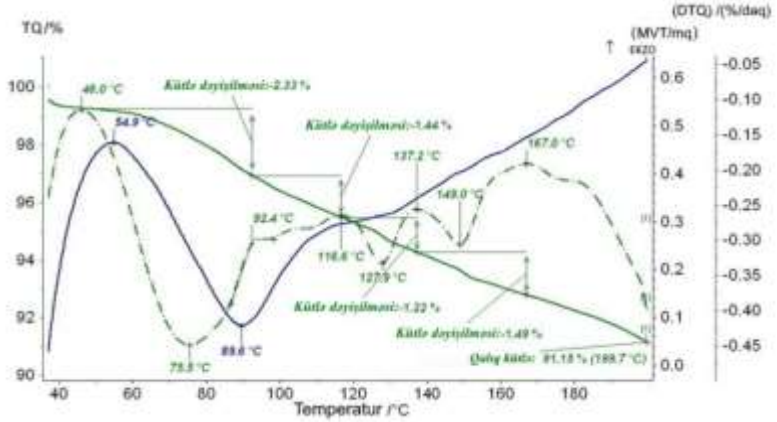

Figure 10. Thermogram of wild barberry berry samples heated in air at a rate of 5°C/min up to 200°C.

Comprehensive technology for processing wild rosehip fruits. It has been established that 42 species out of more than 300 known rosehip species are found in Azerbaijan today, 26 of which grow in the wild. The total area covered by wild rosehip in the country exceeds 2,000 hectares. It has been substantiated that, due to the diversity of biologically active substances and the composition of micro- and macromineral ingredients, rosehip fruits and their processed products can become an important part of a healthy human diet. It has been demonstrated that, despite the rapid advancements in chemical synthesis, the production of biologically active preparations from natural plant raw materials is currently of much greater significance. It has been confirmed that, in many countries around the world, the vitamin industry is developing in two directions: organic synthesis of biologically active preparations and their production from natural plant raw materials.

It has been confirmed that vitamins derived from natural plant raw materials exhibit higher biological activity compared to their synthetic counterparts. It has also been established that medicinal preparations made from rosehip fruits contain a range of unique biologically active substances that cannot be replaced by synthetic alternatives.

The growing demand for natural biological products is supported by the confidence of medical professionals in their high pharmaceutical activity, as evidenced by their effectiveness in treating numerous chronic diseases. It has been shown that most of these plant-based medicinal complexes, with a chemical composition closely aligned with the human body, adapt quickly, integrate smoothly and naturally into vital processes, are not rejected by the body, have no harmful side effects, are non-toxic, and, regardless of the level of use, do not cause dependency.

However, the existing technologies for processing rosehip fruits fail to account for the diversity of active components in their composition and their geographical distribution across the country. They also do not meet modern requirements in terms of raw material and energy efficiency, environmental safety, and overall effectiveness.

Therefore, the development of versatile, low-waste industrial technologies for processing rosehip fruits to produce a wide range of

high-quality biologically active preparations for medical, nutritional, and feed purposes, while increasing technological flexibility, ensuring environmental sustainability, and minimizing energy costs, has been recognized as an important scientific and technical challenge.

To implement the scientific concept of this technology, specialized technological solutions have been proposed, forming the basis for the development of a universal block-modular technological scheme for the comprehensive industrial processing of rosehip fruits.

Based on experimental results obtained from the analysis of the biochemical and physicochemical properties of rosehip fruits and their processed products, optimal technological schemes and recommendations have been developed to facilitate the establishment of industrial production in Azerbaijan.

Biochemical studies on the content of biologically active substances in various parts of rosehip fruits were conducted (table 3). As expected, the rate and degree of extraction of soluble dry substances from the rosehip peel are significantly higher than from the whole fruits. Thus, the maximum extraction of dry substances from whole (uncrushed) fruits (1.7%) is achieved at 80°C for 60 minutes, while the same dry substances can be extracted from the peel under milder extraction conditions—at 20°C for 10 minutes.

Table 3. Content of dry substances in extracts depending on extraction parameters

Sequence	Extraction parameters			Amount of dry matter	
	Hydromodule	Temperature, ^{0}C	Time, min.	Whole fruits	Peel
1	3:1	20	10	0,50	4,40
2	10:1	20	10	0,03	1,50
3	3:1	20	60	0,80	8,90
4	10:1	20	60	0,05	3,10
5	3:1	80	10	1,10	7,50
6	10:1	80	10	0,10	2,70
7	3:1	80	60	1,70	13,00
8	10:1	80	60	0,60	6,50

The composition of dry substances in the extracts obtained from rosehip contains 2-4% vitamin C, while the content of pectin substances is slightly higher, at 7-8%. It is quite natural that the

amount of soluble dry substances in the extract obtained from the peel significantly exceeds the amount in the extract derived from whole (uncrushed) fruits.

To increase the yield of soluble dry substances and eliminate the stage of removing the peel from whole rosehip fruits, the processing of the fruits was carried out in the mode of hydroacoustic cavitation using a rotary cavitation apparatus. The results of the conducted experiments are presented in figures 11, 12, 13, and 14.

Impact of hydromodule processing. As shown in figure 11, at a 4th hydromodule (rosehip fruits - water), the yield of dry substances is 12.0%, and the yield of pectin substances is 2.0% at a temperature of 20°C. These results are achieved after just 10 minutes of processing, with velocity gradient values between the stator and the rotating rotor $1{,}8 \cdot 10^5 \div 4{,}6 \cdot 10^6 \frac{m}{sm \cdot m}$, as well as the density of acoustic energy $0{,}2 \frac{W}{sm^3}$.

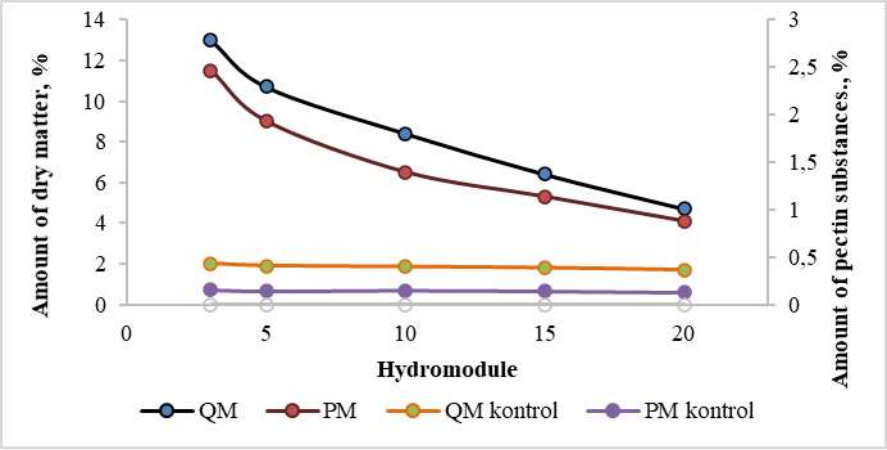

Figure 11. Influence of the hydromodule on the content of dry substances and pectin substances in the water extract.

Impact of the duration of hydroacoustic processing. As shown in the data in Figure 12, with an increase in the duration of

hydroacoustic processing to 25 minutes, the amount of dry substances in the extract increases to 15.0%, and the amount of pectin substances rises to 3.0%.

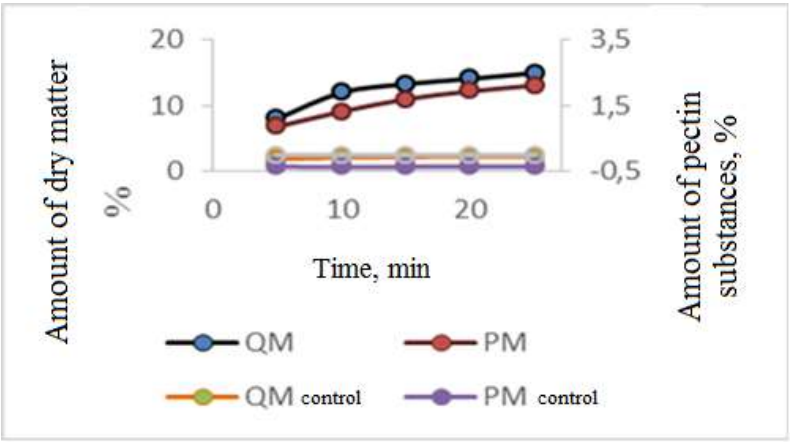

Figure 12. Influence of the hydroacoustic processing on the content of dry substances and pectin substances in the extract.

Impact of temperature. The experiments were conducted at a hydromodule of 4, a processing time of 10 minutes, and a hydroacoustic energy density of 0.2 W/cm^3 (figure 13).

As seen from the data presented in figure 13, increasing the temperature of the hydroacoustic processing of wild rosehip fruits from 20°C to 60°C leads to an increase in the yield of dry substances to 15.4%, and pectin substances to 3.3%.

Impact of preliminary swelling of raw materials. In the experiment, rosehip fruits were first soaked in water for 60 minutes and then crushed. All other conditions were consistent with the data presented in figure 13.

The data presented in figure 14 show that preliminary soaking of both dried and fresh crushed fruits significantly increases the yield of dry substances and pectin substances.

The analysis of the experimental data obtained during the research revealed that the optimal parameters for hydroacoustic processing of wild rosehip fruits in a rotary cavitation extractor are: preliminary

soaking for 60 minutes, a hydromodule of 4, a temperature of 20°C, and a processing duration of 10–15 minutes. For this reason, all subsequent experiments were conducted according to these technological parameters.

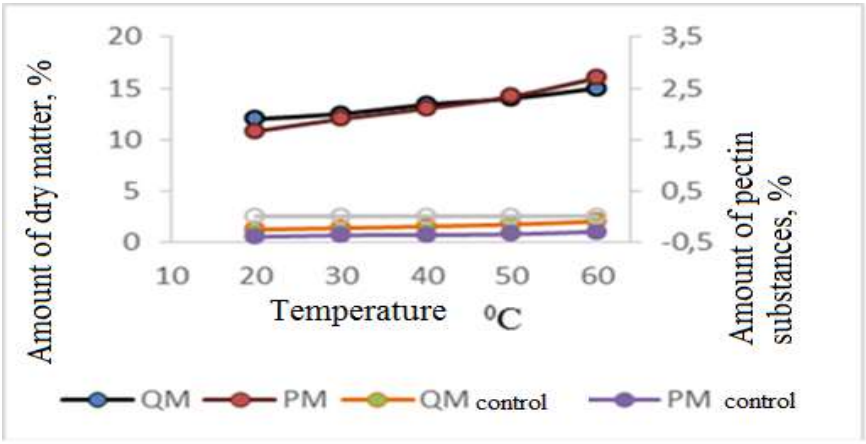

Figure 13. Influence of the temperature of hydroacoustic processing on the content of dry substances and pectin substances in the extract.

Water-soluble biologically active substances, including ascorbic acid and pectin substances, contained in the aqueous extraction of the liquid phase, were found suitable for use in two directions:

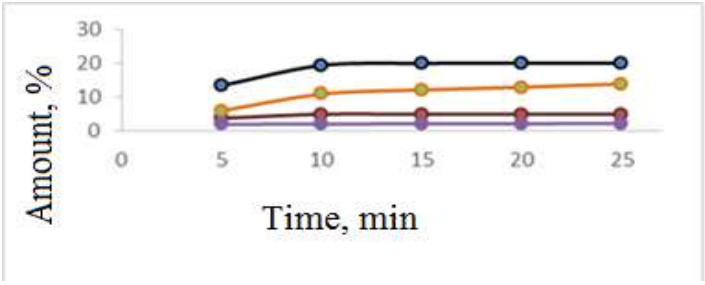

Figure 14. Influence of preliminary soaking of rosehip fruits in water on the content of dry substances and pectin substances in the aqueous extract.

1. To obtain a gel-like product by mixing this extract with sucrose;

2. To produce rosehip syrup with high complex-forming properties by reducing the degree of esterification and molecular weight.

Thus, the more advantageous and efficient method for extracting the total extract from plant food raw materials was recognized as supercritical fluid extraction (SCFE), characterized by high technological performance. Supercritical fluid extraction using carbon dioxide (SCFE-CO_2) is an alternative and promising technology for extracting biologically active substances from various plant food raw materials.

Carbon dioxide (CO_2) has low critical parameters: critical temperature $T_{cr.}$ = 30,9°C, critical pressure $P_{cr.}$ = 72.8 atm and critical density 0.469 g/cm³. CO_2 is non-flammable and non-toxic. This technology allows for the improvement of raw material processing methods by altering extraction conditions and selecting the appropriate raw material. As a nonpolar solvent, CO_2 primarily extracts lipophilic components from raw materials, mainly lipids.

It has been shown that the difficulties in obtaining oil from wild rosehip raw material are mainly related to the unstable quality of the raw material. Research aimed at optimizing the supercritical fluid extraction process using carbon dioxide to obtain rosehip oil was conducted on an extraction unit manufactured by the Swiss company "SITEC." The data obtained showed that the proposed new production technology allows for the production of finished rosehip oil from raw materials with varying quality characteristics, containing three groups of vitamins: carotenoids, tocopherols, and polyunsaturated fatty acids. It was established that approximately 18.43–18.57 kg of rosehip fruits are required to produce 1 kg of rosehip oil.

The biochemical indicators of wild rosehip, including its vitamin, amino acid, and mineral content, were studied, and new experimental data was obtained. Based on the results of these experimental studies, a universal block-modular technological production line for the comprehensive processing of wild rosehip fruits in small-scale production conditions was developed. The production line consists of

three sections: raw material preparation for production, syrup preparation, and oil extraction from rosehip fruits.

Raw material preparation for production. To ensure year-round operation of the production facility, the raw material preparation process includes drying the wild rosehip fruits at low temperatures (60-70°C), grinding the dried fruits in a roller grinder, sieving the ground mass, and additional grinding of seeds in a hammer mill (Figure 15).

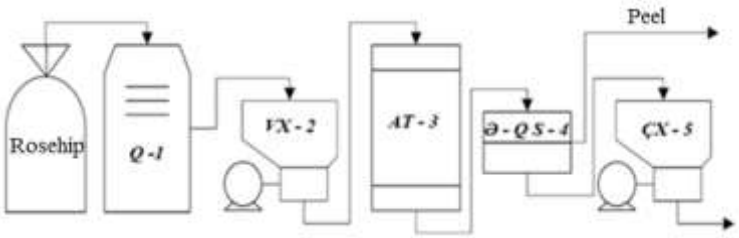

Figure 15. Raw material preparation scheme for production:
1. Q-1 – drying unit; 2. VX-2 – roller grinder; 3. AT-3 – intermediate reservoir; 4. Ə-Q S-4 – sieve-conveyor system; 5. ÇX-5 – hammer mill.

Thus, the process of processing wild rosehip fruits is recommended to be carried out in the following technological sequence: the raw material, packed in bags, is unloaded onto the conveyor belt of the drying unit in a layer 4-5 cm thick. The drying temperature is set at 60-70°C, and the residual moisture of the product is controlled within the range of 5-8%. The drying time is automatically adjusted and takes 45-60 minutes. After drying, the wild rosehip fruits are transferred to the receiving hopper of the roller grinder, where they are ground. The ground fruits are then sent to the intermediate reservoir for further processing, and subsequently to the sieve-conveyor system for sieving. The seeds are further processed in the hammer mill and sent for oil production. The peel may either be directed to the syrup production line or to the production line for vitaminized teas.

Preparation of rosehip syrup. To prepare rosehip syrup (Figure 16), the residual rosehip mass that did not pass through the sieve after preliminary treatment (sieving) is soaked in ionized water for 30 minutes, and then loaded into a rotor-cavitation type extractor. In

the extractor, the raw material and water are mixed in a ratio of 1:5 and processed in a hydromodule using ionized water. The extraction is carried out at a temperature of 20-25°C for 10-15 minutes.

After the aforementioned operations, the resulting mass is passed through a filter press with a fabric filter or separated into liquid (aqueous extract) and solid (wet mass) phases using centrifugation. The aqueous extract is collected in a reservoir, while the mass is placed on special trays for moisture removal and subsequent drying.

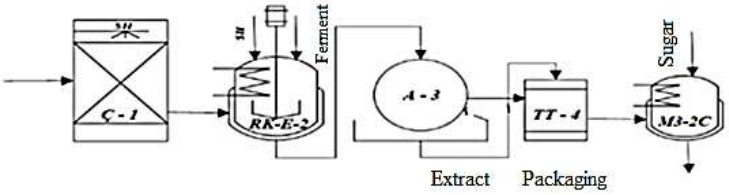

Figure 16. Preparation of Rosehip Syrup:

1. Ç -1 – soaking tank for mass; 2. RK-E-2 – rotor-cavitation type extractor; 3. A-3 – separator; 4. TT-4 – collection reservoir; 5. boiling kettle M3-2C.

The aqueous extract is then transferred to a boiling kettle of the MZ-2C model, where the specified amount of sugar and citric acid is added according to the recipe. The mixture is boiled until a syrup with a concentration of 70-72% is obtained.

The production of oil from wild rosehip. The diagram of the installation for extraction using supercritical carbon dioxide is shown in figure 17.

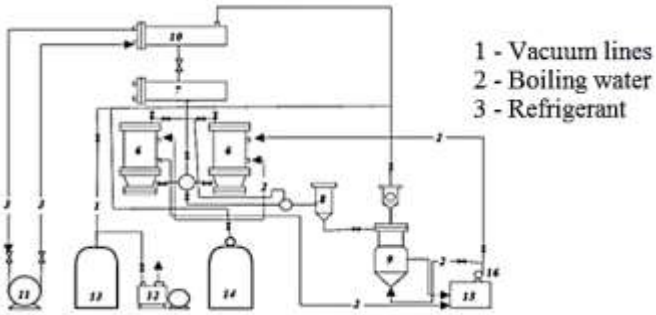

Figure 17. Installation for fluid extraction using supercritical carbon dioxide for extracting oil from the mass of wild rosehip fruits.

It has been established that when carbon dioxide (CO_2) transitions from a liquid phase to a boiling liquid, that is, when the pressure is raised to Pc and forced circulation of the extractant is used, the extraction rate and oil yield significantly increase. Thirty minutes after the start of the extraction process with forced circulation of the extractant, the oil yield is 2.4%, and the average extraction rate is 0.08% per minute. In the case of natural circulation of the extractant, the oil yield is 0.64%, and the average extraction rate is 0.02% per minute.

Given that the production process of wild rosehip oil is small-scale (no more than 250 kg per year), the packaging of the finished product is planned in small volumes in dark glass jars with manual sealing of the lids.

Thus, the developed block-modular technological scheme for the integrated processing of wild rosehip fruits has universal characteristics for processing various types of small-volume fruit and berry raw materials and allows for the production of a wide range of final products, including biologically active food supplements.

In accordance with the developed block-modular technological schemes, two convenient options are proposed for the comprehensive processing of wild rosehip raw materials:

– Production of rosehip fruit peels for sale as a semi-finished product for the production of herbal teas and rosehip oil;

– Production of rosehip syrup and rosehip oil.

Calculation of the economic efficiency of wild rosehip oil production. The following production volumes were assumed for the calculation of economic efficiency: wild rosehip peel — 2,000 kg per year, wild rosehip oil — 250 kg per year, rosehip syrup — 6,000 kg per year.

The following technical and economic indicators were calculated: the cost of finished products, the payback period of expenses, the break-even point, and profit.

In the production of products from plant raw materials, it was established that more than 70% of costs are attributed to raw materials and materials.

The conducted technical and economic calculations showed that the production of 250 liters of rosehip oil costs 8,773.3 manats, while

the total income amounts to 42,500 manats. The resulting profit is 33,726.7 manats (14,839 USD). The profitability level is 384%. This means that for every manat spent on the production of rosehip oil, the profit is approximately 3.84 manats. This confirms the economic efficiency of rosehip oil production. In the global market, this product allows for a profit of 3.84 manats for every manat spent.

The fourth chapter is titled "Marketing Research and Socio-Economic Justification for the Use of Processed Products from Wild Food Raw Materials of Azerbaijan."

It is noted that in recent years, the exacerbation of environmental problems, particularly issues of food security, has raised significant concerns not only among scientists but also among businesspeople, politicians, and the general population.

In this regard, marketing research in the field of healthy and functional food products is applied as a widely used method for studying consumer opinions. Timely responses to global changes in the dietary structure of the population and to demands related to a healthy lifestyle, as well as the organization of food production that meets consumer needs, are evaluated as the main objectives of marketing policy. In this context, there is an urgent need to address the consequences of consuming products that impact human health, which necessitates the formation and development of the market for environmentally friendly food products in Azerbaijan.

It has been established that the structuring of marketing tasks and the promotion of organic food products are determined by the following sequentially implemented provisions:

– Providing food products that cause minimal harm to the environment and meet the needs of the population;

– Justifying the price premium for "green" products;

– Accurate assessment of demand for environmentally friendly products;

– Evaluating the potential supply of environmentally friendly products;

– Creating a supply of environmentally friendly products (EFP) that meets the needs of the population that can afford them, alongside offering conventional food products for other segments of the

population;

– Striving to continue offering safe food products for the majority of the population.

Based on the outlined provisions of marketing research, studies were conducted that included the analysis of statistical data, the characterization of respondents' incomes, their expenditures on food, and their level of awareness about organic products across different age groups. It was found that 30% of the total number of respondents in the city of Baku show potential interest in organic products and are willing to use them regularly.

A survey was conducted among the population across three age groups, each consisting of just over 100 respondents: from 25 to 35 years old, from 35 to 45 years old, and from 45 to 60 years old. The data collection method was a primary survey. The form of interaction with respondents was an online survey through social media. A confidence level of 95% was chosen, and the accuracy ensuring representativeness of the results was set at 5%. As a result of a one-time statistical analysis, the following data were obtained.

It was found that among the respondents in all groups, the majority of consumers are willing to spend more money on higher-quality food products. Ideally, these are functional food products made from locally sourced wild materials, which make up between 10% and 25% compared to traditional food products.

The survey revealed that the level of awareness among respondents from all age groups about the significant role of functional organic food products in a healthy lifestyle is not high.

To increase consumer awareness about the use of various types of bioproducts based on wild plant materials, the following steps are proposed:

- Step I – Raise awareness about the issues related to the use of traditional food products.
- Step II – Inform consumers about the availability of eco-friendly food products on the market.
- Step III – Justify the pricing policy to ensure the accessibility of eco-friendly food products.
- Step IV – Provide information about the locations and

opportunities for eco-friendly food products, as well as the conditions for their purchase.

It has been shown that one way to expand the range of healthy food products is by incorporating wild plant materials, which are ecologically clean and possess a unique combination of biologically active substances, into the production-consumption cycle.

The main objective of the study is to identify how consumers assess the key requirements for such products in order to expand the market for organic foods.

Thus, a survey was conducted through social media among 384 respondents. According to the survey results, the majority of consumers interested in healthy eating are young people aged 18 to 35, making up 51% (see Figure 18). Respondents aged 26 to 35 account for 32%, 36 to 45 years for 8%, 46 to 55 years for 6%, and those over 56 years for just 3%.

The results of the survey on the reasons for choosing healthy food products revealed the following: 49% of respondents indicated that the reason for their choice is that these products are beneficial for health, 15% noted that they are safe for the environment, 15% chose the reason "high product quality," 11% selected "fashion," 7% chose "prestige," and 3% mentioned other reasons (see Figure 19).

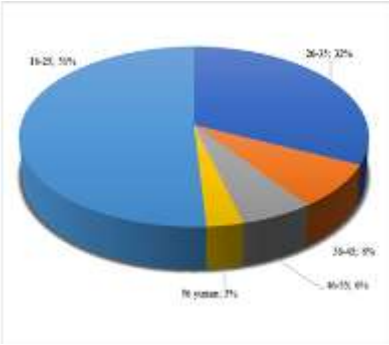

Figure 18. Distribution of healthy food buyers by age groups

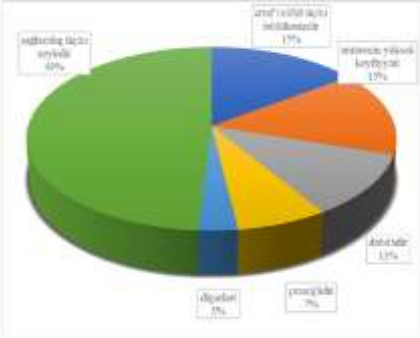

Figure 19. Reasons for choosing healthy food products

The survey results on the criteria for purchasing healthy food products revealed the following: 42% of respondents indicated "price" as an important factor, 25% chose "product quality," 9% cited "opinions of friends and acquaintances," 7% selected "product safety," and 2% mentioned "brand recognition" (see Figure 20).

The respondents' answers to the question about sources of information on products are as follows: 31% indicated "opinions of acquaintances," 26% chose "information on the packaging," 16% referred to "the internet," 15% mentioned "advertising at points of sale," and 12% selected "television" (see Figure 21).

Thus, the marketing research showed that the demand for organic food products in the country is high, and there is significant potential for expanding the market for food products made from wild raw materials.

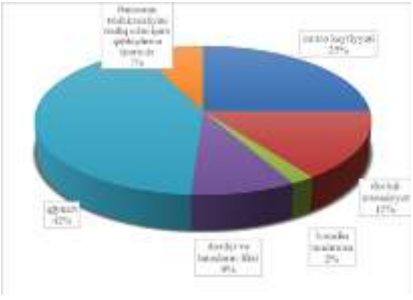

Figure 20. Criteria for purchasing healthy food products

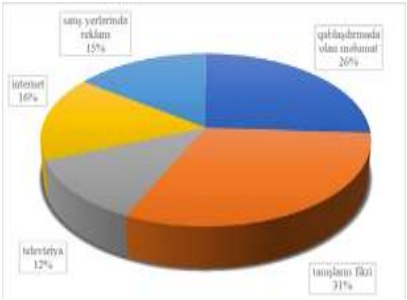

Figure 21. Sources of information for buyers

Results

1. Based on theoretical research and experimental studies, the main biochemical composition indicators of widely distributed wild fruits and berries such as hawthorn, rosehip, medlar, sea buckthorn, and barberry in various regions of the Republic of Azerbaijan have been determined. Innovative green technologies have been developed for the production of new varieties of multifunctional food ingredients and bio-products enriched with biologically active substances from wild fruits and berries.

2. The biochemical and technological foundations of the industrial

processing of Azerbaijan's wild fruit and berry raw materials have been developed, and theoretical-methodological principles have been established. Innovative technological solutions for obtaining bio-ingredients from wild raw materials and their application in the production of healthy food products have been scientifically substantiated. For the first time, the technological potential of five types of wild fruit and berry raw materials for the production of a wide range of bio-products has been determined using low-frequency hydroacoustic extraction, low-temperature sublimation drying, and supercritical fluid carbon dioxide extraction methods.

3. For the first time, a comprehensive set of biochemical indicators of wild sea buckthorn fruits in the territory of Azerbaijan has been determined. It has been established that wild sea buckthorn fruits contain a unique complex of biologically active substances, making them suitable for the production of a wide range of bio-products and multifunctional ingredients. The peel, pulp, and seeds of sea buckthorn fruits have been found to be rich in lipids, carbohydrates, vitamins, and minerals. These findings form the scientific basis for green technologies in the production of juice, natural puree, pectin, and pomace from wild sea buckthorn fruits.

4. For the first time, the identification of isolated pectin substances has been conducted using element analysis, infrared (IR), and nuclear magnetic resonance (NMR) spectroscopy methods. The physicochemical and technological parameters confirming that the pectin substances in sea buckthorn berries are low-esterified pectins have been determined. The high complex-forming ability of pectin in relation to lead ions has been established, allowing its use as an active multifunctional additive in the production of therapeutic and prophylactic products. The optimal technological parameters for extracting oil from sea buckthorn seeds using supercritical fluid carbon dioxide extraction have been determined, and the pharmacological quality, fatty acid composition, and physicochemical characteristics of the obtained oil have been analyzed.

5. For the first time, the physicochemical and mineral composition of wild medlar fruits in the territory of the Republic of Azerbaijan has been comprehensively analyzed. It has been determined that

these fruits contain a high accumulation of essential biologically active substances, providing a biochemical foundation for the development and industrial application of complex processing technologies for wild food raw materials. This finding opens up broad prospects for the production of a wider range of bio-products.

The fractional composition of the lipid complex in the pulp and seeds of medlar fruits has been determined, along with the profile of fatty acids, identifying 14 representatives (C12:0 - C18:3). It has been shown that among the fatty acids, linoleic and linolenic acids, distinguished by their vitamin F activity, are predominant.

6. The fractional composition of carbohydrates in medlar pulp has been determined, revealing that water-soluble hydropectin accounts for more than 60% of the total pectin content. Based on this finding, a low-frequency hydroacoustic processing method has been developed for the first time to obtain fruit paste enriched with activated pectin.

It has been established that the fruit paste exhibits high sorption activity towards zinc ions (2.5 mg Zn^{2+}/mg), which is eight times higher than that of the raw material's native pectin.

The newly developed bio-product has been recommended as a functional food for therapeutic and preventive nutrition. To facilitate practical implementation within the "Bio-Composition" program, regulatory and technical documentation has been developed for the production of "Activated pectin medlar confiture."

7. The optimal technological parameters for extracting oil from medlar seeds using supercritical fluid carbon dioxide extraction have been determined. The organoleptic and physicochemical properties of the obtained oil have been analyzed, and the composition of its fatty acids has been identified. It has been established that the primary components of the oil extracted from wild medlar seeds are polyunsaturated linoleic acid (omega-6) and monounsaturated oleic acid (omega-9). After supercritical fluid extraction, the remaining medlar seed pomace retains a significant amount of polar biologically active antioxidants, particularly polyphenolic compounds, making it a highly valuable food and feed additive.

8. For the first time, the chemical composition characteristics of

wild hawthorn fruits in Azerbaijan have been studied. It has been determined that bio-products obtained from wild hawthorn fruits (natural hawthorn puree, food coloring, pectin, dried pomace, seed oil, and seed pomace) are rich in vitamins, lipophilic compounds, and minerals, possessing high biological and nutritional value. The high biochemical properties of hawthorn fruits provide a scientific basis for developing a rational technological scheme for their industrial processing into healthy and functional food products, multifunctional bio-products, and food ingredients.

It has been established that wild hawthorn fruits contain a high amount of polyphenolic compounds, which have significant biological and nutritional value and can be used as valuable natural food colorants. Based on the proposed green technology, a pigment concentrate rich in biologically active substances (BAS) and mineral elements that enhance the immune system has been obtained.

9. A technological process for nanoencapsulation of aqueous extracts of polyphenolic compounds has been developed using low-methoxylated pectin from sea buckthorn fruits. A comparative analysis of the antioxidant activity of the nanoencapsulated form and the initial polyphenolic compound complex has shown that the former exhibits 15 times higher total antioxidant activity (TAA). This significantly enhances its effectiveness as a biologically active ingredient in the development of functional food products.

The evaluation of the nutritional and biological value of bio-products obtained through green technologies in the complex processing of wild hawthorn fruits (natural hawthorn puree, hawthorn powder obtained after drying, pectin (SE = 75.80%), and pomace obtained after CO_2 extraction) has shown that the initial amounts of biologically active and mineral substances in the composition are high. The total antioxidant activity of fresh fruit, natural puree, and powder obtained after drying was found to be 30.50, 27.30, and 10.20, respectively.

10. For the first time, the biochemical and organoleptic indicator complex of wild barberry fruits in the territory of Azerbaijan has been determined over a wide range. Based on the obtained biochemical results, a new complex processing technology for this

unique food raw material has been proposed. To implement the production of a wide range of functional food products, a bio-product called "Natural barberry puree" has been developed, which contains all the initial biologically active substances (vitamins, polyphenolic compounds, micro- and macromineral elements) from barberry fruits.

An efficient technology for drying barberry fruits using the sublimation method at low temperatures has been developed, and the unique nutritional value of the dried barberry fruits has been assessed. The optimal technological parameters for extracting oil from barberry seeds using supercritical fluid extraction have been determined, along with the organoleptic and physicochemical quality indicators of the obtained oil.

11. The biochemical composition indicators (vitamins, amino acids, macro- and microelements, etc.) of wild rosehip fruits in Azerbaijan have been systematically analyzed. Based on this, a concept for the complex processing of rosehip fruits has been developed and scientifically substantiated using "cold" technologies and universal block-module schemes. This concept aims to produce a wide range of biologically active products that meet high consumer demands.

Considering the modern requirements for resource and energy conservation, as well as ecological safety, new principles for the small-scale complex processing technology of wild rosehip fruits have been proposed. A technological process for supercritical fluid extraction of rosehip seeds has been suggested to obtain oils rich in vitamin groups such as carotenoids, tocopherols, and polyunsaturated fatty acids, suitable for food and pharmaceutical product production. A deep biochemical analysis of rosehip pomace obtained after supercritical fluid extraction has been conducted based on its content of vitamins, amino acids, and macro- and microelements. It has been determined that rosehip pomace can be used as a multifunctional food additive in the production of animal feed and food products.

12. Extensive marketing research has been conducted among different age groups of consumers living in Baku. Based on the sociological surveys, the demand for healthy food products, particularly bio-products made from local wild raw materials, has

been studied. It has been determined that consumers prefer a variety of wild fruit and berry products, highlighting the need to expand the production of new types of healthy food products from wild raw materials.

13. Thus, the scientific hypothesis put forward in the dissertation has been confirmed, the research objectives have been achieved, and the tasks have been completed. An important scientific and practical problem with significant scientific-technical and socio-economic relevance for the country's food industry has been solved. The major operational results of the technical and technological developments have been successfully tested and implemented in leading food industry enterprises with modern equipment and innovative technologies, such as "MARANDİ" LLC, "AzGRANATA" LLC, "AZNAR" JSC named after T. Ahmadov, and "Biyan Products" LLC. The expected technical-economic efficiency has been estimated at 3.84 AZN for every 1 AZN spent.

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The defense of the dissertation will be held on «31» October 2025, at 10⁰⁰ at the meeting of the Dissertation council BED 4.29 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan State Agrarian University.

Address: Az 2000, Republic of Azerbaijan, Ganja city, Ataturk avenue, 450.

Dissertation is accessible at the library of Azerbaijan State Agrarian University.

Electronic versions of the dissertation and its abstract are available on the official website of the Azerbaijan State Agrarian University.

Abstract was sent to the required addresses on «25» September 2025.

Signed to print:19.09.2025
Paper format: (210x297) 1\4
Volume: sign 97268
Number of hard copies: 100