ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES

№2
2026

ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

2026 • 2

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

PUBLISHED SINCE JANUARY 1944

ALMATY, NAS RK

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES.
ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)
Owner: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of Information of the Ministry of Information and Social Development of the Republic of Kazakhstan **№ KZ93VPY00121157** issued **05.06.2025**
Thematic scope: *physics and chemistry.*
Periodicity: 4 times a year.
http://reports-science.kz/index.php/en/archive

ACADEMIC JOURNALOF PHYSICAL AND CHEMICAL SCIENCES

2026 • 2

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES
ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).

Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **05.06.2025 ж.** берген **№ KZ93VPY00121157** Куәлік.

Тақырыптық бағыты: *физика, химия*.

Мерзімділігі: жылына 4 рет.

http://reports-science.kz/index.php/en/archive

ACADEMIC JOURNALOF PHYSICAL AND CHEMICAL SCIENCES

2026 • 2

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES
ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Собственник: ТОО «Центрально-азиатский академический научный центр» (г. Алматы).

Свидетельство **№ KZ93VPY00121157** о повторной регистрации периодического печатного издания информационного агентства, информационного агентства и сетевого издания, выданное Республиканским государственным учреждением «Комитет информации» Министерства культуры и информации Республики Казахстан **05.06.2025**

Тематическая направленность: *физика, химия.*

Периодичность: 4 раза в год.

http://reports-science.kz/index.php/en/archive

CONTENTS

PHYSICS

CHEMISTRY

МАЗМҰНЫ

ФИЗИКА

ХИМИЯ

СОДЕРЖАНИЕ

ФИЗИКА

ХИМИЯ

ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES
ISSN 2224-5227
Volume 2.
Number 358 (2026), 353–366

https://doi.org/10.32014/2026.2518-1483.457

UDC: 615.322
IRSTI: 61.45.36

©Zhetenova M.S.[1]*, Suleimenova M.Sh.[1], Nuraly A.M.[1,2], Mutushev A.Zh.[1,2], Kalimoldina L.M.[1], 2026.
[1]Almaty Technological University, Almaty, Kazakhstan;
[2]Scientific Center for New Technologies, Almaty, Kazakhstan.
*E-mail: madina.zhetenova21@gmail.com

DEVELOPMENT AND RESEARCH OF CAROTENOID-CONTAINING EXTRACTS OBTAINED FROM PLANT RAW MATERIALS

Zhetenova Madina — PhD Student, Assistant, Almaty Technological University, Almaty, Kazakhstan,
E-mail: madina.zhetenova21@gmail.com, https://orcid.org/0009-0005-6596-8789;
Suleimenova Mariya — Candidate of Chemical Sciences, Associate Professor, Almaty Technological University, Almaty, Kazakhstan,
E-mail: s.mariyash@mail.ru, https://orcid.org/0000-0001-5455-6475;
Nuraly Assiya — PhD, Assistant Professor, Leading Researcher, Scientific Center for New Technologies; Almaty Technological University, Almaty, Kazakhstan,
E-mail: assiya488@gmail.com, https://orcid.org/0000-0002-2323-0365;
Mutushev Alibek — PhD, Assistant Professor, Leading Researcher, Scientific Center for New Technologies; Almaty Technological University, Almaty, Kazakhstan,
E-mail: alibek_090@mail.ru, https://orcid.org/0000-0002-5047-5608;
Kalimoldina Laila — Candidate of Technical Sciences, Associate Professor, Almaty Technological University, Almaty, Kazakhstan,
E-mail: kalimoldinal@gmail.com, https://orcid.org/0000-0003-4397-9629.

Abstract. Carotenoids currently play an important and key role in scientific research. Despite the prevalence of carotenoids, there are still some unexplored issues related to variable bioavailability. In this regard, there is a need to study their physical and chemical properties. Thus, the study of carotenoids from plant raw materials is an urgent direction in our modern science and aimed at their application in pharmaceutical industries. They are important biologically active compounds that have activity and are widely used in various industries, especially pharmaceutical ones. Their chemical structure determines their biological activity and physico-chemical properties. The relevance of the study is due to its antioxidant properties. The purpose of this work is to extract carotenoids from plant raw materials (corn and beetroot) and structural characteristics using spectroscopic analysis methods. It was found that the studied carotenoids possess a system of conjugated double bonds, confirmed with the obtained data by IR spectroscopy. IR spectroscopy helped identify the characteristic fluctuations of C-H, C=C bonds, confirming the presence of a polyene chain. Corn powder extract of all parts of corn, beet leaf powder extract obtained by ultrasonic extraction contain a higher number of carotenoids compared to the extract obtained by the traditional method. The amount of carotenoid yield is 30-42% higher after ultrasonic extraction compared to traditional extraction. Studies show their effect on metabolism and the induction of intercellular connections through gap junctions. Thus, carotenoids have a positive effect on a wide range of cellular processes and further research is needed to fully understand their potential in disease prevention and treatment. The scientific novelty of the study is a comprehensive study of the possibility of extracting carotenoids from various parts of Kazakhstan varieties of corn and beet tops by ultrasonic extraction.

Keywords: carotenoids, extraction, vegetable raw materials, antioxidant activity, IR spectroscopy, ultrasonic extraction

Financing. *This study was conducted as part of the targeted financing program for the IRN AR26101397 project «Development of technology for the production of carotenoid-containing preparations based on plant raw materials».*

For citations: *Zhetenova M.S., Suleimenova M.Sh., Nuraly A.M., Mutushev A.Zh., Kalimoldina L.M. Development and Research of Carotenoid-Containing Extracts Obtained from Plant Raw Materials. Academic Journal of Physical and Chemical Sciences. 2026. No.2. Pp. 353–366. DOI: https://doi.org/10.32014/2026.2518-1483.457*

©Жетенова М.С.[1]*, Сүлейменова М.Ш.[1], Нұралы Ә.М.[1,2], Мутушев А.Ж.[1,2], Калимолдина Л.М.[1], 2026.

[1]Алматы технологиялық университеті, Алматы, Қазақстан;
[2]Scientific Center for New Technologies, Алматы, Қазақстан.
*E-mail: madina.zhetenova21@gmail.com

ӨСІМДІК ШИКІЗАТЫНАН АЛЫНҒАН ҚҰРАМЫНДА КАРОТИНОИД БАР СЫҒЫНДЫЛАРДЫ ӘЗІРЛЕУ ЖӘНЕ ЗЕРТТЕУ

Жетенова Мадина — PhD докторант, ассистент, Алматы технологиялық университеті, Алматы, Қазақстан,
E-mail: madina.zhetenova21@gmail.com, https://orcid.org/0009-0005-6596-8789;
Сүлейменова Мария — химия ғылымдарының кандидаты, қауымдастырылған профессор, Алматы технологиялық университеті, Алматы, Қазақстан,
E-mail: s.mariyash@mail.ru, https://orcid.org/0000-0001-5455-6475;
Нұралы Әсия — PhD, ассистент-профессор, жетекші ғылыми қызметкер, Scientific Center for New Technologies; Алматы технологиялық университеті, Алматы, Қазақстан,
E-mail: assiya488@gmail.com, https://orcid.org/0000-0002-2323-0365;
Мутушев Алибек — PhD, ассистент-профессор, жетекші ғылыми қызметкер, Scientific Center for New Technologies; Алматы технологиялық университеті, Алматы, Қазақстан,
E-mail: alibek_090@mail.ru, https://orcid.org/0000-0002-5047-5608;

Калимолдина Лайла — техника ғылымдарының кандидаты, қауымдастырылған профессор, Алматы технологиялық университеті, Алматы, Қазақстан,
E-mail: kalimoldinal@gmail.com, https://orcid.org/0000-0003-4397-9629.

Аннотация. Қазіргі уақытта каротиноидтар ғылыми зерттеулерде маңызды және шешуші рөл атқарады. Каротиноидтардың таралуына қарамастан, өзгермелі биожетімділікке қатысты кейбір мәселелер әлі де зерттелмеген. Осыған байланысты олардың физикалық және химиялық қасиеттерін зерттеу қажет. Осылайша, Өсімдік шикізатынан алынған каротиноидтарды зерттеу Біздің қазіргі ғылымымыздағы өзекті бағыт болып табылады және оларды фармацевтика салаларында қолдануға бағытталған. Олар маңызды биологиялық белсенді қосылыстар болып табылады, олардың белсенділігі бар және әртүрлі салаларда, әсіресе фармацевтикалық салаларда кеңінен қолданылады. Олардың химиялық құрылымы олардың биологиялық белсенділігі мен физика-химиялық қасиеттерін анықтайды. Зерттеудің өзектілігі антиоксиданттық қасиеттерге байланысты. Бұл жұмыстың мақсаты-Өсімдік шикізатынан (жүгері мен қызылша) каротиноидтарды алу және спектроскопиялық талдау әдістерін қолдана отырып құрылымдық сипаттамалар. Зерттелетін каротиноидтардың конъюгаттық қос байланыс жүйесі бар екендігі анықталды, олар алынған ИҚ спектроскопиясымен расталды. ИҚ спектроскопиясы Полиен тізбегінің болуын растайтын байланыстардың тән С-Н, С=С тербелістерін анықтауға көмектесті. Жүгерінің барлық бөліктерінің жүгері ұнтағы сығындысы, қызылша шындарынан алынған ұнтақ сығындысы ультрадыбыстық экстракциямен алынған дәстүрлі әдіспен алынған сығындымен салыстырғанда каратиноидтардың көп мөлшері бар. Дәстүрлі экстракциямен салыстырғанда ультрадыбыстық экстракциядан кейін каратиноидтардың шығарылу мөлшері 30-42% - ға көп. Зерттеулер олардың метаболизмге және саңылаулар арқылы жасушааралық байланыстардың индукциясына әсерін көрсетеді. Осылайша, каротиноидтар жасушалық процестердің кең ауқымына оң әсер етеді және қажет аурулардың алдын алу және емдеуде қолдану әлеуетін толық түсіну үшін қосымша зерттеулер. Зерттеудің ғылыми жаңалығы ультрадыбыстық экстракция әдісімен қазақстандық жүгері мен қызылша шындарының әртүрлі бөліктерінен каротиноидтарды алу мүмкіндігін кешенді зерттеу болып табылады.

Түйін сөздер: каротиноидтар, экстракция, өсімдік шикізаты, антиоксиданттық белсенділік, ИҚ спектроскопиясы, ультрадыбыстық экстракция

©Жетенова М.С.[1]*, Сулейменова М.Ш.[1], Нуралы А.М.[1,2], Мутушев А.Ж.[1,2], Калимолдина Л.М.[1], 2026.
[1]Алматинский технологический университет, Алматы, Казахстан;
[2]Scientific Center for New Technologies, Алматы, Казахстан.
*E-mail: madina.zhetenova21@gmail.com

РАЗРАБОТКА И ИССЛЕДОВАНИЕ КАРОТИНОИДСОДЕРЖАЩИХ ЭКСТРАКТОВ, ПОЛУЧЕННЫХ ИЗ РАСТИТЕЛЬНОГО СЫРЬЯ

Жетенова Мадина — PhD докторант, ассистент, Алматинский технологический университет, Алматы, Казахстан,
E-mail: madina.zhetenova21@gmail.com, https://orcid.org/0009-0005-6596-8789;
Сулейменова Мария — кандидат химических наук, ассоциированный профессор, Алматинский технологический университет, Алматы, Казахстан,
E-mail: s.mariyash@mail.ru, https://orcid.org/0000-0001-5455-6475;
Нуралы Асия — PhD, ассистент-профессор, ведущий научный сотрудник, Scientific Center for New Technologies; Алматинский технологический университет, Алматы, Казахстан,
E-mail: assiya488@gmail.com, https://orcid.org/0000-0002-2323-0365;
Мутушев Алибек — PhD, ассистент-профессор, ведущий научный сотрудник, Scientific Center for New Technologies; Алматинский технологический университет, Алматы, Казахстан,
E-mail: alibek_090@mail.ru, https://orcid.org/0000-0002-5047-5608;
Калимолдина Лайла — кандидат технических наук, ассоциированный профессор, Алматинский технологический университет, Алматы, Казахстан,
E-mail: kalimoldinal@gmail.com, https://orcid.org/0000-0003-4397-9629.

Аннотация. Каротиноиды представляют собой важный класс природных биологически активных соединений, обладающих выраженными антиоксидантными свойствами и широко применяемых в пищевой, фармацевтической и косметической промышленности. Несмотря на значительное количество исследований, ряд вопросов, связанных с их биодоступностью, стабильностью и эффективностью методов извлечения, остаётся недостаточно изученным. В связи с этим исследование каротиноидов растительного происхождения и разработка эффективных способов их экстракции являются актуальным направлением современной науки. Целью работы являлось получение каротиноидсодержащих экстрактов из растительного сырья (различных частей кукурузы и ботвы свёклы) и исследование их структурных особенностей с использованием спектроскопических методов анализа. Для извлечения биологически активных соединений применялись традиционный и ультразвуковой методы экстракции. Структурные характеристики полученных экстрактов изучались методом инфракрасной спектроскопии. Результаты ИК-анализа подтвердили наличие системы сопряжённых двойных связей, характерной для каротиноидов, а также позволили идентифицировать колебания связей С–Н и С=С, свидетельствующие о присутствии полиеновой цепи. Установлено, что экстракты, полученные методом ультразвуковой экстракции из различных частей кукурузы и ботвы свёклы, содержат большее количество каротиноидов по сравнению с образцами, полученными традиционным способом. Выход целевых соединений при использовании ультразвуковой экстракции увеличивался на 30–42 %. Полученные результаты подтверждают перспективность применения ультразвуковой обработки для интенсификации процессов извлечения биологически активных веществ. Научная новизна исследования заключается в комплексном изучении возможности получения каротиноидов из различных частей казахстанских сортов кукурузы и ботвы свёклы с использованием ультразвуковой экстракции. Полученные данные расширяют представления о потенциале растительного сырья как источника природных антиоксидантов и создают предпосылки для их дальнейшего использования в фармацевтической промышленности и профилактической медицине.

Ключевые слова: каротиноиды, экстракция, растительное сырье, антиоксидантная активность, ИК спектроскопия, ультразвуковая экстракция

Introduction. Carotenoids are natural pigments synthesized by plant, algae, fungi. Carotenoids are a class of more than 1200 natural pigments, which consist of beneficial thing. Carotenoids are important for human health because they actively act as antioxidants, helping to protect cells from damage caused by reactive oxygen species. They were associated with a reduced risk of chronic diseases such as diabetes, cancer, heart diseases. In addition, the benefits for the eyes are very great. Also, another role is their activity of provitamin A, the ability of some carotenoids to form vitamin A under the action of dioxygenase enzymes (Nikolay et al., 2023).

Carotenoids are divided into groups according to the number of carbon atoms. Carotenoids containing carbon atoms include also oxides: vitamin A and crocetin— the yellow coloring agent of saffron, norbixin and bixin and others. Likewise, in the human body, carotenoids have an effect against intense light and damage by harmful free radicals and maintain the integrity of biological membranes in structure, functionality. The mechanisms of action of carotenoids on health are considered complex and further research is needed to provide a comprehensive understanding. Carotenoids are indispensable for human health. Many of them are huge, and only a small part is fully studied. Carotenoids are essential for our body. Carotenoids are found in large quantities in plants, including beets and corn, which contain a large amount of carotenoids.

Literary review. Carotenoids are a common class of isoprenoid pigments that can be synthesized by photosynthetic organisms as well as bacteria (Wellala et al., 2022). Carotenoids can be divided into two main groups: nonpolar carotenes: β-carotene and lycopene, hydrocarbon compounds and polar xanthophylls, such as lutein and canthaxanthin, whose structures contain hydrogen, carbon, oxygen (Genç, 2020). Carotenoids can be divided into pro- and provitamin A, which cannot be converted into retinoid groups. Carotenoids are effective compounds with antioxidant properties and are non-toxic.

Underutilized agro-industrial residues offer promising, low-cost feedstocks for the recovery of valuable phytochemicals. In maize (Zea mays), xanthophylls such as zeaxanthin and lutein are mainly associated with the kernel, particularly the endosperm and aleurone layers, whereas maize cobs represent a lignocellulosic byproduct generated after grain removal. Therefore, maize processing residues, including ker-nel-derived fractions and other byproducts, may serve as potential sources of carote-noid-containing materials, depending on their composition and processing.

Beet tops (Beta vulgaris leaves), often discarded after root harvest, are rich in lutein co-occurring with betalains for potential synergistic antioxidant effects. Bilberry leaves (Vaccinium myrtillus) provide lutein together with anthocyanins, enhancing overall bioactivity. These materials are abundant in Kazakhstan's agro-sector, representing an opportunity for local valorization and reduced environmental impact from waste disposal.

Conventional extraction methods such as organic solvent maceration, Soxhlet extraction, or alkaline hydrolysis suffer from several drawbacks: prolonged pro-cessing times (hours to days), high solvent consumption (toxic volatile organics), en-ergy intensity, and thermal/oxidative degradation of labile carotenoids, leading to isomerization (trans-cis) and loss of bioactivity. These limitations conflict with green chemistry principles (e.g., reduced hazardous substances, energy efficiency).

Ultrasonic-assisted extraction (UAE) addresses these issues by harnessing acous-tic cavitation: the formation, growth, and implosion of microbubbles in liquid media generates localized extreme conditions high temperatures (~5000 K), pressures (>1000 atm), microjets (>100 m/s), shear forces, and microturbulence that disrupt cell walls, weaken intermolecular bonds (hydrogen/hydrophobic), enhance solvent penetration, and accelerate mass transfer without bulk heating.

Recent studies demonstrate UAE's superiority for carotenoid recovery from various matrices, achieving 20–93% yield increases over conventional methods while preserving structural integrity and anti-oxidant capacity. Response surface methodology (RSM) with central composite de-sign (CCD) has proven effective for multi-parameter optimization (temperature, time, solvent ratio, power), yielding robust models for process scale-up.

In recent years, more than 700 carotenoids have been identified in nature. The structure of carotenoids is sensitive, especially the molecular structure and high temperatures when exposed to light can be compromised so care must be taken when handling them. The frequency of carotenoids may also differ from the selected extraction methods and purification process.

According to their chemical structure, carotenoids are divided into two main groups: carotenes and xanthophylls. Carotenes are hydrocarbon compounds and consist exclusively of carbon and hydrogen atoms.

The extraction process is the physical separation of the components of a mixture, which is based on the difference in their solubility in two liquids or in an absorber. There are two common types of extraction: solid phase and solvent extraction.

Solvent extraction is mainly based on the extraction of uncharged particles from a water system with an organic solvent or the extraction of polar ionized particles from a solvent into an aqueous solution (Mustafa et al., 2011).

Carotenoids are mainly found in different parts of plants: leaves, seeds, fruits, and roots (Toti et al., 2018). There is also a daily consumption range (mg) of carotenoids. Consumption and daily rate are shown in Table 1.

Table 1. Daily consumption rate and main sources of some carotenoids.

№	Carotenoids	Recommended daily consumption rate (mg)	Main sources
1	β-carotene	0,95-8,700	Carrots, blueberries, blueberries, beans and other vegetables
2	α-carotene	0,13-2,35	Corn, carrot, pumpkin
3	Lutein	1,1-4,13	Broccoli, carrots, corn, beets and other green vegetables, fruits
4	Zeaxanthin	0,89-4,10	Pumpkin, sweet corn, beetroot, tomato, carrot

Daily consumption and their recommendation are useful for absorbing useful activity. Reports from foreign studies have shown that high consumption of carotenoids can help reduce the risk of various diseases. The recommended intake is based on meeting the need for 780-800 mcg of vitamins A.

Many carotenoids are found in cell structures and traditional extraction methods using organic solvents are safe solvents, including biodegradable. However, sometimes it is difficult for solvents to enter the cellular environment to come into contact with carotenoids, so the penetration and extraction of carotenoids to increase efficiency requires physical methods such as ultrasound (Goula et al., 2017). The process of obtaining a drug containing a group of carotenoids consists of several stages. The steps of the process are shown in Figure 1.

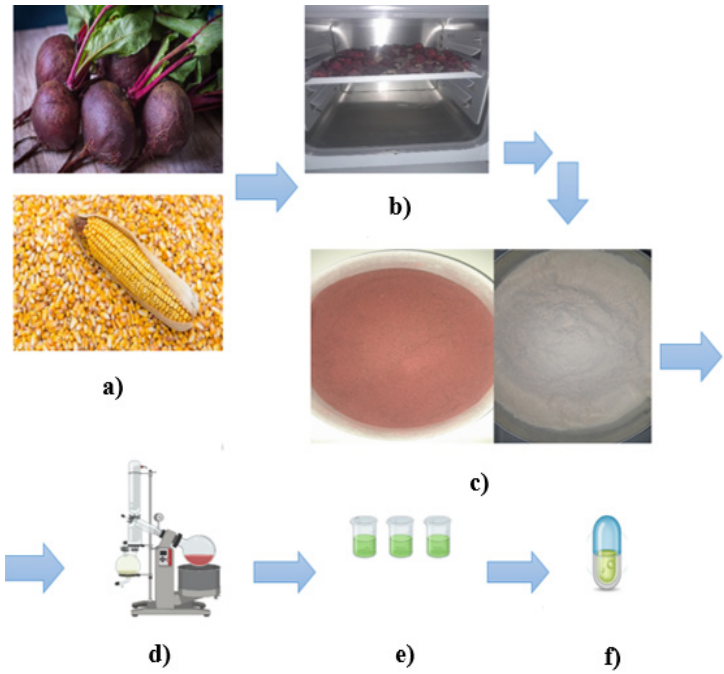

Figure 1. The process of obtaining carotenoids from vegetable raw materials (corn and beetroot): a) source, b) drying in the vacuum drying cabinet, c) crashing of plant raw materials, d) rotary evaporation, e) liquid extraction, f) the finished product.

As a result of the study, it was found that ultrasonic extraction is a more effective method of extracting carotenoids from various parts of corn compared to traditional extraction. Extraction was carried out from 600 gram of corn powder of 8 varieties of corn of all parts and separately of grains and husks using hexane (1:15 by weight/ vol.) at a temperature of 30-40 ° C for 2 hours.

Blueberry leaves and berries were treated in a similar way: washed, dried at 35-40 °C in a vacuum (VAC-24, Thermo Fisher Scientific) for 7 hours to a humidity of <5%, crushed to a particle size of 0.5–0.7 mm and stored under the same conditions.

Lutein from beet tops and blueberry leaves was extracted using ethyl acetate: ethanol (1:1 vol./vol.) under identical conditions. The extracts were subjected to alkaline hydrolysis (5-10% NaOH, 20-30 °C, atmosphere N °, 90 min), neutralization to pH 7 with distilled water, and concentration by rotary evaporation (Laborota 4000) at a temperature of <40 °C.

Materials and Methods. Materials: H_2O, organic solvents: butanol, hexane (CFA) ratio 1:10, 1:20, 10-11% pentane, 5-10% sodium hydroxide solution.

Methods: solvent extraction method, infrared spectroscopy using the IRTracer-100 from Shimadzu.

Corn cobs and beets were dried in a VAC-24 vacuum cabinet at a temperature of 35-40 °C for 5-7 hours. The dried samples were ground in a laboratory mill to a fraction of 0.7 mm. The preparation of raw materials also includes additional drying of 500-600-gram powders at a temperature not exceeding 50-60 ° C in order to prevent thermal degradation of carotenoids.

The extraction process includes the following steps: the extraction of zeaxanthin and lutein was carried out with an organic solvent, hexane and butanol, at a temperature of 30-40 ° C and a ratio of raw materials and solvent 1:10-1:20. The process is based on the diffusion transfer of carotenoids from the plant matrix into the extraction medium and is accompanied by the destruction of protein-lipid complexes.

Further, to convert the essential forms of zeaxanthin and lutein to a free state, alkaline hydrolysis was performed using 5-10% sodium hydroxide solution at a temperature of 23-25 °C in an inert atmosphere. The extract was purified by washing to a neutral pH, followed by extraction with 10-11% pentane and concentration. Additionally, the extract was purified with distilled water to pH = 7. A powder volume of 480-500 grams was obtained.

Quantitative determination of carotenoids in the samples was carried out by the spectrophotometric method. The sample weight of 0.05 g was accurately weighed and placed in a measuring flask with a volume of 0.1 dm3. Extraction of the target compounds was carried out by adding ethanol, preheated to 40 °C, followed by thorough mixing until the extractives were completely dissolved.

The optical density of the obtained solution was measured using a Shimadzu UV-1800 spectrophotometer. The measurements were carried out in a cuvette with an optical layer thickness of 0.01 cm at a wavelength of 450 nm, corresponding to the maximum absorption of carotenoids. Pure ethanol was used as the reference solution.

After the measurement, the sample was cooled to 20 ° C, then the volume of the solution in the measuring flask was brought to the mark with ethanol and thoroughly mixed to ensure uniformity. After obtaining samples for purity determination, as well as structural analysis, studies were conducted using infrared spectroscopy on the IRTracer-100 device from Shimazu.

Results and discussions. As a result of traditional solvent extraction, the total extraction time was about 3-4 hours, and ultrasonic extraction took 35-40 minutes. Extracts of the following samples were obtained: 8 samples of corn powder extract of all parts, 1 sample of beetroot powder extract, 1 sample of blueberry leaf/berry powder.

Carotenoids are lipophilic compounds, so their extraction largely depends on the ability of the raw material matrix to interact with the solvent, as well as on structural changes caused by ultrasonic cavitation.

In this study, the influence of the following indicators was evaluated: bulk density, moisture capacity, oil retention capacity, swelling ability and hydration density on the carotenoid content in ultrasound extracts. The results are summarized in Table 2.

Table 2. Functional and technological properties in traditional extracts.

Material	Bulk density (g/ml)	Moisture capacity (ml/g)	Oil retention capacity (g/g)	Swelling capacity (ml/g)	Hydration density (g/ml)
Beetroot powder	1,8	1,5	1,5	10,5	9,3
Corn powder	1,15	1.1	1.2	11,8	0,5
Blueberry Leaf/ Berry Powder	0,9	0,8	1,8	9,5	2,1

The bulk density reflected the degree of compactness of the powder particles. High values of this indicator (more than 0.8 g/ml) lead to a decrease in porosity and a deterioration in the penetration of the solvent deep into the particles. Under ultrasonic treatment conditions, this limits the effect of cavitation and reduces the efficiency of mass transfer.

The low bulk density of the studied substances (powder from beet tops, powder from corn cobs, powder from blueberry leaves/berries) contributes to an increase in the inter particle space. Moisture capacity characterizes the powder's ability to bind and retain water. High values of these parameters contribute to a more complete wetting of the plant matrix and activation of the ultrasonic capillary effect. Improved hydration leads to swelling of the cell walls, their partial destruction under the action of cavitation forces and a more efficient release of carotenoids associated with proteins and polysaccharides.

An analysis using infrared spectroscopy was performed to determine the chemical structure and purity of the functional group analysis. The result is shown in Figure 2.

Infrared spectroscopy was used to determine the presence of carotenoid-containing substances zeaxanthin and lutein in the obtained extracts (Figure 2). IR spectra were recorded in the range of 4000-400 cm^{-1}. Spectrum analysis revealed characteristic absorption bands corresponding to the functional groups included in the structure of zeaxanthin and lutein.

Infrared spectroscopy (FTIR) is a method that determines the characteristics of bonds to use for quantitative and qualitative analysis. This is an analytical method that relies on molecules absorbing infrared radiation of a certain frequency and also matching the oscillation frequencies of their chemical bonds.

The study by Aldo Rosales (2022) explains that the standard deviation is calculated between the results obtained using IR radiation and the reference values for calibration or verification. In addition, the calibration determination coefficient and the verification determination coefficient are also calculated.

Strong bands related to valence vibrations of the C⁻H bonds of methyl and methylene groups of carbon–hydrogen chains are recorded in the region of 3000-2800 cm^{-1}. A wide band in the range of 3400-3200 cm^{-1} indicates the presence of hydroxyl groups (O–H), which may be associated with both remaining moisture and hydroxylated forms of carotenoids (for example, lutein and zeaxanthin).

In the «fingerprint region» (1500-900 cm^{-1}), there are a number of intense peaks corresponding to the C–O, C–C, and deformation vibrations of the CH_2/CH_3 groups. Bands in the range of 960-900 cm^{-1} are characteristic of out–of-plane deformation vibrations =C-H of trans-disubstituted double bonds typical of the carotenoid structure.

Bands corresponding to valence vibrations of the C-O bonds of alcohol groups are recorded in the range of 1020-1100 cm^{-1}. Their presence further confirms the oxygen-containing nature of the studied compounds and is consistent with the literature data for lutein and zeaxanthin.

The results obtained are important for understanding the structural features of carotenoids and their behavior in various environments. The obtained patterns can used for a more accurate interpretation of the infrared spectra of carotenoids and for methods of qualitative and quantitative analysis. The data obtained expands the understanding of sensitivity.

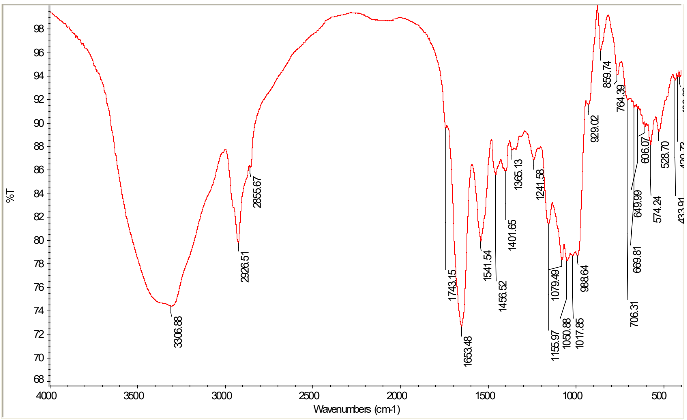

Figure 2. Results of IR spectroscopy of corn flour samples.

Figure 2 shows the IR spectrum of samples from corn powders. Characteristic absorption bands are observed in the spectrum, confirming the presence of carotenoids. Intense bands in the range of 1650-1500 cm^{-1} correspond to valence vibrations of conjugated C=C double bonds of the polyene chain of carotenoids.

The most pronounced peaks in the region of 1550-1520 cm^{-1} are typical for beta-carotene, lutein, and other carotenoids.

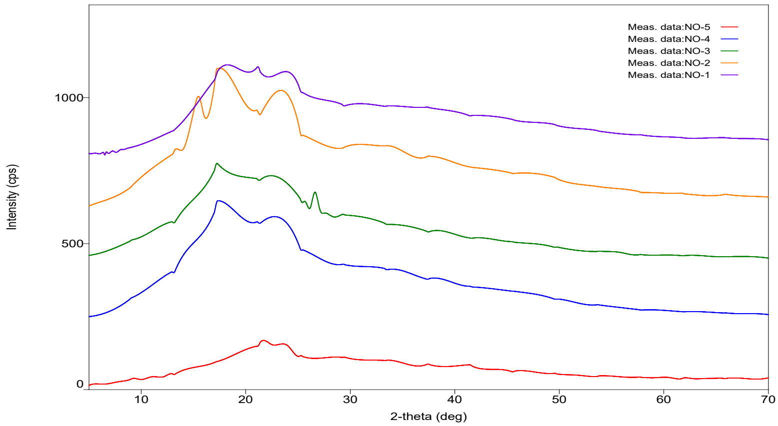

Figure 3. The result of X-ray analysis of samples of corn and beet tops.

Figure 3 shows the diffractograms of the studied samples, and also all samples exhibit similar diffraction peaks, which indicate the formation of a crystalline phase. At the same time, the main diffraction maxima are located in the same regions, which indicates the identity of the structure of the studied samples.

The resulting spectrum confirms the successful extraction of carotenoids by ultrasonic extraction and reveals a characteristic 'profile' of highly conjugated polyene compounds.

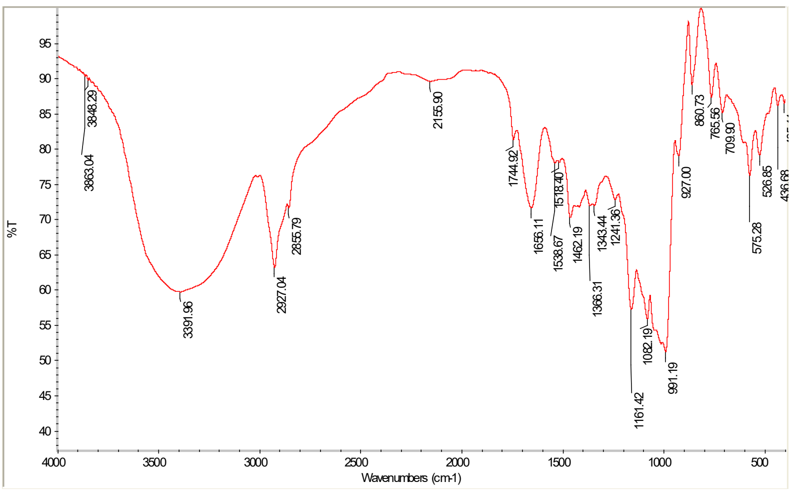

Figure 4. Results of IR spectroscopy in beet samples.

A distinctly pronounced band in the range of 1640-1660 cm^{-1} refers to fluctuations in conjugated C=C double bonds. This area is diagnostically significant for carotenoids and indicates the presence of an extensive system of conjugated double bonds that determine the optical properties of lutein and zeaxanthin. In the range of 1020-1100 cm^{-1}, a group of bands corresponding to valence vibrations of C–O bonds of alcohol groups is observed. Their presence further confirms the oxygen-containing nature of the studied compounds. The bands in the range of 960-1000 cm^{-1} are associated with deformation fluctuations =C-H of vinyl and allylic fragments characteristic of the carotenoid skeleton. In the low frequency range of the spectrum (800-900 cm^{-1}), slight deformation fluctuations of methyl groups are recorded.

The extract of corn powder from all parts of Kizurax-150 corn, extract of powder from beet tops, extract of powder from leaves/blueberries obtained by ultrasonic extraction contain a higher amount of carotenoids compared to the extract obtained by the traditional method. The amount of carotenoid yield is 30-42% higher after ultrasonic extraction compared to traditional extraction. The results of the quantitative determination of carotenoids are shown in Figure 5. The graph is built using the Microsoft Origin program.

As is known, carotenoids are able to absorb ultraviolet radiation and light in various regions of the spectrum, since conjugated double bonds are present in the structure of carotenoids. The solvent used also has a key effect on the absorption of the compound. The carotenoid content is determined by absorbing a sample at a certain wavelength with absorption calculations that are given in foreign literature. The total carotenoid content is expressed in equivalents (Butnariu et al., 2016).

The obtained spectrum confirms the successful extraction of carotenoids by ultrasonic extraction and demonstrates the characteristic "profile" of polyene compounds with a high degree of conjugation.

Due to the fact that the extract of corn powder is the most optimal in terms of functional and technological properties, as well as according to the results of IR spectroscopy, it was later decided to conduct a study to determine the content of phenolic compounds (TPC) and total flavonoid content (TFC) only for samples of corn powder from corn grain and husk.

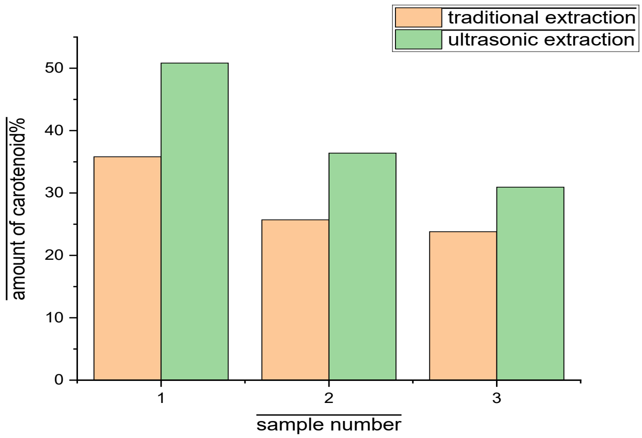

Figure 5. The actual yield of carotenoids during conventional and ultrasonic extraction.

As a result of the study, it was found that ultrasonic extraction is a more effective method of extracting carotenoids from various parts of corn compared to traditional extraction.

Conclusion. During the research, carotenoids were extracted from vegetable raw materials (corn and beetroot). Butanol was chosen as the optimal solvent. The optimal drying temperature is 36-40°C. After receiving the samples, IR spectroscopy and X-ray analysis were performed. IR spectroscopic analysis showed peaks in the range from 1250 to 3300 cm^{-1}. A number of characteristic absorption regions correspond to valence vibrations of C-H bonds, as well as conjugated C=C double bonds. This proves the presence of a hydrocarbon chain with a coupling system that is characteristic of carotenoids.

Samples of four varieties of corn and beet tops were examined. A comparison of the diffractograms showed a similar distribution of X-ray intensity, however, individual differences in the position and intensity of the maxima indicate a different degree of structural ordering of the studied samples.

During the research, the properties and role of carotenoids and their antioxidant activity were studied. The results show that carotenoids play a key role in protecting the body from oxidative stress and at the same time can contribute to the prevention of a number of chronic diseases. In the future, it is advisable to conduct more extensive studies aimed at studying bioavailability and their effectiveness.

The excellent results of ultrasonic extraction (UE) in the extraction of zeaxanthin and lutein from corn cobs, beet tops and blueberry leaves are primarily due to acoustic cavitation, which fundamentally alters the physico-chemical dynamics of the extraction process compared to traditional solvent-based methods.

Alkaline hydrolysis effectively cleaved esterified forms, releasing free xantho-phylls without detectable chemical modification of the polyene backbone, as confirmed by FTIR structural analysis. The key intensification factor was acoustic cavitation in-duced by ultrasound (40 kHz, 200 W), which promoted rapid cell wall disruption, sonoporation, microjet formation, boundary layer thinning, and enhanced mass transfer.

In traditional solvent extraction, carotenoid release is based on passive diffusion and equilibrium distribution, limited by an intact cell wall barrier, protective lipid-protein complexes, and low rates of mass transfer through the boundary layer. The extraction efficiency is limited by the coefficient of dilution and requires a long contact time, elevated temperatures and large volumes of solvent, which often leads to thermal/oxidative degradation and partial trans-cis isomerization of sensitive xanthophylls.

References

Aldo R., José C., Jaime C., Luisa C., Thanda D., Thokozile N., Natalia P. (2023). Near-Infrared Spectroscopy to Predict Provitamin A Carotenoids Content in Maize. Agronomy. – No. 12(5). – P. 1027. DOI: 10.3390/agronomy12051027 (in Eng.).

Butnariu M. (2016). Methods of Analysis (Extraction, Separation, Identification and Quantification) of Carotenoids from Natural Products. J. Ecosyst. Ecography. – No. 6. – P. 1-19. DOI: 10.4172/2157-7625.1000193 (in Eng.).

Ewelina K., Marcin Andrzej K. (2022). Green Extraction of Carotenoids from Fruit and Vegetable Byproducts: A Review. Molecules. – No. 27(2). – P. 518. DOI: 10.3390/molecules27020518 (in Eng.).

Genç Y., Bardakci H., Yücel Ç., Karatoprak G., Akkol E.K., Barak T.H., Sobarzo-Sánchez E. Oxidative stress and marine carotenoids: Application by using nanoformulations. Mar. Drugs. – No. 18. – P. 423. DOI: 10.3390/md18080423 (in Eng.).

Goula A.M., Ververi M., Adamopoulou A., Kaderides K. (2017). Green ultrasound-assisted extraction of carotenoids from pomegranate wastes using vegetable oils. Ultrason. Sonochem. – No. 34. – P. 821-830. DOI: 10.1016/j.ultsonch.2016.07.022 (in Eng.).

Joel B., Kerry B., Mani N. (2023). The Use of Infrared Spectroscopy for the Quantification of Bioactive Compounds in Food: A Review. Molecules. – No. 28(7). – P. 3215. DOI: 10.3390/molecules28073215 (in Eng.).

Nikolay E., Ligia Focsan A., Yunlong G. (2023). The Endless World of Carotenoids—Structural, Chemical and Biological Aspects of Some Rare Carotenoids. Int. J. Mol. Sci. – No. 24(12). – P. 9885. DOI: 10.3390/ijms24129885 (in Eng.).

Papapostolou H., Kachrimanidou V., Alexandri M., Plessas S., Papadaki A., Kopsahelis N. (2023). Natural Carotenoids: Recent Advances on Separation from Microbial Biomass and Methods of Analysis. Antioxidants. – No. 12. – P. 1030. DOI: 10.3390/antiox12051030. (in Eng.).

Saini, R.K.; Keum, Y.S. (2018) Carotenoid extraction methods: A review of recent developments. Food Chem. – No. 240. – P. 90-103. (in Eng.).

Swapnil P., Meena M., Singh S.K., Dhuldhaj U.P., Marwal A. (2021). Vital roles of carotenoids in plants and humans to deteriorate stress with its structure, biosynthesis, metabolic engineering and functional aspects. Curr. Plant Biol. – No. 26. – P. 100203. DOI: 10.1016/j.cpb.2021.100203 (in Eng.).

Wellalala D.C.K., Jinfeng B., Xuan L., Xinye W., Jian L., Jianing L., Dazhi L., Chongting G. (2022) Effect of high pressure homogenization on water-soluble pectin characteristics and bioaccessibility of carotenoids in mixed juice. Food Chemistry. – No. 371. – P. 131073. DOI: 10.1016/j.foodchem.2021.131073 (in Eng.).

Publication Ethics and Publication Malpractice in the journals of the «Central Asian Academic Research Center» LLP (Almaty)

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the originality detection service Cross Check http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will onh accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Requirements for articles design for publication in the journal are available on the websites:

www:nauka-nanrk.kz

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

http://reports-science.kz/index.php/en/archive

Managing Editor: T. Apendiev

Editors: D.S. Alenov, A.Shormakova

Computer layout: G.D. Zhadyranova

Signed for print: June 22, 2026

Format: 70×90 1/16. 24.5 printed sheets. Order No. 2.

«Central Asian Academic Research Center» LLP

Almaty, Shevchenko Street, 28