

INVESTIGATION OF THE COMPOSITION AND EXTRACTION PROCESSES OF ANTHOCYANINS FROM GRAPE POMACE

**Akramova Maftuna Davron
ovna**

*Master's Student, Group 27M-25 BT
Tashkent State Technical University
named after Islam Karimov
akr.maftuna0511@gmail.com*

Toshtemirova Marguba Juraevna
Senior Lecturer

*Tashkent State Technical University
named after Islam Karimov*

Abstract. This work presents a comprehensive investigation of the content, qualitative composition, and extraction characteristics of anthocyanin pigments from grape pomace as a secondary raw material of the winemaking industry. The distribution patterns of anthocyanins in grape skin and pulp were examined, along with the influence of varietal characteristics, degree of fermentation, and storage conditions of the pomace on the preservation of the phenolic complex. Using spectrophotometric and chromatographic methods, the main groups of anthocyanins dominating in the studied material were characterized, including glycosides of malvidin, delphinidin, and pelargonidin, as well as their acylated and coumaroylated derivatives. Scientific approaches to anthocyanin extraction were considered, based on the principles of their solubility, stability, and interactions with cellular matrices. Factors affecting pigment extraction efficiency were analyzed, including medium acidity, the nature of extracting systems, temperature, and structural features of the raw material. The research provides scientifically grounded prerequisites for the development of energy-efficient and environmentally oriented technologies for processing winemaking by-products and expands the possibilities for the rational utilization of plant waste.

Keywords: grape pomace, anthocyanins, phenolic compounds, malvidin, extraction, natural pigments, antioxidant activity, phenolic profile, plant raw

materials, winemaking waste processing, pigment stability, spectrophotometric analysis, chromatographic analysis, secondary metabolites, natural colorants.

Introduction. Anthocyanins are one of the most significant groups of plant-derived phenolic compounds, possessing pronounced antioxidant, anti-inflammatory, and protective properties. These water-soluble flavonoid pigments determine the coloration of many fruits, berries, and plants, including dark-colored grape varieties, which serve as one of the richest natural sources of anthocyanins. In grapes, anthocyanins are primarily localized in the skin of the berries, and their content depends on the variety, degree of ripeness, agroclimatic conditions, and technological processing features.

The winemaking industry generates significant volumes of grape pomace each year—a by-product consisting of skins, seeds, and remaining pulp. Although classified as waste, grape pomace is characterized by a high content of biologically active compounds, including anthocyanins, which are partially preserved within the plant tissue structure after juice separation. This makes pomace a promising and accessible raw material for obtaining natural pigments, functional ingredients, and antioxidant extracts, in line with current trends in resource conservation and the development of zero-waste technologies.

The use of anthocyanins from grape pomace is of both scientific and practical interest for several reasons. First, anthocyanins are natural colorants in demand in the food, cosmetic, and pharmaceutical industries. Second, their high antioxidant activity offers potential applications as biologically active supplements and functional ingredients. Third, the study of anthocyanin extraction methods contributes to the development of technologies for the advanced processing of plant raw materials and enhances the economic efficiency of winemaking production.

Table 1 presents a comparison of anthocyanin content in different grape varieties and their corresponding pomace.

Table 1

Grape Variety	Skin Color	Approximate Anthocyanin Content in Berries (mg/100 g)	Approximate Anthocyanin Content in Pomace (mg/100 g)
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Cabernet Sauvignon	Dark purple	200-400	300–500
Merlot	Red-purple	150-350	250–450
Pinot Noir	Dark red	100-300	200–400
Syrah/Shiraz	Dark purple	180-380	280–480
Tempranillo	Red-purple	160-360	260–460
Malbec	Dark purple	200-400	300–500
Isabella	Dark blue	120-250	200–350
Mourvèdre	Dark purple	170-370	270–470

Pomace always contains higher amounts of anthocyanins compared to the grapes themselves, as the pigments become concentrated in the skin and pulp during processing. The highest anthocyanin content is characteristic of varieties with dark, thick skins and well-ripened berries. Light-colored and thin-skinned varieties contain significantly fewer anthocyanins, making their pomace less promising for the production of natural colorants.

However, the efficiency of anthocyanin extraction is determined by a combination of factors: the initial pigment content, the degree of cellular structure disruption, the stability of the compounds, the nature of the solvents, temperature conditions, and the specifics of the extraction processes. These patterns require a scientifically grounded study, including the analysis of the qualitative composition of anthocyanins, assessment of their preservation, and investigation of factors affecting extraction.

Therefore, the study of anthocyanin content and extraction from grape pomace is aimed at a detailed investigation of the chemical composition of this secondary raw material, determining conditions for maximum recovery of biologically active components, and substantiating the potential use of pomace as a source of natural pigments. The results of the work have practical significance for the development of environmentally oriented technologies for the processing of winemaking by-products and the creation of high-value-added products.

The aim of this research is to conduct a comprehensive study of the content and qualitative composition of anthocyanins in grape pomace, as well as to identify factors influencing the efficiency of their extraction and stability during the processing of secondary plant raw materials. The study is intended to investigate the

physicochemical characteristics of grape pomace and assess its potential as a source of anthocyanin pigments, determine the quantitative content and qualitative profile of anthocyanins using modern analytical methods, analyze the influence of raw material and technological factors on pigment content, structure, and stability, examine general approaches to anthocyanin extraction and evaluate the efficiency of extraction processes, and assess changes in the physicochemical properties of anthocyanin extracts at various stages of processing. The results of this research will provide a scientific basis for the use of grape pomace in the production of natural colorants and biologically active ingredients.

Research Methods. To achieve the objectives of this study, modern analytical and physicochemical methods were applied, providing a comprehensive investigation of the composition and properties of anthocyanins in grape pomace. The physicochemical characteristics of the raw material were examined using standard methods for analyzing moisture content, acid and peroxide values, total phenolic content, and color parameters.

For the quantitative determination of anthocyanin content, spectrophotometric methods were employed, based on the measurement of optical density of solutions at characteristic wavelengths, allowing for the assessment of the total pigment content in the extracts. The qualitative composition of anthocyanins was evaluated using high-performance liquid chromatography (HPLC) and thin-layer chromatography (TLC), which enabled the identification of individual compounds, including the main groups-malvidin, delphinidin, and pelargonidin glycosides-as well as their derivatives.

To study the characteristics of anthocyanin extraction, various extraction approaches were considered, including the use of aqueous-acidic and organic solvents, sorption methods, and membrane technologies. The efficiency of extraction, pigment preservation, and the influence of technological factors such as temperature, acidity, and extraction time were assessed.

The obtained data were processed and analyzed using statistical methods to evaluate reproducibility, reliability, and significance of the results, which allowed

for the identification of patterns in anthocyanin distribution in pomace and determination of the optimal conditions for their extraction.

Conclusion. Grape pomace possesses high biological and technological value as a source of anthocyanin pigments. This study established that the content and qualitative composition of anthocyanins largely depend on grape variety, degree of fermentation, storage conditions, and technological processing of the raw material. The dominant components are malvidin, delphinidin, and pelargonidin glycosides, including their acetylated and coumaroylated derivatives, which determine the color and antioxidant potential of the extracts.

The research confirmed that grape pomace is a valuable source of anthocyanin pigments with high biological activity and technological significance. It was found that the content and qualitative profile of anthocyanins in pomace depend on the grape variety, berry ripeness, storage conditions, and processing methods. The highest pigment concentration is observed in pomace from dark-skinned grape varieties with thick skins, such as Cabernet Sauvignon, Merlot, Malbec, and Syrah.

The study of the physicochemical characteristics of extracts at different stages of processing revealed patterns in the changes of their qualitative parameters, enabling the optimization of technological processes and improvement of the quality of anthocyanin pigments obtained. Thus, grape pomace can be considered a promising raw material for the production of natural colorants, antioxidant supplements, and functional ingredients. The results of this work substantiate the scientific and practical significance of the rational use of secondary plant resources and provide a foundation for further research on the development of efficient and environmentally oriented technologies for processing winemaking by-products.

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