

VERJUICE PRODUCTION TECHNOLOGY: ANALYSIS OF UNRIPE GRAPE COMPOSITION, ITS ROLE IN THE FOOD INDUSTRY AND TRADITIONAL-INNOVATIVE TECHNOLOGICAL APPROACHES

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Abstract. *Recent scientific studies on unripe grapes (verjuice) composition indicate its high potential for application in the food, pharmaceutical, and cosmetics industries. The biological activity of organic acids, polyphenols, vitamins, and minerals present in its composition distinguishes it as a functional food product. This review article analyzes existing scientific sources on the chemical and bioactive composition of unripe grapes, the processing of verjuice products using traditional and innovative technologies, as well as their industrial applications and potential. Additionally, opportunities for expanding the practical significance of these products in local and international food industries through the development of new technological approaches based on unripe grapes are discussed.*

Keywords: *vitis vinifera, verjuice, unripe grape, physical and chemical parameters.*

Introduction. Grapevine (*Vitis vinifera*) is widely cultivated across almost all regions of the world, with an annual yield exceeding 75 million tons [1]. The majority of the harvested grapes, approximately 75%, are directed towards wine production, while the remaining portion is consumed as fresh fruit, raisins, and juice [2–3]. Consequently, the winemaking industry generates a significant amount of secondary organic waste—pomace (grape skins), leaves, vine shoots, and unripe grapes. In recent years, effective utilization of these secondary products, especially unripe grapes, has become a relevant topic in scientific circles as a means to enhance agro-industrial sustainability, reduce environmental burden, and provide economic benefits [4]. Unripe grapes primarily result from green pruning practices and serve to optimize the number of fruits on the vine, thereby improving the quality of the main grape harvest [5]. However, rather than being regarded as waste, these products can be processed as sources of biologically active compounds such as organic acids, phenolic substances, vitamins, and microelements.

This review article analyzes existing scientific literature on the chemical composition, biological significance, and industrial potential of unripe grape (verjuice) products. Additionally, traditional and innovative processing methods, the extraction of bioactive compounds, and the practical applications of these products are comprehensively summarized and scientifically discussed.

Composition of unripe grapes and their role in the food industry. Although unripe grapes (verjuice) have long been used in traditional methods for preparing various acidic juices, sauces, and digestive beverages, modern scientific approaches allow for a much broader reevaluation of this product's potential. Particularly in the mediterranean region, verjuice—known

as a natural acidifying agent—has historically been used in ancient cuisines as a substitute for lemon or vinegar [6–7]. The verjuice product is known by different names across various cultures: verjus in france, agresto in italy, and koruk in turkey. According to scientific literature, unripe grape products harvested at the fully unripe stage (before the veraison phase) are rich in phenolic compounds, flavonoids, tannins, glutathione, vitamins, and acids [8–11]. During this period, the yield of juice ranges between 40–60%, depending on the extraction method, variety characteristics, and harvest time. According to the eichhorn-lorenz phenological system, juice obtained from grapes harvested at stages 32–34 accounts for 54–60%, while mechanical pressing reduces this amount to approximately 47% [8]. The physicochemical parameters of the juice are summarized in table 1 and are characterized by high acidity, low brix values, and a high glucose/fructose ratio. These components give unripe grape products their distinctive sourness, aroma, and shelf-life properties. For this reason, verjuice products have recently been used not only as condiments but also as natural preservatives, antioxidants, and biocatalysts in the food industry [12].

Table 1. Characteristics of grapes, juice yield, and chemical and physical properties of various unripe grape products.

UGPs	Cultivar	Harvest time	Yield (%)	TA (g/L)	pH	Sugar (g/L)	TSS (°Brix)	TP (mg/L)	TAnt (mg/L)	AA (µmol TEAC/L)	References
Verjuice	France	-	-	28.7	-	56.6	-	315	-	-	Nikfardjam et al. (2008)
Verjuice	Germany	-	-	32.4	-	38.2	-	346	-	-	Nikfardjam et al. (2008)
Verjuice	Germany	-	-	31.4	-	22.8	-	786	-	-	Nikfardjam et al. (2008)
Verjuice	Germany	-	-	19.6	-	95.1	-	442	-	-	Nikfardjam et al. (2008)
Verjuice	Germany	-	-	29.4	-	40.3	-	200	-	-	Nikfardjam et al. (2008)
Verjuice	Iran	-	-	25.0	-	0.1	-	1330	-	-	Nikfardjam et al. (2008)
Verjuice	Iran	-	-	39.6	-	0.2	-	780	-	-	Nikfardjam et al. (2008)
Verjuice	Kabarcik	White	45 Days after flowering	47	24.8	2.98	-	7.47	6267.7	-	Hayoglu et al. (2009)
Verjuice	Yediveren	Red	45 Days after flowering	47	30.0	2.91	-	4.50	7538.0	-	Hayoglu et al. (2009)
Verjuice	Yediveren	Red	-	-	33.3	2.48	6.11	5.0	618.54	-	Öncül and Karabiyikli (2015)

Studies on the vitamin composition have shown the presence of water-soluble compounds such as vitamin C (15–20 mg/L), pantothenic acid, niacin, riboflavin, and biotin. For example, extracts obtained from Sangiovese grapes demonstrated a high concentration of these components [15–16]. The content of vitamin C reaches its maximum level particularly at the unripe stage and decreases during ripening. This provides a basis for evaluating verjuice as a functional food product (Table 2).

Table 2. Water-soluble vitamin content of unripe grape products.

UGPs	Cultivar	Water-soluble vitamins					References
		Pantothenic acid (B5) (µg/L)	Ascorbic acid (mg/L)	Choline (µg/L)	Niacin (µg/L)	Pyridoxine (µg/L)	
Verjuice	Kabarcik	-	20.0	-	-	-	Hayoglu et al. (2009)
Verjuice	Yediveren	-	19.0	-	-	-	Hayoglu et al. (2009)
Verjuice	Black grape (<i>Vitis vinifera</i>)	-	150.0 ± 0.64	-	-	-	Shakir and Rashid (2019)
Liquid extract	Sangiovese	452.0 ± 82.5	n.d.	782.3 ± 29.3	62.0 ± 2.6	100.7 ± 8.4	Fia et al. (2020)

Moreover, the antimicrobial effects of verjuice products have been confirmed by Karapinar and Sengun, as well as Öncül and Karabiyikli, demonstrating that these products can serve as natural agents against pathogens for food preservation [6–7]. Tinello and Lante experimentally proved that unripe grape extract acts as a factor that reduces browning of fruits and enhances antioxidant activity [17].

In conclusion, the bioactive compounds present in unripe grape products not only make them traditional condiments but also enable their broad application as functional products in modern food, cosmetic, and pharmaceutical industries. Continued research in this area is likely to lead to the emergence of new and innovative verjuice-based developments.

Traditional and modern technological approaches. The technology for producing verjuice products has historically been based on simple and manual processes, with products such as verjuice and sour grape sauce traditionally prepared using these methods. In the traditional technologies described by Öncül and Karabiyikli, unripe grapes are washed and crushed to extract the juice, after which the pomace (remaining solid residue) is separated, and salt or olive oil is added to prepare the product for storage [7]. Similar methods are used for preparing sour sauces, with the primary difference being the thermal treatment stage during processing. On a commercial scale, the process consists of several steps: freshly collected juice is concentrated, then diluted and heat-treated again before bottling [7–9]. This method serves to increase the product's shelf life and safety. However, modern technological approaches differ significantly from traditional processes. Recent scientific research aims to obtain extracts rich in bioactive compounds from unripe grapes, with innovative extraction methods playing a key role. The eco-friendly extraction technique developed by Fia and colleagues includes a pomace pressing step, which has enhanced the retention efficiency of phenolic compounds in the product [18]. Additionally, new technologies such as cold extraction, maceration, and ultrasonic extraction are being widely implemented. Ultrasonic extraction, in particular, has been noted for significantly increasing the levels of bioactive components—polyphenols, flavonoids, and tannins—in verjuice products [16–17].

Nevertheless, these technologies are currently being tested primarily at an experimental scale and require broader industrial application. Another important direction in extraction technology is the effective isolation of bound polyphenols (NEP – non-extractable polyphenols) from plant matrices. These constitute a large portion of the total phenolic compounds in plants and contribute 70–90% of antioxidant activity [19]. Therefore, modern approaches focus on the complete extraction of NEPs and their effective utilization in pharmaceutical, cosmetic, and food industries. In summary, while traditional approaches focus on the preservation of unripe grape products, modern methods aim to isolate biologically active compounds from this raw material and apply them commercially in the production of functional products. This can enrich the grape industry beyond wine and raisins, creating a diverse range of high-value products.

Conclusion. The above analysis demonstrates that verjuice products are suitable not only as traditional culinary ingredients but also as modern functional foods with health-promoting properties. Their richness in bioactive compounds—particularly antioxidants and antimicrobial agents—holds significant importance for the pharmaceutical and food industries. Future research focusing on new technological solutions for verjuice production, especially in the areas of eco-friendly extraction and the isolation of bioactive components, will enable the wider commercial application of these products.

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