BOLETIM DO INSTITUTO DE PESCA
Review Article

Perspective and potential of grape co-products for aquaculture

Cybele Pinheiro Guimarães[1], Marcelo Borges Tesser[1]*

[1]Universidade Federal do Rio Grande – Instituto de Oceanografia, Laboratório de Nutrição de Organismos Aquáticos – Rio Grande (RS), Brazil.

*Corresponding author: mbtesser@gmail.com

ABSTRACT

The growing demand for aquaculture feed, combined with environmental concerns, has driven the search for sustainable alternatives to conventional feed ingredients. Grape by-products, such as pomace, stalks, seeds, and skin, have great potential because of their nutritional properties, including high concentrations of dietary fiber, proteins, lipids, vitamins, and bioactive compounds, such as polyphenols. The compounds present in these by-products have bioactive properties that can benefit the health of aquatic organisms. Despite the significant discharge of these by-products into the environment, their inclusion in fish and shrimp diets can improve zootechnical parameters such as growth performance, health, and meat quality, while contributing to the sustainability of aquaculture, reducing waste, and promoting a more efficient production cycle. This article aimed to explore the applicability of viticulture by-products in aquaculture, highlighting the beneficial effects of the bioactive compounds present in these by-products and discussing their potential for use in aquaculture production.

Keywords: Viticulture; Co-products; Applications; Aquaculture.

Perspectiva e potencial dos coprodutos da uva para aquacultura

RESUMO

A crescente demanda por rações na aquicultura, associada às preocupações ambientais, tem impulsionado a busca por alternativas sustentáveis para ingredientes convencionais. Os coprodutos oriundos da uva, como o bagaço, engaço, sementes e cascas, apresentam grande potencial por causa das suas propriedades nutricionais, como a alta concentração de fibras alimentares, proteínas, lipídios, vitaminas e compostos bioativos, como os polifenóis. Tais compostos presentes nesses coprodutos possuem propriedades bioativas que podem beneficiar a saúde dos organismos aquáticos. Apesar do descarte significativo desses coprodutos no meio ambiente, sua inclusão na dieta de peixes e camarões pode melhorar parâmetros zootécnicos, como o desempenho de crescimento, a sanidade e a qualidade da carne, ao mesmo tempo que contribui para a sustentabilidade da aquicultura, reduzindo desperdícios e promovendo um ciclo produtivo mais eficiente. Este artigo visou explorar a aplicabilidade dos coprodutos da viticultura na aquicultura, destacando os efeitos benéficos dos compostos bioativos presentes nesses coprodutos e discutindo as potencialidades de sua utilização na produção aquícola.

Palavras-chave: Viticultura; Coprodutos; Aplicação; Aquacultura.

Received: May 23, 2024 | **Approved:** February 10, 2025
Section editor: Fabiana Garcia

INTRODUCTION

In recent years, the food industry has experienced advancements driven by technological innovations in healthy and sustainable foods, ensuring a wide diversification of products that serve varied commercial interests, as well as improvements in processing, production, and distribution (Chakka et al., 2021), including the fruit sector, which has also followed this trend.

Fruit production is an important part of world agriculture (Nirmal et al., 2023) as it is dedicated to the production of fresh and processed products (Ding et al., 2023; Yadav et al., 2023). According to the Food and Agriculture Organization of the United Nations (FAO, 2021), global fruit production in 2021 reached 1.3 billion tons. In this scenario of growth in fruit production, processing fresh fruits into processed products for sale is essential because of their perishability (Davis et al., 2021).

However, during the production chain, losses are between 30 and 40% of the total volume of fruits (Viswanath et al., 2018; Villacís-Chiriboga et al., 2020). These losses are due to improper handling, poor infrastructure, and lack of technology for reusing the waste generated (Yadav et al., 2023). According to Pereira et al. (2022), 50% of the waste produced during the production chain of the Brazilian fruit agroindustry is discharged, and only 1% of this waste produced is reused. This situation results in economic, environmental, and social losses.

The waste produced during the processing stage is designated as a by-product or co-product (Zacharof, 2017; Rodríguez-Ramos et al., 2022). Compared to other food processing sectors, the fruit industry generates co-products such as seeds, stalks, pits, pulps, pomace, foliage, and solid and liquid parts (Nirmal et al., 2023; Teshome et al., 2023).

The large-scale improper disposal of these co-products entails a number of problems, including unpleasant odors, increased carbon dioxide emissions, visual pollution, and soil and groundwater contamination (Pereira et al., 2022; Plakantonaki et al., 2023). To ensure proper use of these co-products, it is essential to adopt preliminary measures aimed at successful integrated recovery (Plakantonaki et al., 2023).

The reuse of this organic matter in an integrated manner could contribute positively to obtaining secondary value-added products, to a sustainable circular economy (Campos et al., 2020; Pereira et al., 2022; Plakantonaki et al., 2023). The circular economy is premised on minimizing waste, preserving the value of resources, maintaining closed production cycles, and decoupling economic growth from environmental degradation by transforming co-products into reused resources (Cosenza et al., 2020; Villacís-Chiriboga et al., 2020; Zhu et al., 2023).

Despite these challenges, co-products are a valuable source of bioactive compounds of broad interest to the industry (Sánchez-Peña et al., 2018) and are currently suggested as substitutes for synthetic nutraceuticals (Fabjanowicz et al., 2024), due to their potential for application in medicines with antibacterial and antifungal properties (Onivogui et al., 2016; Cruz et al., 2019; Hassan et al., 2019).

Because of these possibilities, research is being conducted to explore the use of these co-products and their viability as a source of animal nutrition, while investigating their adverse effects (Huang et al., 2018; Peng et al., 2021, 2022b; Rosas et al., 2022), with the aim of directing and applying these co-products to other agricultural production chains.

Among animal production systems, aquaculture has the highest growth rate due to the technological level employed in the production process and the intensification of production systems (FAO, 2022). In this sense, the nutrition of aquatic organisms is a key factor in the success of the activity. However, there is still a problem with the commodities used in the production of feed industries, including fish meal and fish oil, which are the most expensive items (Câmara et al., 2020). In addition, commodities such as soybeans have been pointed out to generate problems related to increased deforestation, as well as an increased carbon footprint (Escobar et al., 2020).

Production changes for aquatic organisms must be sustainable to relieve the pressure of overfishing and reduce the cost of feed with alternative ingredients available on the market, mainly from the fruit industry, which has beneficial properties. Although fruit co-products may have their own uses and value, they are generally not direct substitutes for commodities in feed production, as each commodity has unique properties and specific applications in feed formulations for organisms. Therefore, despite their properties, fruit co-products cannot necessarily meet all the needs or functions of other plant commodities such as soybeans, wheat, and corn. However, they can contribute significantly to the improvement of the immune and antioxidant system of animals in production (Hassan et al., 2019; Baldissera et al., 2019a; Harikrishnan et al., 2021).

Supplementation and/or inclusion of plant-based co-products in animal diets can improve growth, health, and immunity (Chakka et al., 2021; Rosas et al., 2022; Molosse et al., 2023). They can also help improve the nutritional quality of end-consumers (Sławińska & Olas, 2023). However, the results vary according to the species to be studied, rearing system, and amount included in the diet. Therefore, further investigation is needed to understand its effects in different contexts during animal production.

The intensive production of aquatic organisms can provide a stressful environment for animals, which can consequently affect their health and zootechnical parameters (FAO, 2022). To avoid loss in production and, consequently, commercial unviability, it is necessary to apply promising alternatives, such as nutritious and safe foods, thus ensuring animal welfare and food safety for the consumer.

The inclusion of bioactive compounds in the diets of aquaculture organisms is a promising alternative (Dawood & Koshio, 2019) because of the benefits of the physiological, metabolic, and immunological activities of animals (Morante et al., 2021). To this end, plant-based co-products must be processed and included as food sources for animal nutrition (Leal, 2018).

This review presents an overview of the various reported applications of grape by-products in aquaculture. The main bioactive phenolic compounds that have been reported in recent years are listed. In addition, we discuss the use of grape by-products in the aquaculture sector, their applications, and promising effects.

VITICULTURE

Viticulture is a branch of agriculture dedicated to the cultivation of grapes, mainly for wine production. This type of production is disseminated across several regions worldwide. According to data obtained from the FAO (FAOSTAT, 2025), China led the production, contributing with 29,009,441,73 tons of the global total between 2022 and 2023, followed by Italy, accounting for 15,106,800 tons, while Spain reached 10,724,800 tons. Brazil ranks 13th position, with 3,208,629 tons (FAOSTAT, 2025).

Grape (*Vitis vinifera*) is widely recognized as the predominant species in global wine production, accounting for approximately 50% of wine production (International Organization of Vine and Wine, 2022). Belonging to the Vitaceae family, originally from the Mediterranean and Central Asia, this variety is extensively cultivated in various wine regions due to its remarkable adaptation to a wide range of climatic conditions and soil types (Reynolds et al., 2017; Khan et al., 2020).

The production of wine during its production chain generates several co-products, such as foliage, stems, pomace, bark, seeds, liquid parts that contain lees, and vinasse. It is worth noting that, for each liter of wine produced, approximately 4 and 14 kg of stems and pomace are generated, respectively, and with the constitution of the pomace, the skins have 40–45% and seeds have 20–25% (Spinei & Oroian, 2021).

With the continuous progress in viticulture production, there is concern about the management of the co-products generated, which results in significant amounts of this organic matter, whose improper disposal can cause adverse environmental impacts (Barros et al., 2021). However, these co-products are rich in a variety of bioactive compounds such as polyphenols, antioxidants, fiber, and essential nutrients, which have the potential to be used in a variety of industries. The reuse of these co-products not only contributes to the sustainability of viticulture but also opens up business and innovation opportunities.

CO-PRODUCTS OF WINE PRODUCTION

The disposal of co-products can contaminate rivers and soils (Ferrari et al., 2019). This is because these products have high concentrations of organic matter, which during their fermentation forms organic acids, which provide a potential to trigger environmental problems (Gopinathan & Thirumurthy, 2012). Zhao et al. (2018) report that the co-products of grape processing have significant amounts of alcohol (ethanol) and that, through acidification, these can contaminate soils (Fig. 1).

Advanced recovery technologies are rarely used in the wineries and grape processing industries because of challenges

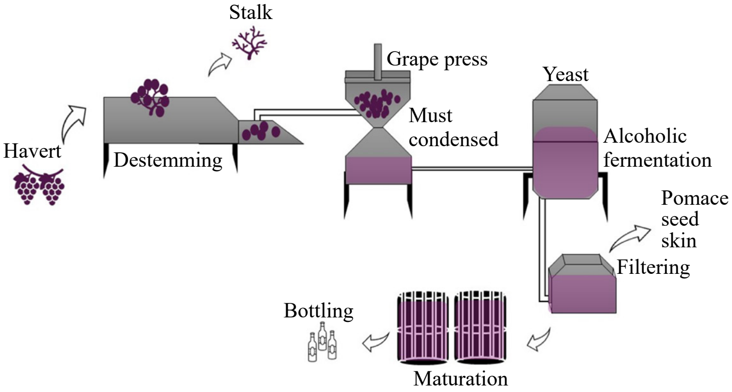

Figure 1. Wine production chain and generation of its co-products: pomace, stalks, seeds, and skins.

such as the need for specific technologies for each type of co-product, variation in their composition, complexity in extraction and purification methods, and the high cost involved (Montalvo et al., 2020). These obstacles limit large-scale application and hinder the economic viability of companies in the sector.

Currently, different sustainable strategies are used to recover by-products from the wine industry. However, it is important to note that proper management of grape by-products requires the implementation of an efficient system for collecting, sorting, and processing these materials (Righi et al., 2020). Companies in the sector must be aware of environmental regulations and invest in technologies that allow the minimization of co-products and the maximization of their use. In addition, awareness and education programs are key to encouraging the adoption of sustainable practices in relation to the management of grape by-products (Tonon et al., 2018).

The significant production of by-products by the agroindustry, in general, has increased due to the continuous expansion of the sector (Zacharof, 2017). To deal with the challenges of improper disposal, studies indicate the feasibility of using these by-products as valuable resources in other areas, such as the aquaculture industry. The incorporation of these materials in feed formulations can reduce production costs, thanks to their high biological value and economic viability.

In addition, several studies highlight the potential of by-products in different segments. In the agroindustrial and environmental sectors, the by-products have proven to be useful resources for improving the sustainability of the production chain (Monteiro et al., 2021; Falcone et al., 2022). According to Kabir et al. (2015), recovered by-products have high nutritional value, while Albuquerque et al. (2019) emphasize that green by-products are rich in soluble fibers and phenolic compounds with functional properties.

BIOACTIVE COMPOUNDS

Polyphenolic compounds are groups of phytochemicals widely distributed in the plant kingdom (Bordiga et al., 2019). These are secondary products synthesized by plants in response to different environmental stimuli, such as abiotic and biotic stress (Das & Bhattacharjee, 2020; Jiang et al., 2023). Phenolics include not only a wide variety of molecules with a polyphenolic structure (hydroxyl groups in aromatic rings), but also molecules with a phenolic ring, such as phenolic acids and alcohols.

The phenolic compounds contained in grapes are classified into flavonoids and non-flavonoids (Shahab et al., 2023). Flavonoids include flavan-3-ols, flavonols, and anthocyanins, while non-flavonoids encompass hydroxybenzoic acids, hydroxycinnamic acids, and stilbenes (Brenes et al., 2016; Jiang et al., 2023). Flavan-3-ols, such as catechin and epicatechin, are present in both the skins and seeds of grapes (Unusan, 2020). Anthocyanins, which are responsible for the color of grapes, accumulate mainly in the skins, while procyanidins are located in the seeds (Teixeira et al., 2018). The main anthocyanins in grape skins are the 3-O-glycosides of malvidin, cyanidin, delphinidin, peonidin, and petunidine (Tang et al., 2018). The pomace and peels also contain phenolic acids, such as caftaric acid, coutaric acid, and transfertaric acid, as well as flavonols, such as quercetin 3-glucuronide and myricetin 3-glucuronide (Shahidi & Ambigaipalan, 2015). In addition, grapes are a rich source of monomeric phenolic compounds, including catechins, epicatechins, and their dimeric, trimeric, and tetrameric proanthocyanidins (Riebel et al., 2017).

The recovery and use of these bioactive compounds have been studied for their beneficial health properties, including antioxidant and antimicrobial activities (Baldissera et al., 2019a; Brenes et al., 2016), anti-inflammatory properties (Bucić-Kojić et al., 2020), cardiac protection, and cancer prevention (Peixoto et al., 2018), in addition to their neuroprotective, chemopreventive, and antiallergic functions (Balea et al., 2020).

In addition, studies have reviewed the functional bioactive components of these co-products, exploring the interactions of phenolics with other food ingredients, as well as their functionalities. An example is the study conducted by Terzi et al. (2023) that investigated the effect of grape seed extract on liver damage caused by the consumption of oxidized oil in the diet of rainbow trout (*Oncorhynchus mykiss*). They observed that supplementation with 0.1% extract had a significant effect on reducing liver damage caused by the consumption of oxidized fish oil, evidenced by biochemical parameters and liver histology. That is, the addition of the extract to the diet has been shown to be beneficial in preventing the adverse effects of consuming oxidized fish oil on the liver of rainbow trout.

On the other hand, fermentation using fungi can potentiate the phenolic compounds present in grape pomace. Bucić-Kojić et al. (2020) investigated that the fungus *Trametes versicolor*, after 15 days of grape pomace fermentation, increased its content of phenolic compounds and its anti-inflammatory potential. This application suggests being environmentally friendly to improve the nutritional and functional properties of the co-product. Filipe et al. (2023) monitored functional stability in diets supplemented with a bioactive extract from grape pomace. This extract was produced by the fungus *Aspergillus ibericus* through fermentation, added to feed and stored at room temperature and 4°C for four months. The diets that received the bioactive compound maintained their stability by reducing lipid peroxidation.

Grape pomace

The composition of phytochemicals in grape pomace can vary depending on factors such as grape variety, growing conditions, and stage of ripeness, for example, with different levels of sugars, pigments, and phenolic compounds among grape varieties. The solid part contains bacterial biomass, undissolved carbohydrates, phenolic compounds, lignin, proteins, metals, inorganic salts, and other materials (Zacharof, 2017), and the liquid part is mainly composed of fermentation broth, which is rich in organic acids and ethanol (Sousa et al., 2014).

Phenolic compounds present in grape pomace are divided into two main categories: simple phenols, and polyphenols. Simple phenols are composed of hydroxycinnamic acids (such as p-coumaric, ferulic, caffeic, and synapic acids) and hydroxybenzoic acids (such as gallic, protocatechuic, syringic, and vinyl acids). Polyphenols include flavonoids (flavonols, flavanols, and anthocyanins), stilbenes (e.g., resveratrol), and tannins (proanthocyanidins, gallotannins, and ellagitannins) (Gil-Sánchez et al., 2017; Zacharof, 2017; Salgado et al., 2019; Sirohi et al., 2020; Monteiro et al., 2021; Plakantonaki et al., 2023; Sinrod et al., 2023).

Additionally, grape pomace is composed of 60–70% water and alcohols, such as ethanol, aldehydes, esters, volatile acids, proteins, cellulose, pectins, mineral salts, and sugar residues (Butnariu & Butu, 2019). In summary, Table 1 shows that the typical composition of grape pomace is 61.85% moisture, 2.04% ash, 5.08% protein, 7.66% lipids, 6.87% fibers, and 16.48% carbohydrates (Oliveira et al., 2016).

Grape stalks

Grape stalks have high fiber content (lignin, 20–30%; cellulose, 20–30%; hemicellulose, 15–25%) (Prozil et al., 2014), phenolic compounds (6%) (Bustamante et al., 2009; Ping et al., 2011; Atatoprak et al., 2022), and nutritional mineral elements, especially nitrogen and potassium (Nerantzis & Tataridis, 2006). The other elements are shown in Tables 1 and 2.

Table 1. Nutritional composition of grape co-products.

Co-product	% dry matter					Reference
	Crude protein	Fatty acids	Ash	Carbohydrates	Crude fiber	
Grape pomace	15.50	10.30	7.00	6.90	-	Pedras et al. (2020)
	5.38	1.14	2.53	90.18	-	Jiang et al. (2011)
	12.34	6.33	7.79	73.73		
	11.44	5.80	6.93	-	-	Rosa et al. (2019)
	13.31	8.47	12.15			
	8.49	8.16	4.65	29.20	46.17	Spinei and Oroian (2021)
	12.10	5.87	9.09	29.24	35.40	Deamici et al. (2016)
	7.70	2.49	21.75	29.64	30.35	Beres et al. (2019)
	13.80	4.20	5.50	10.90	51.40	Beres et al. (2017)
	8.49	8.20	4.65	29.20	46.17	Sousa et al. (2014)
	12.78	5.50	6.89	-		Chedea et al. (2017)
	8.49	3.80	2.92	44.54	40.25	Rosas et al. (2022)
Seeds	9.33	6.26	2.76	-	-	Basalan et al. (2011)
Skin	6.70	-	18.30	-	-	Mendes et al. (2013)
	5.38	1.14	2.53	1.34	17.28	Deng et al. (2011)
	12.34	6.33	7.59	77.53	56.31	
Staks	6.10	-	7.00	-	-	Prozil et al. (2012)
	7.20	9.00	8.60	-	-	Filippi et al. (2022)
	-	-	2.70	-	-	Atatoprak et al. (2022)
	6.92	1,22	7.64	-	-	Basalan et al. (2011)

-: Not evaluated.

Table 2. Composition of phytochemicals of grape co-products.

Phytochemical	Co-product (µg/g extract)					Reference
	Pomace		Seed	Stalk	Skin	
	Simple	Fermented				
Flavanoids (flavan-3-ol)						
Catechin			149.0			Peixoto et al. (2018)
	280.0	370.0				Gil-Sánchez et al. (2017)
			43.0			Mousavi et al. (2021)
					56.1	Pulgar et al. (2021)
	3.5×10^3					Bucić-Kojić et al. (2020)
Epicatechin			984.0			Peixoto et al. (2018)
	103.0	1100.0				Gil-Sánchez et al. (2017)
			30.0			Mousavi et al. (2021)
					13.5	Pulgar et al. (2021)
	0.21					Pertuzatti et al. (2020)
	1.7×10^3					Bucić-Kojić et al. (2020)
Gallocatechin gallate	0.9×10^3					
Epigallocatechin	0.7×10^3					
Flavonoids (flavon-3-ol)						
Procyanidin-B1			2.4			Mousavi et al. (2021)
	1.1×10^3					Bucić-Kojić et al. (2020)
Procyanidin-B2			2.0			Mousavi et al. (2021)
	0.5×10^3					Bucić-Kojić et al. (2020)
Procyanidin B3			1.45			Mousavi et al. (2021)
					36.1	Pulgar et al. (2021)
Procyanidin-B4			4.5			Mousavi et al. (2021)
Procyanidin-B5			3.12			
Procyanidin-C1			3.1			
Procyanidin gallate					9.6	Pulgar et al. (2021)
Procyanidin trimer					64.7	
Procyanidin dimer					24.2	
Kaempferol		160.0			160.0	Gil-Sánchez et al. (2017)
Myricetin		250.0			260.0	
Myricetin 3 glactoside					68.5	Pulgar et al. (2021)
Myricetin 3 glucoside					140.8	
Quercetin	340.0	300.0				Gil-Sánchez et al. (2017)
	12.22					Baldissera et al. (2019a)
Quercetin 3-glicoside			253.0		343.5	Peixoto et al. (2018)
					7.3	Pulgar et al. (2021)
	216.84					Pertuzatti et al. (2020)
Quercetin 3-galactoside					7.3	Pulgar et al. (2021)
Quercetin 3-rutinoside					10.3	
	10.99					Baldissera et al. (2019a)
Quercetin-3-O-glucuronide		230.0				Gil-Sánchez et al. (2017)
Total phenolic acids						

Continue...

Continuation.

Phytochemical	Co-product (µg/g extract)					Reference
	Pomace		Seed	Stalk	Skin	
	Simple	Fermented				
Gallic acid			313.0		104.0	Peixoto et al. (2018)
		2,860.0				Gil-Sánchez et al. (2017)
			5.2			Mousavi et al. (2021)
					120.0	Pulgar et al. (2021)
	1,396.0					Pertuzatti et al. (2020)
	55.11					(Baldissera et al. 2019a)
Protocatechuic acid					17.3	Pulgar et al. (2021)
Syringic acid					1.2	
Caftaric acid					22.5	
Coutaric acid					9.6	
Ellagic acid	564.0	6,010.0				Gil-Sánchez et al. (2017)
Caffeic acid	30.09					Baldissera et al. (2019a)
Coumaric acid					729.0	Peixoto et al. (2018)
Anthocyanins						
Malvidin-hexoside			0.010		0.783	Peixoto et al. (2018)
Malvidin-rutinoside			0.024		2.335	
Malvidin-dihexoside					0.267	
Malvidin-acetylhexoside					0.192	
Delphinidin-rutinoside					1.60	
Petunidin-3-O-rutinoside					2.65	
Peonidin-3-O-rutinoside					0.115	
Cyanidin-3-O-glucoside	23.32					Pertuzatti et al. (2020)
Total Phytochemicals (mg/g)						
Tannins					6.04	Deng et al. (2011)
					19.89	
	159.0					Prozil et al. (2012)
					3.4	Mendes et al. (2013)
Resveratrol	69.09					Baldissera et al. (2019a)
Cellulose	303.0					Prozil et al. (2012)
	15.0					Pedras et al. (2020)
					12.5	Mendes et al. (2013)
				5.19		Atatoprak et al. (2022)
				19.43		
	210.0					Prozil et al. (2012)
	11.3					Pedras et al. (2020)
Hemicellulose				8.36		Atatoprak et al. (2022)
				8.01		
				7.76		
				8.22		
Lignin				39.16		
				48.47		
	174.0					Prozil et al. (2012)

Seeds and skins (husks)

The seed (Table 1) contains 10–20% lipids (Nicolai et al., 2018), 10–20% phenolic compounds (Passos et al., 2009), 10–11% protein, 60–70% carbohydrates, and non-phenolic antioxidants (Yu & Ahmedna, 2013), such as tocopherols, which can vary from 357 to 578 mg/kg of seed depending on the extraction method (Baydar & Akkurt, 2001). The seed is rich in extractable phenolic antioxidants, such as phenolic acids, flavonoids, procyanidins, and resveratrol (Yu & Ahmedna, 2013), and contains important compounds comprised of monomers, oligomers, and polymers or proanthocyanidins (Nazima et al., 2015).

Grape skins contain several types of polyphenols, including anthocyanins, hydroxycinnamic acids, catechins, and flavonols, which comprise 28–35% polyphenols (Ribeiro et al., 2015). As can be seen in Table 2, grape skins contain esters and tartaric hydroxycinnamic acids (6–45 mg/kg of grapes), monomeric and dimeric flavan-3-ols (9–96 mg/kg), and flavonols (25–197 mg/kg) (Rodríguez Montealegre et al., 2006), reaching total phenolic levels of 9,661 to 16,742 mg gallic acid equivalents/100 g of fresh mass (Yilmaz et al., 2015).

In its composition, moisture and ash correspond to 7.73 and 8.15%, respectively, protein to 3.62%, lipid content 3.36%, carbohydrates 77.13%, and fiber 19.67% (De Alencar et al., 2022). Grape skin is a complex lignocellulosic material that contains large amounts of hemicellulosic sugars and produces solutions containing a wide variety of xylose and glucose monomers (Devesa-Rey et al., 2011).

INCLUSION OF GRAPE CO-PRODUCTS IN AQUACULTURE

Grape co-products contain a significant amount of active ingredients that confer important properties (Trošt et al., 2016), such as phenolic compounds, in the diet of aquatic organisms, demonstrating the following benefits: immune response (Morante et al., 2021; Peng et al., 2022b), zootechnical performance (Arslan et al., 2018; Rosas et al., 2022), nutritional digestibility (Peña et al., 2020), antioxidant actions (Dawood et al., 2020; Mohammadi et al., 2021; Peng et al., 2022b), and antimicrobial properties (Baldissera et al., 2019b). However, studies are needed to indicate the percentage of inclusion of grape co-products as a dietary ingredient in feed formulations and the species to be used (Table 3).

POTENTIAL OF GRAPE CO-PRODUCTS IN THE NUTRITION OF AQUATIC ORGANISMS

Zootechnical performance

The mechanisms by which grape co-products affect the growth performance of aquatic species remain unclear. The results observed in the literature regarding the use of grape co-products may be related to the quantity included in the feed owing to differences in their polyphenolic content, experimental duration, species, and size of the animal. According to Erinle and Adewole (2022), the ability of grape co-products to improve growth performance depends on the form of the coproduct and the quantity incorporated into the diet. Tannins are considered anti-nutritional factors that can affect animal metabolism. According to Brenes et al. (2016), the main obstacles to the inclusion of grape co-products in monogastric nutrition are the high level of fiber in the cell wall and the high tannin content.

However, Peng et al. (2020) documented that the inclusion of condensed tannins up to 1 g/kg in diets for sea bass, *Lateolabrax maculatus*, did not affect growth performance. According to Kesbiç and Yigit (2019), including different levels of aqueous grape seed extract, which contains tannins, in the diets enabled better growth performance for rainbow trout (*O. mykiss*). Rosas et al. (2022) verified the zootechnical performance of marine shrimp, *Litopenaeus vannamei*, with the inclusion of grape pomace. In the current study, the authors reported that it is feasible to add up to 25 $g{\cdot}kg^{-1}$ of the co-product to shrimp diets without affecting zootechnical parameters. Peña et al. (2020) concluded that the inclusion of grape pomace as a component of the feed for *O. mykiss* could be included at levels of up to 180 $g{\cdot}kg^{-1}$ without negative effects on growth, and the level of 60 $g{\cdot}kg^{-1}$ showed a positive effect on digestibility and increased feed efficiency. Selecting highly digestible ingredients and improving feed formulation, palatability, digestibility, and nutrient retention can potentially improve feed efficiency (Kokou & Fountoulaki, 2018).

In the contexts presented, some studies have investigated the impact of different additives and dietary components on feed efficiency in various animal species. The results of Arslan et al. (2018) showed that feed conversion was significantly lower in trout fed with 1 $g{\cdot}kg^{-1}$ of grape seed oil extract, that is, a smaller amount of feed is needed to produce the same gain in body weight compared to the other groups. However, Chen et al. (2022) reported that, in a study with Chinese sea bass (*Lateolabrax maculatus*), diets supplemented with 2 $g{\cdot}kg^{-1}$ of condensed tannins from grape seeds resulted in reduced final body weight, weight gain rate, specific growth rate,

Table 3. Different methods of using grape co-products and their effects on aquatic organisms.

Bioinput extract	Aquatic organism	Dose/concentration	Best results	Reference
Grape seed extract	Sea bass (*Dicentrarchus labrax* L.)	100 and 200 (mg/kg)	The inclusion of 200 mg/kg boosted renal melanomacrophage activity, strengthening the fish's immune response.	Arciuli et al. (2017)
Grape seed extract	Rainbow trout (*Oncorhynchus mykiss*)	0.0, 0.5,1.0, and 2.0 (‰)	The concentration of 1‰ presented the best zootechnical performance and quality of trout fillet.	Kesbiç and Yigit (2019)
Grape seed extract	Rainbow trout (*Oncorhynchus mykiss*)	0, 100, and 200 (mg/kg)	The 100-mg/kg dose improved gene expression and histological structures of the immune system in fish mucosal tissues.	Mousavi et al. (2021)
Grape seed extract	Rainbow trout (*Oncorhynchus mykiss*)	0.0% (oxidized fish oil), 0.1% (extract), 11.0% (oxidized fish oil) + 0.3% (extract), 0.0% (fresh fish oil); 11.0% (fresh fish oil) + 0.1% (extract) and 11.0% (fresh fish oil) + 0.3% (extract)	Supplementing with 0.1%-grape seed extract protected the liver from oxidized fish oil damage, improving liver and biochemical indicators.	Terzi et al. (2023)
Grape seed condensed tannin extract	Chinese seabass (*Lateolabrax maculatus*)	0.0, 1.0, 2.0 (g/kg), 2.0 (extract) + 4.0 (polyethylene glycol) (g/kg)	The inclusion of 1.0 g/kg of condensed tannin extract improved antioxidant and immune capacity, as well as zootechnical performance, gut health, and enzyme activity.	Chen et al. (2022)
Grape seed condensed tannin extract	Chinese seabass (*Lateolabrax maculatus*)	0, 1 mg/kg of aflatoxin B1, and 1 mg/kg of aflatoxin B1 + 1 g/kg (extract)	The inclusion of 1 g/kg of condensed tannin extract protected against aflatoxin B1 toxicity, enhancing performance, antioxidant response, intestinal health, and microbiota.	Peng et al. (2022a)
Grape seed condensed tannin extract	Chinese seabass (*Lateolabrax maculatus*)	0.0, 1.0, 2.0 (extract) (g/kg), and 2.0 (extract) + 4.0 (polyethylene glycol) (g/kg)	Supplementation of 1 g/kg of condensed tannin in diets improved serum antioxidant and immunological activity.	Peng et al. (2022b)
Grape seed proanthocyanidin extract	Grass carp (*Ctenopharyngodon idella*)	250 mg/kg (extract)/animal body weight	It reduced triglycerides in hepatocytes, lowered serum cholesterol, increased anti-inflammatory cytokines, and prevented liver fat accumulation.	Lu et al. (2020)
Grape seed proanthocyanidin extract	Nile tilapia (*Oreochromis niloticus*)	0, 100, 200, and 400 (mg/kg)	The inclusion of 280 mg/kg increased zootechnical performance, myofibrillar growth, antioxidant activity and improved the sensory quality and centesimal composition of the fillet.	Yang et al. (2023)

Continue...

Continuation.

Bioinput extract	Aquatic organism	Dose/concentration	Best results	Reference
Grape seed proanthocyanidin extract	Common carp (*Cyprinus carpio*)	0, 200, 400, 600, 800, and 1,500 (mg/kg)	The inclusion of 200 mg/kg improved zootechnical performance, antioxidant activity, fillet quality, and serum biochemical properties.	Mohammadi et al. (2021)
Grape seed proanthocyanidin extract	American eel (*Anguilla rostrata*)	Commercial diet supplemented 400 mg/kg (extract)	Decreased total cholesterol and triglyceride levels.	Wang et al. (2020)
Grape seed proanthocyanidin extract	Nile tilapia (*Oreochromis niloticus*)	0, 200, 400, 600, and 800 (mg/kg)	The inclusion of 200 mg/kg improved growth, reduced triglycerides and cholesterol, increased lysozyme, albumin, and protein levels, and lowered crude lipids in the fillets.	Zhai et al. (2014)
Dry grape extract	Shrimp (*Litopenaeus vannamei*)	0, 150, 250, 375, and 500 (ppm)	The inclusion of 375 ppm provided the best zootechnical performance, with an increase in antioxidant potential due to the presence of procyanidins.	Chien et al. (2023)
Grape crude extracts	Tambaqui (*Colossoma macropomum*)	0, 20, 40, 60, and 80 (g/kg)	The inclusion of 80 g/kg in the diet improved zootechnical performance and immunity.	Morante et al. (2021)
Grape seed ethanolic extract	Rainbow trout (*Oncorhynchus mykiss*)	0, 10, and 50 (g/kg)	The inclusion of 10 g/kg improved zootechnical performance, biochemical parameters and antioxidant activity.	Mousavi et al. (2021)
Microencapsulated grape pomace extract	Rainbow trout (*Oncorhynchus mykiss*)	Commercial diet (low soy content) + 2.0% (maltodextrin); commercial diet (high soy content) + 2.0% (maltodextrin) and commercial diet (high soy content + 1.2% (maltodextrin) + 0.8% (extract).	The inclusion containing the extract (0.8%) obtained positive results in antioxidant capacity.	Pulgar et al. (2021)
Grape pomace				
Grape pomace	Grass carp (*Ctenopharyngodon idella*)	0, 150, and 300 (mg/kg)	The dosages improved immunological and inflammatory responses during *Pseudomonas aeruginosa* infection.	Baldissera et al. (2019a)
Grape pomace	Grass carp (*Ctenopharyngodon idella*)	0, 150, and 300 (mg/kg)	The 300-mg/kg dosage improved bioenergetic dysfunction caused by *Pseudomonas aeruginosa* by enhancing antioxidant properties and phosphoryl transfer enzymes, preserving energy balance and health.	Baldissera et al. (2019b)
Grape pomace	Rohu (*Labeo rohita*)	0, 100, 200, and 300 (mg/kg)	Inclusion of 200 mg/kg in the diet increased growth, improved antioxidant status and strengthened immune defenses.	Harikrishnan et al. (2021)

Continue...

Continuation.

Bioinput extract	Aquatic organism	Dose/concentration	Best results	Reference
Grape pomace	Silver catfish (*Rhamdia quelen*)	10 g/kg	The inclusion of 10 g/kg increased plasma glucose, favoring metabolism, cellular respiration, ATP production and maintenance of homeostasis.	Lazzari et al. (2019)
Grape pomace	Rainbow trout (*Oncorhynchus mykiss*)	Experiment I: 0, 20, 40, and 60 (g/kg); Experiment II: 0, 60, 120, and 180 (g/kg)	The inclusion of 60 g/kg in both experiments improved apparent digestibility and feed conversion, resulting in better zootechnical performance.	Peña et al. (2020)
Grape pomace	Shrimp (*Litopenaeus vannamei*)	0.0, 2.5, 5.0, 10.0, and 15.0 (g/100 g)	The inclusion of 2.5% grape pomace in the diet did not negatively affect zootechnical performance, antioxidant capacity or lipid peroxidation.	Rosas et al. (2022)
Seed				
Grape seed	Japanese sea bass (*Lateolabrax japonicus*)	0.0, 0.2, 0.4, 0.6, 0.8, and 1.0 (g/kg)	The inclusion of up to 1 g/kg in the diet improved antioxidant capacity, immunity and resistance to copper sulfate stress, without compromising zootechnical performance and *in-vivo* digestibility	Peng et al. (2020)
Grape seed	Shrimp (*Litopenaeus vannamei*)	0.0, 0.5, 1.0, 2.0, and 4.0 (g/kg)	The inclusion of grape seed extract up to 4 g/kg increased growth, without impacting nutrient digestibility, antioxidant activity or intestinal histomorphology.	Peng et al. (2021)
Oil				
Grape seed oil	Rainbow trout (*Oncorhynchus mykiss*)	0, 250, 500, and 1000 (mg/kg)	Supplementation of 1,000 mg/kg of grape seed oil in the diet improved growth, fatty acid composition and antioxidant enzyme activity, promoting the health of the organisms.	Arslan et al. (2018)
Others				
Grape seed extract with dried macroalgae (Ulva lactuca)	Abalone (*Haliotis laevigata*)	Commercial diet (control); commercial diet + 5% grape seed extract; commercial diet + 30% dry lean seaweed; commercial diet + 5% grape seed extract + 30% dry macroalgae and 100% macroalgae	The addition of 5% grape seed extract and 30% macroalgae to the diet provided the best results, increasing the survival rate and improving serum activity.	Lange et al. (2014)
Grape seed extract with dried macroalgae (Ulva lactuca)	Abalone (*Haliotis laevigata*)	Commercial diet (22°C); commercial diet (25°C); commercial diet + 5% extract (25°C); macroalgae (22°C) and macroalgae (25°C)	The diet with 5% extract showed the highest survival rate under heat stress, both at 22 and 25°C, compared to the other diets.	Shiel et al. (2017)

and feed intake, compared to other diets. The researchers suggested that the inclusion of tannins at this level may compromise feed efficiency, which presented a value of 1.2, higher than that observed in the other groups.

In aquaculture, feed efficiency plays a crucial role, influencing not only the profitability of the business but also the environmental sustainability and quality of the fish produced. Using alternative foods efficiently reduces costs, minimizes environmental impacts, and improves the growth and health of organisms, and is a key objective for producers and researchers (Arslan et al., 2018). Tannins present in grape seeds show potential health benefits, but their effects need to be fully understood (Unusan, 2020).

In another study, the effects of dietary grape seed extract on growth performance in rainbow trout were investigated for 60 days, showing that feeding with extract improved growth parameters, including specific growth rate, at a lower dosage (10 $g \cdot kg^{-1}$) (Mousavi et al., 2021). The researchers justified that the increase in digestive enzymes after administration of different dosages could accentuate this performance. An increase in digestive enzymes, such as proteases and lipases, increases the efficiency of digestion by breaking down proteins and lipids, facilitating the absorption of nutrients essential for the growth and maintenance of the organism. Furthermore, Arslan et al. (2018) indicated that the combination of greater feed efficiency, antioxidant effects, nutritional benefits, and potential immunostimulatory properties of grape seed oil may contribute to better growth performance.

Wang et al. (2022) describe that grape seed extract influenced the lipid metabolism of the American eel *Anguilla rostrata* through the metabolic regulation of linoleic and arachidonic acids. Linoleic and arachidonic fatty acids are important for the growth, development, immunity, and health of organisms, as they are essential polyunsaturated fatty acids that play crucial roles in biological processes, including regulating inflammation and acting on the structure and function of cell membranes, helping to maintain their integrity and fluidity.

The use of grape co-products to prevent oxidative stress

In aquaculture, aquatic organisms are susceptible to attacks by reactive oxygen species (ROS), which can compromise growth and health (Ardiansyah & Fotedar, 2016). During cultivation, organisms may encounter stressful environments that trigger oxidative stress. Potential stressors for fish include temperature variation, photoperiod, water quality, nutrition, predation, exposure to toxins, sound effects, isolation, and persecution (Cheng et al., 2015). The immune and antioxidant systems have protective effects against these stresses. Antioxidant defenses can detoxify ROS and reactive nitrogen metabolites (RNMs) that can modify and damage almost all cellular and tissue components under different conditions (Kruidenier et al., 2003).

During electron transport in mitochondria, oxygen can be partially reduced, generating ROS such as superoxide anions (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH^-). These compounds can cause damage to DNA, RNA, lipids, and proteins. This damage causes the repair system to malfunction and contributes to the development of various diseases. However, grape co-products have been studied as natural antioxidants to prevent or delay the actions of free radicals (Cruz et al., 2019; Adeshina & Abdel-Tawwab, 2020).

Phenolic compounds, flavonoids, and phenolic acids have a structural function in scavenging free radicals because of their high antioxidant and metal-chelating activities (Brenes et al., 2016)). The antioxidant properties of polyphenols result mainly from their ability to donate hydrogen from the hydroxyl groups positioned along the aromatic ring to terminate the oxidation of lipids and other biomolecules by free radicals (Foti et al., 1996).

Morante et al. (2021) reported that the inclusion of 80 g of crude grape pomace extract per kg of feed in the diet of the tambaqui *Colossoma macropomum* improved the metabolic, immunological, and antioxidant functions of the fish. In this study, a qualitative phytochemical analysis was carried out, which revealed the presence of lignans, monoterpenes, sesquiterpenes, and terpenes in higher concentrations in the raw extracts of pomace, which are known to have bioactive and antioxidant properties. Furthermore, fish fed with this concentration showed higher plasma triglycerides, in addition to increased values of albumin and lysozyme activity, indicating a possible improvement in the metabolic and immunological function of the organisms and suggesting a viable and effective alternative as a feed additive in tambaqui aquaculture.

Environmental changes during the cultivation of aquatic organisms can be considered stressors that compromise the growth performance, survival rate, health, and immunity of animals. According to a study by Lange et al. (2014), high water temperature conditions in the summer affect the productivity of abalone farming farms. The use of diets containing grape seed extract proved to be effective in significantly increasing abalone survival compared with the standard commercial diet. Furthermore, inclusion also resulted in a significant increase in the activity of serum superoxide dismutase, an important antioxidant enzyme associated with the body's defense against oxidative stress (Shahab et al., 2023).

Harikrishnan et al. (2021) evaluated the effects of grape pomace on growth, antioxidant activity, anti-inflammatory activity, innate-adaptive immunity, and the expression of immunological genes in carp *Labeo rohita* in the presence of the bacterium *Flavobacterium columnare*. According to this study, for both groups (healthy fish and affected fish), the results for the parameters evaluated with diets enriched with 200 and 300 mg of grape pomace were satisfactory. Diets with 200 mg of grape pomace showed a higher growth rate, antioxidant capacity, and immune defense mechanisms, while the results for the 300 mg of grape pomace diet were more effective against *F. columnare*. Proanthocyanidins are considered disease reducers. According to Unusan (2020), proanthocyanidins inhibit bacterial adhesion and congestion, biofilm formation, and inflammation. Research has shown that phenolic compounds exhibit beneficial effects against diseases owing to their redox properties (capacity to reduce pathological microorganisms).

Relationship of grape co-products and fillet quality

The increasing consumption of fish is linked to their nutritional characteristics. This type of protein is a source of polyunsaturated fatty acids (omega-3 and omega-6), vitamins (B12 and C), and mineral salts (iron, zinc, calcium, magnesium, selenium, phosphorus, and copper) (Ouriveis et al., 2020). Therefore, these characteristics are considered to be important quality parameters.

The use of plant-based by-products in animal diets has demonstrated a positive impact on meat quality, especially due to the presence of antioxidant compounds, such as polyphenols. These compounds help reduce lipid oxidation, contributing to the preservation and improvement of the sensory and nutritional characteristics of meat products. Brenes et al. (2016) highlighted that supplementing animal feed with grape-derived by-products resulted in superior apparent digestibility of nutrients, promoting potential improvements in the final quality of meat.

In Kesbiç and Yigit (2019), grape seed extract offered as a food supplement for rainbow trout at concentrations of 0.0, 0.5, 1.0, and 2.0% showed positive effects on the protein content in fish fillets, which was significantly higher in the 0.5% concentration group than in the control. The increase in protein content in rainbow trout fillets was attributed to changes in the intestinal microbiota induced by the inclusion of grape seed extract in the diet. These changes optimized protein digestibility and increased feed utilization efficiency. These findings highlight the potential of grape seed extract as a promising functional supplement in diets for farmed fish (Kesbiç & Yigit, 2019).

Lazzari et al. (2019) evaluated the addition of several plant co-products, including grapes, in the feed for jundiá *Rhamdia quelen*. The authors observed an effect on the proximate composition of the animal carcass in the group that included grapes. Lipid levels were lower than those in the other groups. According to this study, the content of phenolic compounds can affect the digestibility of nutrients and, consequently, increase or reduce lipid levels. In general, proteins contribute to the muscle structure, texture, and firmness of meat through the formation of muscle fibers, while lipids contribute to the flavor, juiciness, and tenderness of meat. Furthermore, adequate amounts of lipids in meat can improve palatability (Gonçalves, 2011). A balance between these components is essential to guarantee the quality of fish meat. Zhai et al. (2014) found higher protein levels and lower lipid levels in *Oreochromis niloticus* tilapia fillets that were fed a diet containing grape seed proanthocyanidin levels of up to 200 $mg{\cdot}kg^{-1}$. The researchers' report indicated that the high protein levels in all groups that received the diet were related to a decrease in lipid levels.

Mohammadi et al. (2021) demonstrated that grape seed extract, rich in proanthocyanidins, improved the growth performance of the common carp *Cyprinus carpio*, in addition to a possible increase in the crude protein content of the fillets and antioxidant effects in reducing free radicals in the liver. According to the authors, the performance of improving the protein content in fillets depends on the applied degree of polymerization and concentration of the extract, as it affects biodegradation and protein absorption. Oligomeric proanthocyanidins are less effective for digestion and absorption, whereas high-grade polymerized proanthocyanidins have been shown to affect protein biodegradation. The authors concluded that the concentration of 200 $mg{\cdot}kg^{-1}$ in the diet may affect the proximate composition of the carcass.

Pazos et al. (2005) investigated the ability of phenolic compounds obtained from grape pomace to inhibit lipid oxidation in different systems such as fish oils, emulsions and fatty fish during frozen storage. The researchers fractionated the phenolics and tested their antioxidant efficacy, observing that different fractions had variable efficacy depending on the system tested, with an emphasis on flavanol oligomers, which showed greater potential in frozen fish fillets, resulting in oxidative stability and increasing shelf time.

CONCLUSION

The use of grape by-products, such as pomace, stalks, and seeds, in diets for aquatic organisms offers significant benefits for both aquaculture production and environmental sustainability. These by-products, which are rich in bioactive compounds such as polyphenols, have shown positive effects on several zootechnical parameters, including health and meat quality, in addition to promoting improvements in palatability, protein digestibility, feed efficiency, and reduction of lipid levels in fillets. Such beneficial effects have been observed in fish and shrimp, demonstrating the viability of their application in different production systems. However, the application of these grape by-products still faces challenges, particularly regarding determining the optimal inclusion levels that maximize their positive effects in aquaculture.

Therefore, it is essential to advance our understanding on the multifunctional potential of the active compounds present in these plant by-products and their interactions with the nutrition of aquatic organisms. Future studies should focus on optimizing the inclusion concentrations, considering their effects on growth parameters, fillet quality, and the overall sustainability of aquaculture production. This will enable these ingredients to become effective and widely adopted solutions in the aquaculture sector.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable.

AUTHORS' CONTRIBUTION

Conceptualization: Guimarães, C.P., Tesser, M.B.; **Writing – original draft:** Guimarães, C.P.; **Data curation:** Guimarães, C.P.; **Resources:** Tesser, M.B.; **Writing – review & edition:** Tesser, M.B.; **Supervision:** Tesser, M.B.; **Final aprroval:** Tesser, M.B.

FUNDING

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

Financial code 001

Conselho Nacional de Desenvolvimento Científico e Tecnológico

Grant No. 305112/2023-6

Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul

Grant No. 19/2551-0001874-6

ACKNOWLEDGMENTS

Not applicable.

REFERENCES

Adeshina, I., & Abdel-Tawwab, M. (2020). Dietary taurine incorporation to high plant protein-based diets improved growth, biochemical, immunity, and antioxidants biomarkers of African catfish, *Clarias gariepinus* (B.). *Fish Physiology and Biochemistry*, 46(6), 1323-1335. https://doi.org/10.1007/S10695-020-00791-Y

Albuquerque, M. A. C., Levit, R., Beres, C., Bedani, R., LeBlanc, A. M., Saad, S. M. I., & LeBlanc, J. G. (2019). Tropical fruit by-products water extracts of tropical fruit by-products as sources of soluble fibres and phenolic compounds with potential antioxidant, anti-inflammatory, and functional properties. *Journal of Functional Foods*, 52, 724-733. https://doi.org/10.1016/j.jff.2018.12.002

Arciuli, M., Fiocco, D., Fontana, S., Arena, M. P., Frassanito, M. A., & Gallone, A. (2017). Administration of a polyphenol-enriched feed to farmed sea bass (*Dicentrarchus labrax* L.): Kidney melanomacrophages response. *Fish and Shellfish Immunology*, 68, 404-410. https://doi.org/10.1016/j.fsi.2017.07.043

Ardiansyah & Fotedar, R. (2016). Water quality, growth and stress responses of juvenile barramundi (*Lates calcarifer* Bloch), reared at four different densities in integrated recirculating aquaculture systems. *Aquaculture*, 458, 113-120. https://doi.org/10.1016/j.aquaculture.2016.03.001

Arslan, G., Sönmez, A. Y., & Yank, T. (2018). Effects of grape (*Vitis vinifera*) seed oil supplementation on growth, survival, fatty acid profiles, antioxidant contents, and blood parameters in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research*, 49(6), 2256-2266. https://doi.org/10.1111/are.13686

Atatoprak, T., Amorim, M. M., Ribeiro, T., Pintado, M., & Madureira, A. R. (2022). Grape stalk valorization for fermentation purposes. *Food Chemistry: Molecular Sciences*, 4, 100067. https://doi.org/10.1016/j.fochms.2021.100067

Baldissera, M. D., Souza, C. F., Descovi, S. N., Verdi, C. M., Zeppenfeld, C. C., Silva, A. S., Santos, R. C. V., & Baldisserotto, B. (2019a). Grape pomace flour ameliorates *Pseudomonas aeruginosa*-induced bioenergetic dysfunction in gills of grass carp. *Aquaculture*, 506, 359-366. https://doi.org/10.1016/j.aquaculture.2019.03.065

Baldissera, M. D., Souza, C. F., Descovi, S. N., Verdi, C. M., Zeppenfeld, C. C., Silva, L. L., Gindri, A. L., Cunha, M. A., Santos, R. C. V., Baldisserotto, B., & Silva, A. S. (2019b). Effects of dietary grape pomace flour on the purinergic signaling and inflammatory response of grass carp experimentally infected with *Pseudomonas aeruginosa*. *Aquaculture*, 503, 217-224. https://doi.org/10.1016/j.aquaculture.2019.01.015

Balea, Ş. S., Pârvu, A. E., Pârvu, M., Vlase, L., Dehelean, C. A., Pop, T. I. (2020). Antioxidant, anti-inflammatory and antiproliferative effects of the *Vitis vinifera* L. var. Fetească Neagră and Pinot Noir pomace extracts. *Frontiers in Pharmacology*, 11, 1-11. https://doi.org/10.3389/fphar.2020.00990

Barros, E. S. C., de Amorim, M. C. C., Olszevski, N., & Silva, P. T. de S. E. (2021). Composting of winery waste and characteristics of the final compost according to Brazilian legislation. *Journal of Environmental Science and Health, Part B*, 56(5), 447-457. https://doi.org/10.1080/03601234.2021.1900694

Basalan, M., Gungor, T., Owens, F. N., & Yalcinkaya, I. (2011). Nutrient content and in vitro digestibility of Turkish grape pomaces. *Animal Feed Science and Technology*, 169(3-4), 194-198. https://doi.org/10.1016/j.anifeedsci.2011.07.005

Baydar, N. G., & Akkurt, M. (2001). Oil content and oil quality properties of some grape seeds. *Turkish Journal of Agriculture and Forestry*, 25(3), 163-168. https://journals.tubitak.gov.tr/agriculture/vol25/iss3/3

Beres, C., Costa, G. N. S., Cabezudo, I., Silva-James, N. K., Teles, A. S. C., Cruz, A. P. G., Mellinger-Silva, C., Tonon, R. V., Cabral, L. M. C., & Freitas, S. P. (2017). Towards integral utilization of grape pomace from winemaking process: A review. *Waste Management*, 68, 581-594. https://doi.org/10.1016/j.wasman.2017.07.017

Beres, C., Freitas, S. P., Godoy, R. L. de O., Oliveira, D. C. R., Deliza, R., Iacomini, M., Mellinger-Silva, C., & Cabral, L. M. C. (2019). Antioxidant dietary fibre from grape pomace flour or extract: Does it make any difference on the nutritional and functional value? *Journal of Functional Foods*, 56, 276-285. https://doi.org/10.1016/j.jff.2019.03.014

Bordiga, M., Travaglia, F., & Locatelli, M. (2019). Valorisation of grape pomace: an approach that is increasingly reaching its maturity: a review. *Food Science and Technology*, 54(4), 933-642. https://doi.org/10.1111/ijfs.14118

Brenes, A., Viveros, A., Chamorro, S., & Arija, I. (2016). Use of polyphenol-rich grape by-products in monogastric nutrition: A review. *Animal Feed Science and Technology*, 211, 1-17. https://doi.org/10.1016/j.anifeedsci.2015.09.016

Bucić-Kojić, A., Fernandes, F., Silva, T., Planinic, M., Selo, G., Sibalic, D., Pereira, D. M., & Andrade, P. B. (2020). Enhancement of the anti-inflammatory properties of grape pomace treated by *Trametes versicolor*. *Food Function*, 11(1), 680-688. https://doi.org/10.1039/c9fo02296a

Bustamante, M. A., Paredes, C., Morales, J., Mayoral, A. M., & Moral, R. (2009). Study of the composting process of winery and distillery wastes using multivariate techniques. *Bioresource Technology*, 100(20), 4766-4772. https://doi.org/10.1016/j.biortech.2009.04.033

Butnariu, M., & Butu, A. (2019). Qualitative and quantitative chemical composition of wine. In A. M. Grumezescu & A. M. Holban (Eds.), *Quality Control in the Beverage Industry* (Vol. 17, pp. 385-417). Elsevier. https://doi.org/10.1016/B978-0-12-816681-9.00011-4

Câmara, J. S., Lourenço, S., Silva, C., Lopes, A., Andrade, C., & Perestrelo, R. (2020). Exploring the potential of wine industry by-products as source of additives to improve the quality of aquafeed. *Microchemical Journal*, 155, 104758. https://doi.org/10.1016/j.microc.2020.104758

Campos, D. A., Gómez-García, R., Vilas-Boas, A. A., Madureira, A. R., & Pintado, M. M. (2020). Management of fruit industrial by-products—a case study on circular economy approach. *Molecules*, 25(2), 320. https://doi.org/10.3390/molecules25020320

Chakka, A. K., Sriraksha, M. S., & Ravishankar, C. N. (2021). Sustainability of emerging green non-thermal technologies in the food industry with food safety perspective: A review. *LWT*, 151, 112140. https://doi.org/10.1016/j.lwt.2021.112140

Chedea, V. S., Pelmus, R. S., Lazar, C., Pistol, G. C., Calin, L. G., Toma, S. M., Dragomir, C., & Taranu, I. (2017). Effects of a diet containing dried grape pomace on blood metabolites and milk composition of dairy cows. *Journal of the Science of Food and Agriculture*, 97(8), 2516-2523. https://doi.org/10.1002/jsfa.8068

Chen, B., Qiu, J., Wang, Y., Huang, W., Zhao, H., Zhu, X., & Peng, K. (2022). Condensed tannins increased intestinal permeability of Chinese seabass (*Lateolabrax maculatus*) based on microbiome-metabolomics analysis. *Aquaculture*, 560, 738615. https://doi.org/10.1016/j.aquaculture.2022.738615

Cheng, B. S., Bible, J. M., Chang, A. L., Ferner, M. C., Wasson, K., Zabin, C. J., Latta, M., Deck, A., Todgham, A. E., & Groshholz, E. (2015). Testing local and global stressor impacts on a coastal foundation species using an ecologically realistic framework. *Global Change Biology*, 21(7), 2488-2499. https://doi.org/10.1111/gcb.12895

Chien, A., Chou, C. Y., Cheng, Y. C., Sheen, S. S., & Kirby, R. (2023). The optimal dietary level of dry grape extract and its effect on the growth performance and antioxidant activity of the white shrimp *Litopenaeus vannamei*. *Aquaculture Reports*, 29, 101527. https://doi.org/10.1016/j.aqrep.2023.101527

Cosenza, J. P., De Andrade, E. M., & De Assunção, G. M. (2020). A circular economy as an alternative for Brazil's sustainable growth: Analysis of the national solid waste policy. *Revista de Gestão Ambiental e Sustentabilidade*, 9(1), e16147. https://doi.org/10.5585/GEAS.V9I1.16147

Cruz, R. G., Beney, L., Gervais, P., Lira, S. P., Vieira, T. M. F. S., & Dupont, S. (2019). Comparison of the antioxidant property of acerola extracts with synthetic antioxidants using an in vivo method with yeasts. *Food Chemistry*, 277, 698-705. https://doi.org/10.1016/j.foodchem.2018.10.099

Das, R., & Bhattacharjee, C. (2020). Grapes. In A. K. Jaiswal (Ed.), *Nutritional Composition and Antioxidant Properties of Fruits and Vegetables* (pp. 695-708). Elsevier. https://doi.org/10.1016/B978-0-12-812780-3.00043-X

Davis, K. F., Downs, S., & Gephart, J. A. (2021). Towards food supply chain resilience to environmental shocks. *Nature Food*, 2, 54-65. https://doi.org/10.1038/s43016-020-00196-3

Dawood, M. A. O., Eweedah, N. M., Khalafalla, M. M., Khalid, A., Asely, A., Fadl, S. E., Amin, A. A., Paray, B. A., & Ahmed, H. A. (2020). *Saccharomyces cerevisiae* increases the acceptability of Nile tilapia (*Oreochromis niloticus*) to date palm seed meal. *Aquaculture Reports*, 17, 100314. https://doi.org/10.1016/j.aqrep.2020.100314

Dawood, M. A. O., & Koshio, S. (2019). Application of fermentation strategy in aquafeed for sustainable aquaculture. *Aquaculture Reports*, 12(2), 987-1002. https://doi.org/10.1111/raq.12368

De Alencar, M. G., de Quadros, C. P., Luna, A. L. L. P., Figueiredo Neto, A., Costa, M. M., Queiroz, M. A. A., Carvalho, F. A. L., Araújo, D. H. S., Gois, G. C., Santos, V. L. A., Silva Filho, J. R. V., & Rodrigues, R. T. S. (2022). Grape skin flour obtained from wine processing as an antioxidant in beef burgers. *Meat Science*, 194, 108963. https://doi.org/10.1016/j.meatsci.2022.108963

Deamici, K. M., de Oliveira, L. C., da Rosa, G. S., & de Oliveira, E. G. (2016). Drying kinetics of fermented grape pomace: Determination of moisture effective diffusivity. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 20(8), 763-768. https://doi.org/10.1590/1807-1929/agriambi.v20n8p763-768

Deng, Q., Penner, M. H., & Zhao, Y. (2011). Chemical composition of dietary fiber and polyphenols of five different varieties of wine grape pomace skins. *Food Research International*, 44(9), 2712-2720. https://doi.org/10.1016/j.foodres.2011.05.026

Devesa-Rey, R., Vecino, X., Varela-Alende, J. L., Barral, M. T., Cruz, J. M., & Moldes, A. B. (2011). Valorization of winery waste vs. the costs of not recycling. *Waste Management*, 31(11), 2327-2335. https://doi.org/10.1016/j.wasman.2011.06.001

Ding, Z., Ge, Y., Sar, T., Kumar, V., Harirchi, S., Binod, P., Sirohi, R., Sindhu, R., Wu, P., Lin, F., Zhang, Z., Taherzadeh, M. J., Awasthi, M. K. (2023). Valorization of tropical fruit waste for production of commercial biorefinery products - A review. *Bioresource Technology*, 374, 128793. https://doi.org/10.1016/j.biortech.2023.128793

Erinle, T. J., & Adewole, D. I. (2022). Fruit pomaces - their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques. *Animal Nutrition*, 9, 357-377 https://doi.org/10.1016/j.aninu.2021.11.011

Escobar, N., Tizado, E. J., zu Ermgassen, E. K. H. J., Löfgren, P., Börner, J., & Godar, J. (2020). Spatially-explicit footprints of agricultural commodities: Mapping carbon emissions embodied in Brazil's soy exports. *Global Environmental Change*, 62, 102067. https://doi.org/10.1016/j.gloenvcha.2020.102067

Fabjanowicz, M., Różańska, A., Abdelwahab, N. S., Pereira-Coelho, M., Haas, I. C. S., Madureira, L. A. S., & Plotka-Wasylka, J. (2024). An analytical approach to determine the health benefits and health risks of consuming berry juices. *Food Chemistry*, 432, 137219. https://doi.org/10.1016/j.foodchem.2023.137219

Falcone, D. B., Klinger, A. C. K., Salete, G., & Toledo, P. D. (2022). Fruit residues in rabbits' nutrition—review. *Revista Científica Rural* 24, 51-63.: https://doi.org/10.29327/246831.24.1-5

Food and Agriculture Organization (FAO) (2021). *World Food and Agriculture - Statistical Yearbook 2021*. FAO. https://doi.org/10.4060/cb4477en

Food and Agriculture Organization (FAO) (2022). *The State of World Fisheries and Aquaculture 2022*. FAO. https://doi.org/10.4060/cc0461en

FAOSTAT (2025). *Crops and livestock products*. Retrieved from https://www.fao.org/faostat/en/#data/QCL

Ferrari, V., Taffarel, S. R., Espinosa-Fuentes, E., Oliveira, M. L. S., Saikia, B. K., & Oliveira, L. F. S. (2019). Chemical evaluation of by-products of the grape industry as potential agricultural fertilizers. *Journal of Cleaner Production*, 208, 297-306. https://doi.org/10.1016/j.jclepro.2018.10.032

Filipe, D., Gonçalves, M., Fernandes, H., Oliva-Teles, A., Peres, H., Belo, I., & Salgado, J. M. (2023). Shelf-life performance of fish feed supplemented with bioactive extracts from fermented olive mill and winery by-products. *Foods*, 12(2), 305. https://doi.org/10.3390/foods12020305

Filippi, K., Papapostolou, H., Alexandri, M., Vlysidis, A., Myrtsi, E. D., Ladakis, D., Pateraki, C., Haraoutounian, S. A., & Koutinas, A. (2022). Integrated biorefinery development using winery waste streams for the production of bacterial cellulose, succinic acid, and value-added fractions. *Bioresource Technology*, 343, 125989. https://doi.org/10.1016/j.biortech.2021.125989

Foti, M., Piattelli, M., Baratta, M. T., & Ruberto, G. (1996). Flavonoids, coumarins, and cinnamic acids as antioxidants in a micellar system. structure-activity relationship. *Journal of Agricultural and Food Chemistry*, 44(2), 497-501. https://doi.org/10.1021/jf950378u

Gil-Sánchez, I., Ayuda-Durán, B., González-Manzano, S., Santos-Buelga, C., Cueva, C., Martín-Cabrejas, M. A., Sanz-Buenhombre, M., Guadamarra, A., Moreno-Arribas, M. V., & Bartolomé, B. (2017). Chemical characterization and in vitro colonic fermentation of grape pomace extracts. *Journal of the Science of Food and Agriculture*, 97(10), 3433-3444. https://doi.org/10.1002/jsfa.8197

Gonçalves, A. A. (2011). *Tecnologia do pescado: Ciências, tecnologia, inovação e legislação*. Atheneu.

Gopinathan, M., & Thirumurthy, M. (2012). Feasibility studies on static pile co-composting of organic fraction of municipal solid waste with dairy wastewater. *Environmental Research, Engineering and Management*, 60(2), 34-39. https://doi.org/10.5755/j01.erem.60.2.963

Harikrishnan, R., Devi, G., Van Doan, H., Balasundaram, C., Esteban, M. A., & Abdel-Tawwab, M. (2021). Impact of grape pomace flour (GPF) on immunity and immune-antioxidant-anti-inflammatory genes expression in *Labeo rohita* against *Flavobacterium columnaris*. *Fish and Shellfish Immunology*, 111, 69-82. https://doi.org/10.1016/j.fsi.2021.01.011

Hassan, Y. I., Kosir, V., Yin, X., Ross, K., & Diarra, M. S. (2019). Grape pomace as a promising antimicrobial alternative in feed: A critical review. *Journal of Agricultural and Food Chemistry*, 67(35), 9705-9718. https://doi.org/10.1021/acs.jafc.9b02861

Huang, Q., Liu, X., Zhao, G., Hu, T., & Wang, Y. (2018). Potential and challenges of tannins as an alternative to in-feed antibiotics for farm animal production. *Animal Nutrition*, 4(2), 137-150. https://doi.org/10.1016/j.aninu.2017.09.004

International Organization of Vine and Wine (2022). Annual assessment of the world Vine and wine sector in 2022. International Organization of Vine and Wine.

Jiang, L., Gao, Y., Han, L., Zhang, W., & Fan, P. (2023). Designing plant flavonoids: Harnessing transcriptional regulation and enzyme variation to enhance yield and diversity. *Frontiers in Plant Science*, 14, 1220062. https://doi.org/10.3389/fpls.2023.1220062

Jiang, Y., Simonsen, J., & Yanyun, Z. (2011). Compression-molded biocomposite boards from red and white wine grape pomaces. *Journal of Applied Polymer Science*, 119(5), 2834-2846. https://doi.org/10.1002/app.32961

Kabir, F., Tow, W. W., Hamauzu, Y., Katayama, S., Tanaka, S., & Nakamura, S. (2015). Antioxidant and cytoprotective activities of extracts prepared from fruit and vegetable wastes and by-products. *Food Chemistry*, 167, 358-362. https://doi.org/10.1016/j.foodchem.2014.06.099

Kesbiç, O. S., & Yigit, M. (2019). Structural and chemical changes of grape seed extract after thermal processing and its use in rainbow trout (*Oncorhynchus mykiss*) diets as an organic feed supplement. *Aquaculture*, 503, 275-281. https://doi.org/10.1016/j.aquaculture.2019.01.021

Khan, N., Fahad, S., Naushad, M., & Faisal, S. (2020). Grape production critical review in the world. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3595842

Kokou, F., & Fountoulaki, E. (2018). Aquaculture waste production associated with antinutrient presence in common fish feed plant ingredients. *Aquaculture*, 495, 295-310. https://doi.org/10.1016/j.aquaculture.2018.06.003

Kruidenier, L., Kuiper, I., Lamers, C., & Verspaget, H. W. (2003). Intestinal oxidative damage in inflammatory bowel disease: semi-quantification, localization, and association with mucosal antioxidants. *Journal of Pathology*, 201(1), 28-36. https://doi.org/10.1002/path.1409

Lange, B., Currie, K. L., Howarth, G. S., & Stone, D. A. J. (2014). Grape seed extract and dried macroalgae, *Ulva lactuca* Linnaeus, improve survival of greenlip abalone, *Haliotis laevigata* Donovan, at high water temperature. *Aquaculture*, 433, 348-360. https://doi.org/10.1016/j.aquaculture.2014.06.028

Lazzari, R., Uczay, J., Henriques, J. K. S., Durigon, E. G., Kunz, D. F., Peixoto, N. C., Fronza, D. (2019). Growth and digestive enzymes of silver catfish fed diets containing fruit residue. *Arquivos Brasileiros de Medicina Veterinária e Zootecnia*, 71(1), 323-330. https://doi.org/10.1590/1678-4162-10343

Leal, I. F. (2018). *Resíduo seco da industrialização da acerola na alimentação de suínos na fase inicial* (Dissertation, Universidade Estadual do Oeste do Paraná). https://tede.unioeste.br/handle/tede/4025

Lu, R. H., Qin, C. B., Yang, F., Zhang, W. Y., Zhang, Y. R., Yang, G. K., Yang, L. P., Meng, X. L., Yan, X., & Nie, G. X. (2020). Grape seed proanthocyanidin extract ameliorates hepatic lipid accumulation and inflammation in grass carp (*Ctenopharyngodon idella*). *Fish Physiology and Biochemistry*, 46, 1665-1677. https://doi.org/10.1007/s10695-020-00819-3

Mendes, J. A. S., Xavier, A. M. R. B., Evtuguin, D. V., & Lopes, L. P. C. (2013). Integrated utilization of grape skins from white grape pomaces. *Industrial Crops and Products*, 49, 286-291. https://doi.org/10.1016/j.indcrop.2013.05.003

Mohammadi, Y., Bahrami Kamangar, B., & Zarei, M. A. (2021). Effects of diets containing grape seed proanthocyanidin extract on the growth and oxidative capacity of common carp (*Cyprinus carpio*). *Aquaculture*, 540, 736689. https://doi.org/10.1016/j.aquaculture.2021.736689

Molosse, V. L., Deolindo, G. L., Lago, R. V. P., Cécere, B. G. O., Zotti, C. A., Vedovato, M., Copetti, P. M., Fracasso, M., Morsch, V. M., Xavier, A. C. H., Wagner, R., & Silva, A. S. (2023). The effects of the inclusion of ensiled and dehydrated grape pomace in beef cattle diet: Growth performance, health, and economic viability. *Animal Feed Science and Technology*, 302, 115671. https://doi.org/10.1016/j.anifeedsci.2023.115671

Montalvo, S., Martinez, J., Castillo, A., Huiliñir, C., Borja, R., García, V., & Salazar, R. (2020). Sustainable energy for a winery through biogas production and its utilization: A Chilean case study. *Sustainable Energy Technologies and Assessments*, 37, 100640. https://doi.org/10.1016/j.seta.2020.100640

Monteiro, G. C., Minatel, I. O., Pimentel Junior, A., Gomez-Gomez, H. A., Camargo, J. P. C., Diamante, M. S., Basílio, L. S. P., Tecchio, M. A., & Lima, G. P. P. (2021). Bioactive compounds and antioxidant capacity of grape pomace flours. *LWT*, 135, 110053. https://doi.org/10.1016/J.LWT.2020.110053

Morante, V. H. P., Copatti, C. E., Souza, A. R. L., Costa, M. M., Braga, L. G. T., Souza, A. M., Melo, F. V. S. T., Camargo, A. C. S., & Melo, J. F. B. (2021). Assessment of crude grape extract as a feed additive for tambaqui (*Colossoma macropomum*), an omnivorous fish. *Aquaculture*, 544, 737068. https://doi.org/10.1016/j.aquaculture.2021.737068

Mousavi, S., Sheikhzadeh, N., Hamidian, G., Mardani, K., Oushani, A. K., Firou zamandi, M., Esteban, M. A., & Shohreh, P. (2021). Changes in rainbow trout (*Oncorhynchus mykiss*) growth and mucosal immune parameters after dietary administration of grape (*Vitis vinifera*) seed extract. *Fish Physiology and Biochemistry*, 47, 547-563. https://doi.org/10.1007/s10695-021-00930-z

Nazima, B., Manoharan, V., & Prabu, S. M. (2015). Grape seed proanthocyanidins ameliorates cadmium-induced renal injury and oxidative stress in experimental rats through the up-regulation of nuclear related factor 2 (Nrf2) and antioxidant responsive elements. *Biochemistry and Cell Biology*, 93(3), 210-226. https://doi.org/10.1139/bcb-2014-0114

Nerantzis, E. T., & Tataridis, P. (2006). Integrated enology—Utilization of winery by-products into high added value products. *e-Journal of Science and Technology*, 1, 79-89.

Nicolai, M., Pereira, P., Rijo, P., Amaral, O., Amaral, A., & Palma, L. (2018). *Vitis vinifera* L. pomace: Chemical and nutritional characterization. *Journal of Biomedical and Biopharmaceutical Research*, 15(2), 156-166. https://doi.org/10.19277/bbr.15.2.182

Nirmal, N. P., Khanashyam, A. C., Mundanat, A. S., Shah, K., Babu, K. S., Thorakkattu, P., Al-Asmari, F., & Pandiselvam, R. (2023). Valorization of fruit waste for bioactive compounds and their applications in the food industry. *Foods*, 12(3), 556. https://doi.org/10.3390/foods12030556

Oliveira, R. M., Oliveira, F. M., Hernandes, J. V., & Jnacques, C. (2016). Composição centesimal de farinha de uva elaborada com bagaço da indústria vitivinícola. *Revista CSBEA*, 2(1), 2-7.

Onivogui, G., Letsididi, R., Diaby, M., Wang, L., & Song, Y. (2016). Influence of extraction solvents on antioxidant and antimicrobial activities of the pulp and seed of *Anisophyllea laurina* R. Br. ex Sabine fruits. *Asian Pacific Journal of Tropical Biomedicine*, 6(1), 20-25. https://doi.org/10.1016/j.apjtb.2015.09.023

Ouriveis, N. F., Costa Leite, B. F., Gimenes, N. K., Gomes, M. N. B., Faria, F. J. C., Souza, A. S., & Brumatti, R. C. (2020). Fatores relacionados ao consumo da carne de peixe pela população de Campo Grande, MS, Brasil. *Brazilian Journal of Development*, 6(1), 1861-1872. https://doi.org/10.34117/bjdv6n1-131

Passos, C. P., Yilmaz, S., Silva, C. M., & Coimbra, M. A. (2009). Enhancement of grape seed oil extraction using a cell wall degrading enzyme cocktail. *Food Chemistry*, 115(1), 48-53. https://doi.org/10.1016/j.foodchem.2008.11.064

Pazos, M., Gallardo, J. M., Torres, J. L., & Medina, I. (2005). Activity of grape polyphenols as inhibitors of the oxidation of fish lipids and frozen fish muscle. *Food Chemistry*, 92(3), 547-557. https://doi.org/10.1016/j.foodchem.2004.07.036

Pedras, B. M., Regalin, G., Sá-Nogueira, I., Simões, P., Paiva, A., & Barreiros, S. (2020). Fractionation of red wine grape pomace by subcritical water extraction/hydrolysis. *Journal of Supercritical Fluids*, 160, 104793. https://doi.org/10.1016/j.supflu.2020.104793

Peixoto, C. M., Dias, M. I., Alves, M. J., Calhelha, R. C., Barros, L., Pinho, S. P., & Ferreira, I. C. F. R. (2018). Grape pomace as a source of phenolic compounds and diverse bioactive properties. *Food Chemistry*, 253, 132-138. https://doi.org/10.1016/J.FOODCHEM.2018.01.163

Peña, E., Badillo-Zapata, D., Viana, M. T., & Correa-Reyes, G. (2020). Use of grape pomace in formulated feed for the rainbow trout fry, *Oncorhynchus mykiss* (Walbaum, 1792). *Journal of the World Aquaculture Society*, 51, 542-550. https://doi.org/10.1111/jwas.12669

Peng, K., Chen, B., Wang, Y., Zhao, H., Zheng, C., Chen, X., & Huang, W. (2022a). Condensed tannins protect against aflatoxin B1-induced toxicity in *Lateolabrax maculatus* by restoring intestinal integrity and regulating bacterial microbiota. *Aquaculture*, 555, 738255. https://doi.org/10.1016/j.aquaculture.2022.738255

Peng, K., Chen, B., Zhao, H., Wang, Y., Zheng, C., Lu, H., Huang, M., Zhao, J., & Huang, W. (2022b). Reevaluation of dietary condensed tannins on growth, antioxidant and immune response, and muscle quality of Chinese seabass (*Lateolabrax maculatus*). *Aquaculture*, 558, 738413. https://doi.org/10.1016/j.aquaculture.2022.738413

Peng, K., Huang, W., Zhao, H., Sun, Y., & Chen, B. (2021). Dietary condensed tannins improved growth performance and antioxidant function but impaired intestinal morphology of *Litopenaeus vannamei*. *Aquaculture Reports*, 21, 100853. https://doi.org/10.1016/j.aqrep.2021.100853

Peng, K., Zhou, Y., Wang, Y., Wang, G., Huang, Y., & Cao, J. (2020). Inclusion of condensed tannins in *Lateolabrax japonicus* diets: Effects on growth, nutrient digestibility, antioxidant and immune capacity, and copper sulfate stress resistance. *Aquaculture Reports*, 18, 100525. https://doi.org/10.1016/J.AQREP.2020.100525

Pereira, B. S., de Freitas, C., Vieira, R. M., & Brienzo, M. (2022). Brazilian banana, guava, and orange fruit and waste production as a potential biorefinery feedstock. *Journal of Materials Cycles and Waste Management*, 24, 2126-2140. https://doi.org/10.1007/s10163-022-01495-6

Pertuzatti, P. B., Mendonça, S. C., Alcoléa, M., Guedes, C. T., Amorim, F. E., Beckmann, A. P. S., Gama, L. A., & América, M. F. (2020). Bordo grape marc (*Vitis labrusca*): Evaluation of bioactive compounds in vitro and in vivo. *LWT*, 129, 109625. https://doi.org/10.1016/j.lwt.2020.109625

Ping, L., Brosse, N., Sannigrahi, P., & Ragauskas, A. (2011). Evaluation of grape stalks as a bioresource. *Industrial Crops and Products*, 33(1), 200-204. https://doi.org/10.1016/j.indcrop.2010.10.009

Plakantonaki, S., Roussis, I., Bilalis, D., & Priniotakis, G. (2023). Dietary fiber from plant-based food wastes: A comprehensive approach to cereal, fruit, and vegetable waste valorization. *Processes*, 11(5), 1580. https://doi.org/10.3390/pr11051580

Prozil, S. O., Evtuguin, D. V., & Lopes, L. P. C. (2012). Chemical composition of grape stalks of *Vitis vinifera* L. from red grape pomaces. *Industrial Crops and Products*, 35(1), 178-184. https://doi.org/10.1016/j.indcrop.2011.06.035

Prozil, S. O., Evtuguin, D. V., Silva, A. M. S., & Lopes, L. P. C. (2014). Structural characterization of lignin from grape stalks (*Vitis vinifera* L.). *Journal of Agricultural and Food Chemistry*, 62(24), 5420-5428. https://doi.org/10.1021/jf502267s

Pulgar, R., Mandakovic, D., Salgado, P., Venegas, L., Ortiz, D., Peña-Neira, A., & Wacyk, J. (2021). Micro-encapsulated grape pomace extract (MGPE) as a feed additive improves growth performance, antioxidant capacity, and shifts the gut microbiome of rainbow trout. *Aquaculture*, 544, 737129. https://doi.org/10.1016/j.aquaculture.2021.737129

Reynolds, A. G. (2017). The grapevine, viticulture, and winemaking: A brief introduction. In G. P. Martelli, B. Meng, M. Fuchs & D. A. Golino (Eds.), *Grapevine Viruses: Molecular Biology, Diagnostics and Management* (pp. 3-29). Springer International Publishing.

Ribeiro, L. F., Ribani, R. H., Francisco, T. M. G., Soares, A. A., Pantarolo, R., & Haminiuk, C. W. I. (2015). Profile of bioactive compounds from grape pomace (*Vitis vinifera* and *Vitis labrusca*) by spectrophotometric, chromatographic and spectral analyses. *Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences*, 1007, 72-80. https://doi.org/10.1016/j.jchromb.2015.11.005

Riebel, M., Sabel, A., Claus, H., Xia, N., Li, H., König, H., Decker, H., & Fronk, P. (2017). Antioxidant capacity of phenolic compounds on human cell lines as affected by grape-tyrosinase and Botrytis-laccase oxidation. *Food Chemistry*, 229, 779-789. https://doi.org/10.1016/j.foodchem.2017.03.003

Righi, E., Variani, C., & Bitencourt, B. M. (2020). Análise da produção industrial e dos resíduos em uma vinícola na Serra Gaúcha, Brasil. *Revista Brasileira de Gestão Ambiental e Sustentabilidade*, 7(15), 319-340. https://doi.org/10.21438/rbgas(2020)071523

Rodríguez Montealegre, R., Romero Peces, R., Chacón Vozmediano, J. L., Martínez Gascueña, J., & García Romero, E. (2006). Phenolic compounds in skins and seeds of ten grape *Vitis vinifera* varieties grown in a warm climate. *Journal of Food Composition and Analysis*, 19(6-7), 687-693. https://doi.org/10.1016/j.jfca.2005.05.003

Rodríguez-Ramos, F., Cañas-Sarazúa, R., & Briones-Labarca, V. (2022). Pisco grape pomace: Iron/copper speciation and antioxidant properties, towards their comprehensive utilization. *Food Bioscience*, 47, 101781. https://doi.org/10.1016/j.fbio.2022.101781

Rosa, P. P., Xavier, A. A. S., Chesini, R. C., Oliveira, A. P. T., Camacho, J. S., Faria, M. R., & Nunes, L. P. (2019). Caracterização físico-química de silagens de bagaço de uvas tintas e brancas. *Boletim da Industria Animal*, 76, 1-7. https://doi.org/10.17523/bia.2019.v76.e1443

Rosas, V. T., Mureb, R. A., Monserrat, J. M., Wasielesky Jr., W., & Tesser, M. B. (2022). Inclusion of grape bagasse (*Vitis* sp.) in the diet of white shrimp (*Litopenaeus vannamei*) and its effects on growth and antioxidant system. *Aquaculture Research*, 1-9. https://doi.org/10.1111/are.15972

Salgado, M. M. M., Ortega Blu, R., Janssens, M., & Fincheira, P. (2019). Grape pomace compost as a source of organic matter: Evolution of quality parameters to evaluate maturity and stability. *Journal of Cleaner Production*, 216, 56-63. https://doi.org/10.1016/j.jclepro.2019.01.156

Sánchez-Peña, N. E., Narváez-Semanate, J. L., Pabón-Patiño, D., Fernández-Mera, J. E., Oliveira, M. L. S., da Boit, K., Tutikian, B. F., Crissien, T. J., Pinto, D. C., Serrano, I. D., Ayala, C. I., Duarte, A. L., Ruiz, J. D., & Silva, L. F. O. (2018). Chemical and nano-mineralogical study for determining potential uses of legal Colombian gold mine sludge: Experimental evidence. *Chemosphere*, 191, 1048-1055. https://doi.org/10.1016/j.chemosphere.2017.08.127

Shahab, M., Roberto, S. R., Adnan, M., Fahad, S., Koyama, R., Saleem, M. H., Nasar, J., Saud, S., Hassan, S., & Nawaz, T. (2023). Phenolic compounds as a quality determinant of grapes: A critical review. *Journal of Plant Growth Regulation*, 42, 5325-5331. https://doi.org/10.1007/s00344-023-10953-w

Shahidi, F., & Ambigaipalan, P. (2015). Phenolics and polyphenolics in foods, beverages, and spices: Antioxidant activity and health effects - A review. *Journal of Functional Foods*, 18(Part b), 820-897. https://doi.org/10.1016/j.jff.2015.06.018

Shiel, B. P., Hall, N. E., Cooke, I. R., Robinson, N. A., Stone, D. A. J., & Strugnell, J. M. (2017). The effect of commercial, natural and grape seed extract supplemented diets on gene expression signatures and survival of greenlip abalone (*Haliotis laevigata*) during heat stress. *Aquaculture*, 479, 798-807. https://doi.org/10.1016/j.aquaculture.2017.07.025

Sinrod, A. J. G., Shah, I. M., Surek, E., & Barile, D. (2023). Uncovering the promising role of grape pomace as a modulator of the gut microbiome: An in-depth review. *Heliyon*, 9(10), e20499. https://doi.org/10.1016/j.heliyon.2023.e20499

Sirohi, R., Tarafdar, A., Singh, S., Negi, T., Gaur, V. K., Gnansounou, E., & Bharathiraja, B. (2020). Green processing and biotechnological potential of grape pomace: Current trends and opportunities for sustainable biorefinery. *Bioresource Technology*, 314, 123771. https://doi.org/10.1016/j.biortech.2020.123771

Sławińska, N., & Olas, B. (2023). Selected seeds as sources of bioactive compounds with diverse biological activities. *Nutrients*, 15(1), 187. https://doi.org/10.3390/nu15010187

Sousa, E. C., Uchôa-Thomaz, A. M. A., Carioca, J. O. B., Morais, S. M., Lima, A., Martins, C. G., Alexandrino, C. D., Ferreira, P. A. T., Rodrigues, A. L. M., Rodrigues, S. P., Silva, J. N., & Rodrigues, L. L. (2014). Chemical composition and bioactive compounds of grape pomace (*Vitis vinifera* L.), Benitaka variety, grown in the semiarid region of Northeast Brazil. *Food Science and Technology*, 34(1), 135-142. https://doi.org/10.1590/S0101-20612014000100020

Spinei, M., & Oroian, M. (2021). The potential of grape pomace varieties as a dietary source of pectic substances. *Foods*, 10(4), 867. https://doi.org/10.3390/foods10040867

Tang, G. Y., Zhao, C. N., Liu, Q., Feng, X. L., Xu, X. Y., Cao, S. Y., Meng, X., Li, S., Gan, R. Y., & Li, H. B. (2018). Potential of grape wastes as a natural source of bioactive compounds. *Molecules*, 23(10), 2598. https://doi.org/10.3390/molecules23102598

Teixeira, N., Mateus, N., de Freitas, V., & Oliveira, J. (2018). Wine industry by-product: Full polyphenolic characterization of grape stalks. *Food Chemistry*, 268, 110-117. https://doi.org/10.1016/j.foodchem.2018.06.070

Terzi, F., Demirci, B., Acar, Ü., Yüksel, S., Salum, Ç., Erol, H. S., & Kesbiç, O. S. (2023). Dietary effect of grape (*Vitis vinifera*) seed extract mitigates hepatic disorders caused by oxidized fish oil in rainbow trout (*Oncorhynchus mykiss*). *Fish Physiology and Biochemistry*, 49, 441-454. https://doi.org/10.1007/s10695-023-01193-6

Teshome, E., Teka, T. A., Nandasiri, R., Rout, J. R., Harouna, D. V., Astatkie, T., & Urugo, M. M. (2023). Fruit by-products and their industrial applications for nutritional benefits and health promotion: A comprehensive review. *Sustainability*, 15(10), 7840. https://doi.org/10.3390/su15107840

Tonon, R. V., Silva, C. M., Galdeano, M. C., & Santos, K. M. O. (2018). *Tecnologias para o aproveitamento integral dos resíduos da indústria vitivinícola*. Embrapa Agroindústria de Alimentos.

Trošt, K., Klančnik, A., Mozetič Vodopivec, B., Lemut, M. S., Novsak, K. J., Raspor, P., & Mozina, S. S. (2016). Polyphenol, antioxidant and antimicrobial potential of six different white and red wine grape processing leftovers. *Journal of the Science of Food and Agriculture*, 96(14), 4809-4820. https://doi.org/10.1002/jsfa.7981

Unusan, N. (2020). Proanthocyanidins in grape seeds: An updated review of their health benefits and potential uses in the food industry. *Journal of Functional Foods*, 67, 103861. https://doi.org/10.1016/j.jff.2020.103861

Villacís-Chiriboga, J., Elst, K., Van Camp, J., Vera, E., & Ruales, J. (2020). Valorization of byproducts from tropical fruits: Extraction methodologies, applications, environmental, and economic assessment: A review (Part 1: General overview of the byproducts, traditional biorefinery practices, and possible applications). *Comprehensive Reviews in Food Science and Food Safety*, 19(2), 405-447. https://doi.org/10.1111/1541-4337.12542

Viswanath, M., Venkataramudu, K., Srinivasulu, B., Gopal, K., & Lakshmi, K. S. (2018). Processing for value addition of minor fruits. *Journal of Pharmacognosy and Phytochemistry*, 7(6), 1555-1559.

Wang, Y., Chen, X. H., Cai, G., & Zhai, S. (2022). Grape seed proanthocyanidin extract regulates lipid metabolism of the American eel (*Anguilla rostrata*). *Natural Product Research*, 36(22), 5889-5893. https://doi.org/10.1080/14786419.2021.2022666

Wang, Y., Wang, Y., Shen, W., Wang, Y., Cao, Y., Nuerbulati, N., Chen, W., Lu, G., Xiao, W., & Qi, R. (2020). Grape seed polyphenols ameliorated dextran sulfate sodium-induced colitis via suppression of inflammation and apoptosis. *Pharmacology*, 105(1-2), 9-18. https://doi.org/10.1159/000501897

Yadav, A., Kumar, N., Upadhyay, A., Pratibha, & Anurag, R. K. (2023). Edible packaging from fruit processing waste: A comprehensive review. *Food Reviews International*, 39(4), 2075-2106. https://doi.org/10.1080/87559129.2021.1940198

Yang, H., Li, Y., Wang, G., Xie, J., Kaneko, G., & Yu, E. (2023). Dietary grape seed proanthocyanidin extract improved the chemical composition, antioxidant capacity, myofiber growth and flesh quality of Nile tilapia muscle. *Aquaculture Reports*, 33, 101878. https://doi.org/10.1016/j.aqrep.2023.101878

Yilmaz, Y., Göksel, Z., Erdoğan, S. S., Ozturk, A., Atak, A., & Ozer, C. (2015). Antioxidant activity and phenolic content of seed, skin and pulp parts of 22 grape (*Vitis vinifera* L.) cultivars (4 common and 18 registered or candidate for registration). *Journal of Food Processing and Preservation*, 39(6), 1682-1691. https://doi.org/10.1111/jfpp.12399

Yu, J., & Ahmedna, M. (2013). Functional components of grape pomace: Their composition, biological properties and potential applications. *International Journal of Food Science and Technology*, 48(2), 221-237. https://doi.org/10.1111/j.1365-2621.2012.03197.x

Zacharof, M. P. (2017). Grape winery waste as feedstock for bioconversions: Applying the biorefinery concept. *Waste and Biomass Valorization*, 8, 1011-1025. https://doi.org/10.1007/s12649-016-9674-2

Zhai, S. W., Lu, J. J., & Chen, X. H. (2014). Effects of dietary grape seed proanthocyanidins on growth performance, some serum biochemical parameters and body composition of tilapia (*Oreochromis niloticus*) fingerlings. *Italian Journal of Animal Science*, 13(3), 3357. https://doi.org/10.4081/ijas.2014.3357

Zhao, J. X., Li, Q., Zhang, R. X., Liu, W. Z., Ren, Y. S., Zhang, C. X., & Zhang, J. X. (2018). Effect of dietary grape pomace on growth performance, meat quality and antioxidant activity in ram lambs. *Animal Feed Science and Technology*, 236, 76-85. https://doi.org/10.1016/j.anifeedsci.2017.12.004

Zhu, Y., Luan, Y., Zhao, Y., Liu, J., Duan, Z., & Ruan, R. (2023). Current technologies and uses for fruit and vegetable wastes in a sustainable system: A review. *Foods*, 12(10), 1949. https://doi.org/10.3390/foods12101949