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Original scientific paper

APPLICATION OF GRAPE POMACE IN MEAT INDUSTRY: A PERSPECTIVE ON SUSTAINABLE SOLUTIONS

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A b s t r a c t: Wine industry, with its long-standing tradition and global significance, generates substantial amounts of waste in the form of grape pomace - a by-product consisting of seeds, skins, and stems. This residual material is rich in bioactive compounds such as dietary fibers, polyphenols, minerals, and essential fatty acids, all of which exhibit strong antioxidant and antimicrobial properties. Opportunities are emerging for the reuse of this waste as part of the transition from the traditional linear "take-make-dispose" model toward sustainable solutions grounded in the principles of the circular economy. In light of the increasing demand for sustainability, current research efforts are focused on the valorization of grape pomace, including its application in the meat industry. The aim of this study is to promote sustainability in agro-industrial processes by exploring the functional properties of grape pomace and its utilization in meat processing. This paper examines the potential benefits of incorporating grape pomace in meat industry, emphasizing its role in food safety, innovation and development of products enriched with natural alternatives to synthetic additives, while simultaneously enhancing their nutritional profile.

Key words: grape pomace; meat industry; antioxidants; sustainability; circular economy

ПРИМЕНА НА ГРОЗДОВАТА КОМИНА ВО ИНДУСТРИЈАТА ЗА МЕСО: ПОГЛЕД НА ОДРЖЛИВИТЕ РЕШЕНИЈА

А п с т р а к т: Винската индустрија, која има долга традиција и глобално значење, генерира значајни количества отпад во форма на гроздова комина, нус-производ составен од семки, лушпи и дршки. Овој нус-производ е богат со биоактивни компоненти како диететски влакна, полифеноли, минерали и есенцијални масни киселини, кои се одликуваат со силно антиоксидативно и антимикробно дејство. Се отвора можност за повторна употреба на овој отпад како дел од напорите за премин од традиционалниот линеарниот модел "земи–произведи–фрли" кон одржливи решенија засновани на принципите на кружната економија. Во контекст на се поголемата потреба за одржливост, истражувањата се насочуваат кон валоризација на гроздовата комина, вклучувајќи ја и нејзината примена во индустријата за месо. Целта на ова истражување е да се промовира одржливоста во агроиндустриските процеси преку проучување на функционалните својства на гроздовата комина и нејзината примена во преработката на месо. Овој труд ги истражува потенцијалните придобивки од примената на гроздовото комине во месната индустрија, нагласувајќи ја неговата улога во безбедноста на храната, иновациите и развојот на производи збогатени со природни алтернативи на синтетичките адитиви, кои истовремено имаат подобрени нутритивни својства.

Клучни зборови: гроздова комина; индустрија за месо; антиоксиданти; одржливост; циркуларна економија

INTRODUCTION

Grapes, olives, pomegranates and figs are considered as fruits of prehistoric origin, which have been continuously present until now (Taskesenlioglu et al., 2022). Archaeological findings from 6,000 to 8,000 years ago in the Middle East indicate to the beginnings of the domestication of the grapevine *Vitis vinifera* subsp. *vinifera* from its wild ancestor *Vitis vinifera* subsp. *sylvestris* (Grassi and De Lorenzis, 2021; McGovern, 2003).

Grapes are non-climacteric berries that can be cultivated on all continents (Granato et al., 2016). The cultivation of grapevines, along with global grape and wine production, has a rich centuries-old tradition. Numerous archaeological records and oral traditions confirm that grapevines have co-evolved with humanity, as evidenced by a substantial body of scholarly literature (Beukers and Hondelink, 2025; Gonçalves et al., 2024; Bouby, 2023; Task-esenlioglu et al., 2022; Unusan, 2020; Li et al., 2018; Bouby et al., 2013; Myles et al., 2011; Terral et al., 2009; This et al., 2006).

The grapevine (*Vitis vinifera* L.) is one of the most important agricultural crops globally (Antonić et al., 2020). Global grape production for the 2023/2024 season is estimated at 28.39 million metric tons (Statista, 2025). Grapes are cultivated for wine production and fresh consumption (Keller, 2020), as well as for grape juice, jams, and raisins (Gonçalves et al., 2024). Antonić et al. (2020) state that approximately 75% of the total grape yield is used for wine production. The global wine output for 2024 is projected to range between 227 mhl and 235 mhl (OIV, 2024).

The winemaking industry generates large volumes of waste and by-products within a short production cycle, accounting for 20 – 30% of the initial grape weight (Yang et al., 2022; García-Lomillo et al., 2017), while some sources report figures as high as 40% (De Iseppi et al., 2020; Leal, 2020).

Grape pomace, the primary solid by-product of winemaking, is composed mainly of seeds, skins, and stems, which contain considerable amounts of bioactive compounds. This waste stream represents a current challenge for both environmental and economic sustainability. Da Conceição Lopes et al. (2025) emphasize the ongoing exploration of various strategies for the valorization of winery waste within the framework of the circular economy. Coderoni and Perito (2019) argue that the utilization of winery by-products is becoming increasingly significant due to their ecological, economic, and social benefits, as their processing results in value-added products aligned with circular economy principles.

In meat industry, winery-derived biological waste has the potential to be used in the development of novel meat products with reduced levels of synthetic additives, improved nutritional profiles, and enhanced health benefits.

This study explores the potential application of grape seeds and their extracted compounds in the meat industry.

Bioactive Components and Nutritional Potential of Grape Pomace

Grape pomace, a by-product of winemaking, primarily consists of grape skins, stems, and seeds (Spinei and Oroian 2021). It typically comprises approximately 22.5% seeds, 42.5% skins, 24.9% stems, and other components (Spinei and Oroian 2021).

Fig. 1. Representation of the morphological composition of grape pomace (Author's own elaboration)

In the past, grape pomace was typically discarded or used in very small amounts for compost production. However, research conducted over the past few decades indicates that grape pomace is a rich source of nutritional and biologically active compounds, such as dietary fibers, polyphenols, minerals, and others (Kurćubić et al., 2024). The chemical composition of grape pomace is complex and varies depending on the grape variety, agroecological conditions, viticultural practices, and the winemaking process (Bordiga et al., 2019). According to Caponio et al. (2023), significant variability in the composition of grape pomace arises from the method of wine production. During red wine production, the entire grape mass is included in the fermentation process, whereas in rosé and white wine production, only the grape juice undergoes fermentation.

According to literature data, the chemical composition of grape pomace is as follows: 50 – 70% water, 10 – 20% cellulose, 6 – 8% sugars, 2 – 4% organic compounds, 1 – 2% organic acids, 1 – 2% tannins, and 1 – 2% minerals (Antonić et al., 2020; Ribeiro et al., 2015). Grape pomace is particularly rich in dietary fibers, which constitute between 51.4% and 83.6% of the dry matter, with notable differences observed between the insoluble and soluble fiber fractions in pomace derived from red and white wines (O'Shea et al., 2012). The insoluble fraction (cellulose, hemicellulose, and lignin) in pomace from white wine accounts for 61.3%, whereas in pomace from red wine it accounts for 73.5%. The soluble fiber fraction ranges from 3.7% to 10.3% (Sousa, 2014).

The polyphenol content in grape pomace varies depending on the grape variety, processing conditions, and extraction methods. Polyphenols – includeing flavonoids, proanthocyanidins, and phenolic acids are responsible for the strong antioxidant activity of grape pomace (Vázquez-Armenta et al., 2018).One of the main polyphenolic compounds present in grape pomace are proanthocyanidins, which exhibit significant antioxidant activity (Alfaia et al., 2022). Felhi et al. (2016) emphasized that phenolic compounds possess strong antioxidant and antimicrobial effects. Their antioxidant activity enables effective scavenging of superoxide anions, hydroxyl radicals, and lipid peroxyl radicals, thereby minimizing oxidative reactions (Ruberto et al., 2005).

The total phenolic content in grape seeds ranges from 825.80 to 3313.5 mg/100 g expressed as gallic acid equivalents, which is approximately 20 times higher than the phenolic content found in grape pulp. In grape skins, gallic acid content ranges from 64.50 to 351.97 mg/100 g (Yordanova and Ivanov, 2021).

Grape seeds contain ten times more flavones compared to grape skins (Tang et al., 2018). Grape skins are rich in polyphenols such as anthocyanins, catechins, and flavonols (Karaman et al., 2015).

According to Alfaia et al. (2022), grape pomace has a high content of polyunsaturated fatty acids, particularly omega-6 fatty acids, with levels ranging from 58.1% to 62.7%. These fatty acids include linoleic acid (18:2n-6), which is the most prevalent. In addition, grape pomace contains monounsaturated fatty acids such as oleic acid (18:1n-9), with concentrations ranging from 12.2% to 14.0%. The content of saturated fatty acids, such as palmitic acid (16:0), ranges from 12.0% to 13.4%, and stearic acid (18:0) ranges from 4.31% to 5.07%.

Application of Grape Pomace in the Meat Industry

The meat industry daily uses additives, as they play a crucial role in enhancing the safety, shelf-life, sensory properties, and technological functionality of meat products. Antioxidants are utilized in the production of meat products to prevent or delay the oxidation of fats and pigments. According to Ribeiro et al. (2019), fat oxidation is one of the main factors leading to reduced shelf life and nutritional value of meat products. This results in changing the to sensory attributes (color, flavor, aroma, and texture), leaving a negative impression on consumers. Synthetic antioxidants, such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and propyl gallate, are used to reduce or inhibit oxidative reactions and preserve the sensory properties of meat products (Crippa et al., 2018). However, according to their findings, the use of synthetic antioxidants may be associated with toxicological risks, such as DNA mutations and an increased risk of neoplastic diseases.

Today, the modern consumer is increasingly concerned with their health and is changing their dietary habits. They are starting to demand meat products with less additives (Silovska Nikolova and Belichovska, 2021). Kumar et al. (2015) point out that there is a growing demand for natural products with antioxidant effects, which could replace synthetic antioxidants in meat industry. Grape pomace, as a by-product of winemaking industry, can serve as a source of natural antioxidants. As shown in Figure 2, grape pomace can be applied in meat industry as a natural preservative, improving sensory characteristics (color, texture, taste, and aroma), providing nutritional benefits, reducing losses during thermal processing, and extending shelf life.

In the study by Lorenzo et al. (2013), it was found that extracts from grape seeds and chestnuts have a stronger antioxidant effect compared to the synthetic antioxidant butylhydroxytoluene (BHT) in dry-cured Spanish chorizo sausage. Grape seed extract significantly reduced fat oxidation and improved the sensory characteristics of the product, making it an excellent natural alternative to synthetic antioxidants.

Wang et al. (2014) used polyphenols from green tea, grape seed extracts and α-tocopherol in production of dry-cured pork fat. They found that plant polyphenols and α-tocopherol significantly reduced pH, fat oxidation, and residual nitrites, while simultaneously decreased the formation of biogenic amines and N-nitrosodimethylamine (NDMA) compared to the control group. Grape seed extract could be an excellent natural alternative to improve the quality, shelf life, and safety of dry-cured bacon.

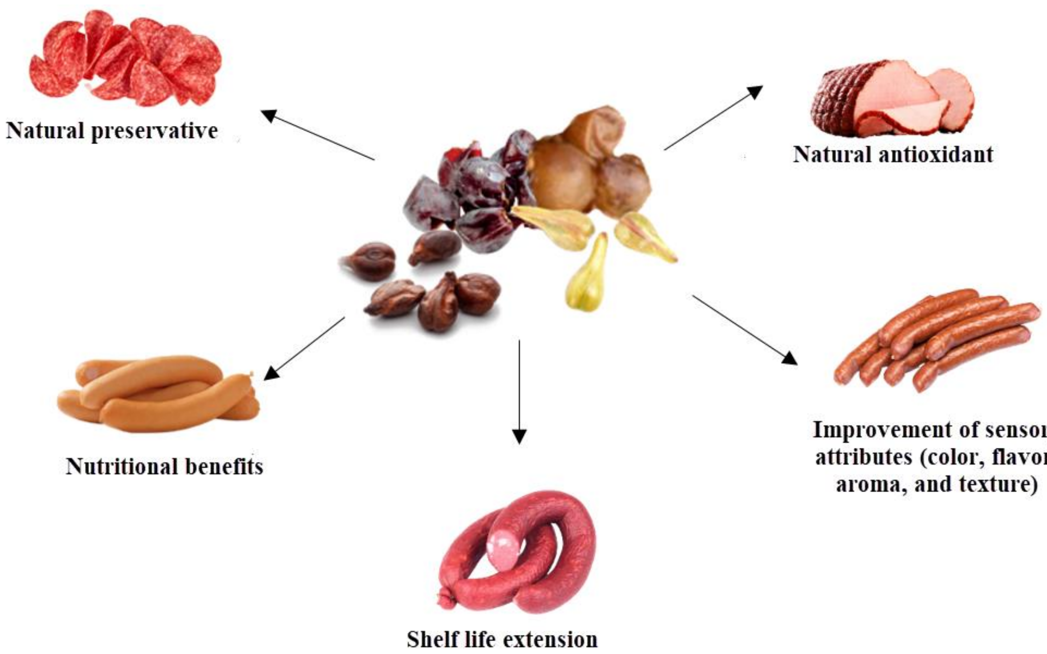

Fig. 2. Benefits of grape seeds and skins application in meat industry (Author's own elaboration)

In the study by Ribas-Agustí et al. (2014), grape seed extract was added to two types of dry-cured sausages, "salchichón" and "fuet." It was found that during storage, until the end of the shelf life, there was no significant reduction in the concentration of phenolic compounds. No statistically significant differences in sensory characteristics were observed between the control samples and those treated with grape seed extract.

The research by Cagdas and Kumcuoglu (2014) showed that addition of grape seed powder (GSP) to chicken nuggets had a significant effect in slowing down lipid oxidation. They stored thermally processed (fried) chicken nuggets at -18°C for five months. The results showed that samples with added GSP had significantly ($p<0.05$) lower lipid oxidation compared to the control sample.

El-Zainy et al. (2016) investigated the effect of ethanolic grape seed extract (GSE) on beef sausages during storage at -18°C. They found that GSE reduced lipid oxidation and the total microbial count. They pointed out that GSE has a synergistic effect with nitrites, and together they demonstrate a better antioxidant and antimicrobial effect than when used separately.

Libera et al. (2018) examined the effect of ethanolic grape seed extract (GSE) at concentrations of 0.1%, 0.2%, and 0.5% as a natural antioxidant in the production of dry-cured pork neck. They found that adding grape seed extract effectively inhibited lipid hydrolysis processes in dry neck, reducing the content of free fatty acids after two months of storage under different conditions.

Meena et al. (2021) determined the antioxidant capacity of grape seed extract (GSE) and its effect on the physicochemical, microbiological, and sensory properties of frozen lamb nuggets during storage. They found that GSE has high antioxidant capacity, reduces the total microbial count, psychrophilic bacteria, yeasts, and molds, and positively affects sensory characteristics (improving flavor, juiciness, and overall impression).

Kurćubić et al. (2024) pointed out that use of grape skins in meat products, such as sausages and patties, has a positive effect on improving texture, extending shelf life, and enriching the nutritional composition. Their use contributes to reducing environmental footprints.

Riazi et al. (2016) investigated the impact of adding grape skin powder (1% and 2% w/w) and reduced amounts of sodium nitrite (30, 60, and 120 mg/kg) in beef sausage. They found that the addition of 1% (w/w) grape skin powder, combined with reduced sodium nitrite, significantly reduced lipid oxidation and increased antioxidant activity, without negatively affecting the sensory properties of the product. Additionally, more intense and darker color was observed in the ready sausage.

Grape Skin Flour (GSF), according to De Alencar et al. (2022), was used as a natural antioxidant to replace synthetic butylhydroxytoluene (BHT) in beef burgers, frozen at –20°C and stored for up to 120 days. The best results were obtained by adding 0.5 and 1 g GSF per 100 g of meat, where no significant differences were observed compared to the control sample with added BHT. Samples with higher levels of GSF (1.5 and 2 g/100 g) showed increased lipid oxidation and deteriorated sensory properties. All GSF variants showed a raw fiber content of over 3 g/100 g, allowing the products to be labeled as a source of dietary fiber.

The research conducted by Silva et al. (2022) focused on use of microencapsulated grape waste extract to prevent oxidative processes in raw and previously thermally processed hamburgers. The results showed that the microencapsulated extract has a high antioxidant potential, increasing the oxidative stability of the product and preventing significant color changes during storage. The authors highlight that the microencapsulated extract showed better results compared to the synthetic antioxidant.

Fadhil (2023) investigated the effect of adding grape seed powder in various concentrations in basturma stored for 14 days at room temperature. The results showed that the inclusion of grape seed powder led to a statistically significant reduction ($p < 0.05$) in the total bacterial count, with the highest antimicrobial effect observed at 4%. Overall, the use of this natural additive resulted in a significant reduction in bacterial count from the first day of storage, and the effect was due to the presence of flavonoids.

CONCLUSION

Although traditionally considered as waste product, grape pomace represents a valuable source of bioactive and nutritional compounds with significant potential for further utilization. Its high content of polyphenols, dietary fiber, and essential fatty acids makes it suitable for application in various industries, particularly the food industry. The potential use of grape seeds and grape extracts in the meat industry may contribute to the development of healthier and more environmentally sustainable processed meat products with reduced reliance content of additives. Thus, the valorization of grape pomace, not only reduces waste, but, also, creates added value in line with the principles of the circular economy.

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