

THE INORGANIC COMPONENTS CONTENT IN RAW-COOKED MEAT PRODUCTS ENHANCED WITH THE GRAPE POMACE

Tomáš Tóth¹, Judita Lidiková¹, Marek Bobko^{*1}, Michal Baluch¹, Alica Bobková¹, Janette Musilová¹, Andrea Mésárošová¹, Natália Čeryová¹, Lukáš Jurčaga¹

Address(es): doc. Ing. Marek Bobko, PhD.

¹ Slovak University of Agriculture in Nitra, Institute of Food Sciences, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia.

*Corresponding author: marek.bobko@uniag.sk

<https://doi.org/10.55251/jmbfs.11895>

ARTICLE INFO

Received 4. 10. 2024
Revised 21. 1. 2025
Accepted 5. 2. 2025
Published 1. 4. 2025

Regular article



ABSTRACT

Antioxidant nature stands out as the main bioactive property of grape pomace, which is attributed to their rich phenolic composition. Apart of phenolic compounds, grape pomace also represents an abundant source of mineral substances. Mineral compounds perform a variety of vital physiological tasks, including the regulation of acid-base balance, osmotic pressure, adrenal gland function, proper cardiac action, and protein and carbohydrate metabolism. In our study we evaluated micro- and macroelement profile of pork sausages enhanced with grape pomace extract and powder obtained from two different varieties – Cabernet Franc and Merlot. The highest sodium (Na) level (4869.20 mg/kg) was found in sausages with the addition of Merlot grape pomace, albeit in the form of an extract. The Ca content varied from 60.90 to 95.60 mg/kg, with sample with Cabernet Franc powder (CF-P) addition having the highest concentration. Sample with Merlot powder addition (M-P) had the highest magnesium (Mg) (106.7 mg/kg) and phosphorus (P) (2718.3 mg/kg) levels. Samples examined in our study were absent from highly hazardous elements - lead (Pb) or cadmium (Cd). Based on our findings we believe grape pomace could be an interesting source of mineral substances for enhanced meat products, however, further multidisciplinary study, including food safety, toxicology, or sensory analysis, is still needed.

Keywords: meat product, mineral substance, microelement, macroelement

INTRODUCTION

Agro-food co-products of fruit processing industry, such as grapes, apples and oranges, are rich in bioactive phytochemicals with beneficial effects on human health. This fact suggests they have the potential to serve as suitable functional food ingredients. Plant co-products are obtained in significant quantities annually and they originate mainly from the wine industry and the juice production industry. Their possible inclusion in food represents a great challenge for waste disposal (Erinle and Adewole, 2022; Selim *et al.*, 2023). Co-products are interesting due to their abundance, availability, low price and high content of valuable components such as fiber and polyphenolic compounds. Co-product of wine-making industry is called grape pomace and consists of skins, remaining pulp, seeds, and stalks (Balbinoti *et al.*, 2019). The disposal of this waste poses environmental challenges, including the contamination of ground and surface water, attraction of disease-carrying vectors, and depletion of oxygen in soil and groundwater, which can negatively affect soil quality and have further impact on wildlife. Large amounts of grape pomace discarded in landfills can hinder biodegradation due to its low pH and the presence of antibacterial compounds like polyphenols Bustamante *et al.* (2007). In the past, part of the waste from the co-products of the winery was used as animal feed and as fertilizer (García-Lomillo and González, 2017), however, it has been noted that most animals are unable to digest it effectively or utilize it as an energy source (Nistor *et al.*, 2014). On the other hand, grape pomace contains significant amounts of substances that can be considered beneficial to health (Bender *et al.*, 2019). Constantin *et al.* (2024) states that grape co-products are a rich source of natural antioxidants, fiber, organic acids as well as proteins that have important therapeutic uses. Also, bioactive substances from co-products of winery have proven to have potential antidiabetic and anticancer effects. The biotechnological potential of grape pomace has led to numerous studies exploring its use as a fortifying ingredient in food products. These studies have shown that grape pomace can enhance the nutritional profile and overall value of the final product. A variety of food categories have been investigated, including plant-based items, meat, fish, and dairy products (Antonić *et al.*, 2020). The concentration of grape pomace used in these studies ranged from as little as 0.06% (in pork burgers, Garrido *et al.* (2011) to up to 100% (in tea infusion, Bekhit *et al.* (2011). Grape pomace contains compounds with antibacterial properties and can improve meat quality (Anton *et al.*, 2006) and has beneficial properties to maintain the physicochemical, sensory and nutritional quality of meat. Grape co-product

extracts have functional properties, inhibit pathogenic microorganisms and may be effective in preventing lipid oxidation. Their potential benefit may be to increase the nutritional value of meat and bread products, and they may also play a role in the color stability of meat products (Kalli *et al.*, 2018).

Red meat serves as a vital source of minerals in the human diet, offering highly bioavailable nutrients essential for proper growth and health. Compared to plant-based sources, minerals in meat are more readily absorbed by the body. Several factors can influence the mineral content in animal tissues, including the age and sex of the animal, the season of sampling (e.g., during hunting), and their diet (Amici *et al.*, 2012). Additionally, the habitat of wild game animals has a significant impact on the presence of heavy metals, as these animals are more directly influenced by their natural environment compared to farm-raised livestock (Chiari *et al.*, 2015). Meat and meat products are rich in essential nutrients, offering high-quality protein, B-complex vitamins, and antioxidants. They are also a source of n-3 polyunsaturated fatty acids and bioactive compounds like taurine, carnosine, and creatine. Additionally, they provide a variety of vital minerals necessary for the proper functioning of living organisms, including calcium, sodium, magnesium, potassium, iron, copper, manganese, and zinc (Stasiak *et al.*, 2017).

Grape pomace can serve as a good source of minerals in the human diet with a relatively low content of risk elements (Lidiková *et al.*, 2024). Mohamed Ahmed *et al.* (2020) states that grape pomace is a good source of Fe, P, Zn and K. Antonić *et al.* (2020) found that Fe and Zn are found in greater amounts in grape pomace and have an effect on antioxidant potential. Many mineral substances activate the action of certain hormones, vitamins and enzymes and participate in the metabolisms that take place in the human body. The presence and intake of macronutrients from the diet is very important and their deficiency can cause serious health problems (Šnirc *et al.*, 2023).

Grape pomace containing biogenic elements is an interesting ingredient for enriching meat products and increasing the intake of these elements in the human diet. The antioxidant and color enhancing properties of red grape pomace in food products are well known and documented. Previous studies however omitted the mineral enrichment potential of grape pomace, as well as hazard of contamination by heavy metal potential. The aim of the work therefore, was to determine the content of mineral micro- and macro-elements in a raw-cooked meat product after the addition of grape pomace of two varieties in two different forms and evaluated

its potential enhancement or increased harmfulness connected to mineral concentration.

MATERIAL AND METHODS

Plant material

Grape pomace of Cabernet Franc (CF), and Merlot (M) were provided by the Tajna winery (Slovakia). All samples were taken from the same site, in the municipality of Tajná, located in the Nitra wine region of Slovakia. The collected samples were dried at 50 °C for four days using a drying oven Memmert SF 110 (Memmert GmbH, Schwabach, Germany) and then thoroughly homogenized for 60 seconds at 25 000 rpm using batch mill IKA A10 (IKA-Werke GmbH & Co. KG, Staufen, Germany).

Meat product preparation

The meat product was made using the following ingredients: water, pork meat, nutmeg, black pepper, sweet and sour paprika, and a salting mixture containing 0.3% sodium nitrite. The pork loin and shoulder for the production of meat products were purchased from a local butcher. The meat was grounded, combined with all the spices and finely homogenized. This meat batter was divided into 5 parts and following groups were prepared: Control – group without any antioxidant addition. CF-E – group with Cabernet Franc extract addition 5 mL/kg; M-E – group with Merlot extract addition 5 mL/kg; CF-P – group with Cabernet Franc powder addition 5 g/kg; M-P – group with Cabernet Franc extract addition 5 g/kg.

Extract preparation

20 grams of dried and homogenized plant material was mixed with 100 mL of 80% ethanol and allowed to rest for 24 h, in the dark, at room temperature. The liquid fraction was then evaporated until dry at 65 °C in a vacuum rotary evaporator. The weighed dry residue was redissolved in 50 mL of water. The final extract was stored at 4 °C, in the dark.

Determination of macroelements in samples of soft meat product

Contents of macroelements were determined according to Musilová et al. (2024). 1 g of the sample was mineralized in 10 ml of concentrated HNO₃ and 5 ml of concentrated HClO₄ using the mineralization device MARS X-press (CEM Corp., Matthews, NC, USA). The mineralized sample was filtered through quantitative filter paper Filtrak 390 (Munktell, GmbH, Bärenstein, Germany). To determine K, Na, Ca, and Mg content, 2 ml of filtered sample was diluted with distilled water to the volume of 50 ml and measured against a blank solution using atomic absorption spectrophotometer VARIAN AASpectra DUO 240FS (Varian, Ltd., Mulgrave, VIC, AUS). To determine P content, 1 ml of filtered sample was diluted with 8 ml of solution (C₆H₈O₆, H₂SO₄, (NH₄)₂MoO₄, and C₄H₄KO₇Sb₀ × 5 H₂O) and deionized water to the volume of 50 ml and measured against blank solution using a UV/Visible Scanning Spectrophotometer Shimadzu UV-1800 (Shimadzu, Kyoto, Japan).

Table 1 Macroelements levels in meat product samples (mean±S.D.) [mg/kg]

Sample	K	Na	Ca	Mg	P
Control	2788.60±251.75 ^a	4789.70±432.40 ^a	73.30±6.62 ^a	102.90±9.29 ^a	2695.30±243.32 ^b
CF-E	2780.10±250.98 ^a	4636.10±418.53 ^a	71.00±6.41 ^a	102.10±9.22 ^a	2100.60±189.64 ^a
M-E	2776.30±250.64 ^a	4869.20±439.58 ^a	65.30±5.90 ^a	104.40±9.42 ^a	2647.90±239.05 ^b
CF-P	2810.90±253.76 ^a	4822.10±435.33 ^a	95.60±8.63 ^b	96.60±7.72 ^a	2690.20±242.86 ^b
M-P	2919.30±263.55 ^a	4712.60±425.44 ^a	74.80±6.75 ^a	106.70±9.63 ^a	2718.30±245.40 ^b

Note: Control – group without any antioxidant addition. CF-E – group with Cabernet Franc extract addition 5 mL/kg; M-E – group with Merlot extract addition 5 mL/kg; CF-P – group with Cabernet Franc powder addition 5 g/kg; M-P – group with Cabernet Franc extract addition 5 g/kg; a, b = groups within a column with different superscripts differ significantly at $p \leq 0.05$, one-way ANOVA

All determined macroelements determined in our study showed very little variance among meat product samples. Concentrations of K, Na, and Mg showed no statistical significance ($p \geq 0.05$) among all samples. Possible increased content of K after the addition of grape pomace attributed to the use of potassium hydrogen tartrate (Caponio et al., 2023) in the vinification process was not confirmed. Significant increase ($p \leq 0.05$) of Ca was observed only in one sample group – with addition of Cabernet Franc pomace powder (CF-P). Potassium plays an important role in lowering blood pressure and reducing the risk of osteoporosis due to reduced urinary calcium excretion (Sousa et al., 2014). Mg is characterized by antioxidant properties and its higher content can be a good alternative for the development of functional meat (Tan et al., 2018). On the other hand, significant decrease ($p \leq 0.05$) of P was observed only in samples with Cabernet Franc extract addition (CF-E). Both those significant changes were separated, and grape pomace extract or powder addition did not show systematic effect on meat product macroelement profile. Measurement levels of macroelements themselves are in line with findings of other authors studying macroelements profile of various meat

Determination of microelements in samples of soft meat product

Microelements in samples of soft meat product were determined according to Lidiková et al. (2021). The fresh sample was weighed, and 2 g was put into a mineralization cartridge. Then, 5 ml of concentrated nitric acid (Suprapur®, Merck, Darmstadt, Germany) and 5 ml of redistilled water (0.054 µS/cm) were added using an automatic pipette. The cartridge was sealed and placed in the MARS X-press mineralization device (CEM Corp., Matthews, NC, USA) for mineralization for 55 minutes. After the specified time, the mineralizate was filtered using Filtrak 390 paper (Munktell, GmbH, Bärenstein, Germany) into 50 ml volumetric flasks. The missing volume in the volumetric flask was filled with redistilled water to the mark. Simultaneously with the sample, a blank experiment was prepared. The measurement was performed on the Varian 240FS atomic absorption spectrometer (Varian Inc., Mulgrave, VIC, Australia).

Statistical analysis

In our study we performed analysis of variance (ANOVA) deploying Duncan's test to determine the statistical differences among samples at significance level $\alpha = 0.05$ and Pearson correlation test using XLSTAT® software (version 2018.5.52280, Addinsoft, New York).

RESULTS AND DISCUSSION

Microelements levels in meat and mead products vary significantly depending on factors such as animal species or meat cut (Djinovic-Stojanovic et al., 2017). Halagarda et al. (2018) concluded study in which they reported high variance of both micro- and macroelements in traditional polish pork sausages from different regions. Based on this fact, it is highly difficult to compare micro- and macroelements levels observed by us with results of other authors.

Bioactive substances from grape co-products act as antioxidant, anti-diabetic and anti-cancer substances. These substances have proven potential health benefits. Grape pomace extracts are added to meat products to increase antioxidant and preservative properties as well as to increase meat color stability (Beres et al., 2017). Several authors deal with the effect of natural antioxidants from co-products during grape processing. Many authors have devoted themselves to the application of extracts from grape co-products to beef, pork and chicken, but also to prepared meat products such as sausages and hamburgers (Escobar-Avello et al., 2019). In many studies, the susceptibility to lipid oxidation and the change in color of pork sausages were observed after the addition of grape pomace. Regarding monitoring the level of micro- and macroelements after the addition of grape pomace, a limited number of studies have already been published.

Macroelements analysis results

During macroelements analysis 5 elements were examined and measured, potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) and phosphorus (P). Results of macroelements determination are listed in Table 1.

products (Halagarda et al., 2018; Stojanovic et al., 2022). Cid et al. (2019) in their studies researching the mineral substance profile in grape pomace stated that the most prevalent macroelement is potassium (K). Even though the differences in our study were not significant, we were still could observe the increase of potassium concentration in meat product samples, especially after grape pomace powder addition. The main reason for the very small increase is the rather small concentration of macroelements in grape pomace as reported by Cid et al. (2019).

Microelements analysis results

Microelements variability in meat product samples was notably higher than in macroelements profile. During our analysis 9 different elements were analyzed, copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), chromium (Cr), nickel (Ni), Cobalt (Co), lead (Pb), and cadmium (Cd), but only seven were measured. Microelements profiles of our samples are listed in Table 2.

Table 2 Microelements levels in meat product samples (mean±S.D.) [mg/kg]

Sample	Cu	Zn	Mn	Fe	Cr	Ni	Co	Pb	Cd
Control	0.59±0.05 ^a	6.65±0.06 ^a	0.32±0.03 ^a	8.73±0.79 ^a	0.04±0.00 ^a	0.05±0.00 ^a	0.07±0.01 ^a	ND	ND
CF-E	0.67±0.06 ^a	7.03±0.63 ^a	0.34±0.34 ^{ab}	8.80±0.79 ^a	0.15±0.01 ^c	0.12±0.01 ^b	0.12±0.01 ^{bc}	ND	ND
M-E	0.70±0.06 ^a	7.01±0.63 ^a	0.36±0.03 ^{ab}	8.63±0.78 ^a	0.11±0.01 ^b	0.22±0.02 ^c	0.10±0.01 ^b	ND	ND
CF-P	0.68±0.06 ^a	6.98±0.63 ^a	0.41±0.04 ^b	8.42±0.76 ^a	0.09±0.01 ^b	0.21±0.02 ^c	0.14±0.01 ^c	ND	ND
M-P	0.90±0.08 ^b	7.12±0.64 ^a	0.40±0.04 ^b	9.26±0.84 ^a	0.09±0.01 ^b	0.20±0.02 ^c	0.10±0.01 ^b	ND	ND

Note: Control – group without any antioxidant addition. CF-E – group with Cabernet Franc extract addition 5 mL/kg; M-E – group with Merlot extract addition 5 mL/kg; CF-P – group with Cabernet Franc powder addition 5 g/kg; M-P – group with Cabernet Franc extract addition 5 g/kg; ND – not detected; LOD for Pb - 0.0894 and Cd - 0.0621; a, b = groups within a column with different superscripts differ significantly at p ≤ 0.05, one-way ANOVA

When evaluating the content of microelements in sausages, we can state that the highest content of Cu, Zn, Mn and Fe was recorded after the addition of powdered Merlot grape pomace in the amount of 5g/kg (M-P). During our study, we observed significant ($p \leq 0.05$) increased concentration of all macroelements, except Zn and Fe, after any grape pomace addition. This observed increase is expected as **García-Lomillo and Gonzalez-SanJosé (2017)** in their work stated that the application of grape pomace can improve the mineral content of meat products.

The content of Cr in the produced sausages ranged from 0.09 to 0.15 mg/kg, while in this case the highest value was recorded in sample P1 (addition of Cabernet Franc extract 5ml/kg). When evaluating the Co content in sausages with the addition of grape pomace, we can state that the highest Co value was recorded in sample CF-P (with the addition of Cabernet Franc powder 5g/kg). We were also able to observe significant differences in mineral substance concentration between different grape varieties addition, e.g. Cu and Co concentration in CF-P and M-P samples. **Mohamed Ahmed et al. (2020)** reported zinc, manganese and iron as the most prevalent microelements in grape pomace. Variations in mineral content may be due to differences in the variety as well as the growing region. **Gerardi et al. (2020)** tested and even observed differences among 4 varieties of grapes produced at the same vine region. **Lachman et al. (2013)** states in his work that the content of minerals in grape pomace and subsequently in food products can be influenced by climatic conditions as well as viticultural practices and the wine production process.

The use of grape pomace in the food industry can also affect its toxicological potential, such as heavy metal content. Mercury, lead, chromium, cadmium, and arsenic have been the most common heavy metals that induced human poisonings (**Balali-Mood et al., 2021**). From those elements, chromium, lead and cadmium were examined and only chromium was detected. The Panel on Food Additives and Nutrient Sources added to Food (ANS) of the European Food Safety Authority (EFSA) concluded that there is no health concern regarding the safety of chromium(III) added for nutritional purposes to conventional foods, including food supplements and foods for particular nutritional uses, provided that the intake of chromium(III) from these sources does not exceed 250 µg per day (**EFSA, 2010**). As we can see from our results, chromium levels detected in our samples do not represent a threat to human health. Enhanced lead concentration in blood affects behavior, cognitive performance, postnatal growth, delays puberty, and reduces hearing capacity in infants and children. In adults, Pb causes cardiovascular, central nervous system, kidney, and fertility problems (**Kumar et al., 2020**). Chronic dietary Cd exposure induced renal damage is characterized by proximal tubule dysfunction. Several epidemiological studies suggest that Cd exposure may potentiate the effects diabetes on the kidney (**Chunhabundit, 2016**). As we mentioned above, both Pb and Cd were under the detection limit in our samples (LOD for Pb - 0.0894 and Cd - 0.0621).

Pearson correlation test

To further examine mineral substance profile of pork sausages Pearson correlation test was deployed. The correlation matrix of this statistical test is displayed at **Figure 1**.

Akoglu (2018) stated that if we wish to label the strength of the association, for absolute values of r, 0-0.19 is regarded as very weak, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as very strong correlation, but these are rather arbitrary limits, and the context of the results should be considered. In our study we observed the very strong correlation of alkali metals concentration (K, Na) with alkaline earth metal magnesium (Mg) and strong with calcium (Ca) concentration. Also, both alkali metals and alkaline earth metals levels showed very strong correlation with iron (Fe) and zinc (Zn) concentration. On the other hand, potassium (K), sodium (Na) and magnesium (Mg) levels showed weak correlation with chromium (Cr), nickel (Ni) and cobalt (Co) levels. Very weak correlation was documented between two elements pairs: chromium and calcium (Ca), and cobalt (Co) and phosphorus (P). The only negative correlation was examined between phosphorus (P) and chromium (Cr) concentration levels. **Pereira et al. (2020)** reported that aluminum correlates significantly with copper (Spearman's coefficient = 0.786; p = 0.021) and iron (Spearman's coefficient = 0.929; p = 0.001) in the samples of grape pomace, while copper correlates significantly with iron (Spearman's coefficient = 0.738; p = 0.037) and zinc (Spearman's coefficient = 0.833; p = 0.010). The findings of **Jiang et al. (2007)** revealed notable correlations among the majority of mineral element

concentrations. Magnesium (Mg), iron (Fe), and manganese (Mn) exhibited significant positive associations with most other mineral elements, while copper (Cu) displayed a significant negative correlation with potassium (K) and magnesium (Mg) levels in rice. This negative correlation was not observed in our study due to different correlations of mineral content in various plant material as presented by **Monti et al. (2007)**. Due to limited studies published dealing with the mineral content of grape pomace enhanced meat products our discussion is considerably limited.

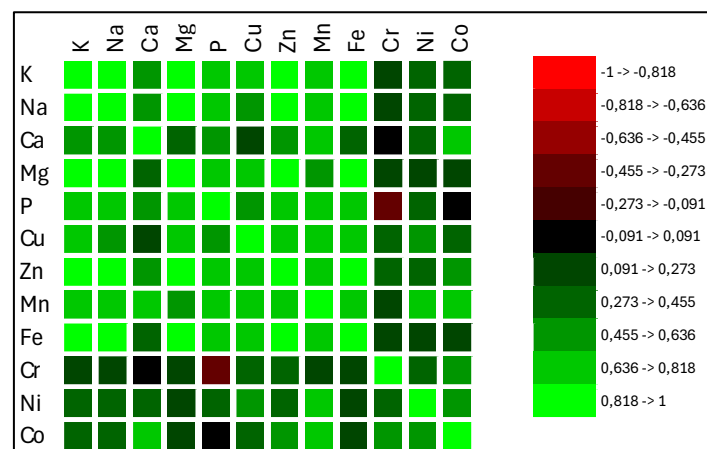


Figure 1 The correlation matrix of examined mineral substances with legend

CONCLUSION

In our study we evaluated micro- and macroelement profile of pork sausages enhanced with grape pomace extract and powder obtained from two different varieties. We observed minimal and statistically insignificant changes in macroelement profile of sausages after grape pomace addition. Microelement profile showed higher variance among sample groups, especially in the concentration of manganese (Mn), chromium (Cr), nickel (Ni) and cobalt (Co). From the health point of view, particularly harmful elements, lead (Pb) and cadmium (Cd) were not detected in our samples. Based on our results we are able to state that grape pomace addition cannot significantly enhance the mineral profile of meat products, especially the levels of macroelements. On the other hand, we proved that grape pomace did not contaminate the meat products with high dosages of harmful heavy metals. However, further multidisciplinary study, including food safety or sensory analysis, is still needed. Those studies could potentially confirm or disprove grape pomace suitability for usage in meat industry.

Acknowledgments: This research was supported by the Slovak Research and Development Agency under grant No. APVV-22-0255 and by International Visegrad Fund.

REFERENCES

Ahmed, I. a. M., Özcan, M. M., Juhaimi, F. A., Babiker, E. F. E., Ghafoor, K., Banjanin, T., Osman, M. A., Gassem, M. A., & Alqah, H. a. S. (2020). Chemical composition, bioactive compounds, mineral contents, and fatty acid composition of pomace powder of different grape varieties. *Journal of Food Processing and Preservation*, 44(7). <https://doi.org/10.1111/jfpp.14539>
 Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, 18(3), 91–93. <https://doi.org/10.1016/j.tjem.2018.08.001>
 Amici, A., Danieli, P. P., Russo, C., Primi, R., & Ronchi, B. (2012). Concentrations of some toxic and trace elements in wild boar (*Sus scrofa*) organs and tissues in different areas of the Province of Viterbo, Central Italy. *Italian Journal of Animal Science*, 11(4), e65. <https://doi.org/10.4081/ijas.2011.e65>
 Anton, M., Nau, F., & Nys, Y. (2006). Bioactive egg components and their potential uses. *World S Poultry Science Journal*, 62(03), 429–438. <https://doi.org/10.1079/wps2005105>

- Antonić, B., Jančíková, S., Dordević, D., & Tremlová, B. (2020). Grape Pomace Valorization: A Systematic Review and Meta-Analysis. *Foods*, 9(11), 1627. <https://doi.org/10.3390/foods9111627>
- Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R., & Sadeghi, M. (2021). Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. *Frontiers in Pharmacology*, 12. <https://doi.org/10.3389/fphar.2021.643972>
- Balbino, T. C. V., Stafussa, A. P., Haminiuk, C. W. I., Maciel, G. M., Sassaki, G. L., De Matos Jorge, L. M., & Jorge, R. M. M. (2019). Addition of grape pomace in the hydration step of parboiling increases the antioxidant properties of rice. *International Journal of Food Science & Technology*, 55(6), 2370–2380. <https://doi.org/10.1111/ijfs.14481>
- Bekhit, A. E. A., Cheng, V. J., McConnell, M., Zhao, J. H., Sedcole, R., & Harrison, R. (2011). Antioxidant activities, sensory and anti-influenza activity of grape skin tea infusion. *Food Chemistry*, 129(3), 837–845. <https://doi.org/10.1016/j.foodchem.2011.05.032>
- Bender, A. B. B., Speroni, C. S., Moro, K. I. B., Morisso, F. D. P., Santos, D. R. D., Da Silva, L. P., & Penna, N. G. (2019). Effects of micronization on dietary fiber composition, physicochemical properties, phenolic compounds, and antioxidant capacity of grape pomace and its dietary fiber concentrate. *LWT*, 117, 108652. <https://doi.org/10.1016/j.lwt.2019.108652>
- Beres, C., Costa, G. N., Cabezudo, I., Da Silva-James, N. K., Teles, A. S., Cruz, A. P., Mellinger-Silva, C., Toton, R. V., Cabral, L. M., & 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>
- Bustamante, M., Moral, R., Paredes, C., Pérez-Espinoza, A., Moreno-Caselles, J., & Pérez-Murcia, M. (2007). Agrochemical characterisation of the solid by-products and residues from the winery and distillery industry. *Waste Management*, 28(2), 372–380. <https://doi.org/10.1016/j.wasman.2007.01.013>
- Caponio, G. R., Minervini, F., Tamma, G., Gambacorta, G., & De Angelis, M. (2023). Promising Application of Grape Pomace and Its Agri-Food Valorization: Source of Bioactive Molecules with Beneficial Effects. *Sustainability*, 15(11), 9075. <https://doi.org/10.3390/su15119075>
- Chiari, M., Cortinovis, C., Bertoletti, M., Alborali, L., Zanoni, M., Ferretti, E., & Caloni, F. (2015). Lead, cadmium and organochlorine pesticide residues in hunted red deer and wild boar from northern Italy. *Food Additives & Contaminants Part A*, 32(11), 1867–1874. <https://doi.org/10.1080/19440049.2015.1087058>
- Chunhabundit, R. (2016). Cadmium Exposure and Potential Health Risk from Foods in Contaminated Area, Thailand. *Toxicological Research*, 32(1), 65–72. <https://doi.org/10.5487/tr.2016.32.1.065>
- Cid, B. P., Martínez, M. M., Vázquez, F. a. V., & Segade, S. R. (2019). Content and bioavailability of trace elements and nutrients in grape pomace. *Journal of the Science of Food and Agriculture*, 99(15), 6713–6721. <https://doi.org/10.1002/jsfa.9953>
- Constantin, O. E., Stoica, F., Rațu, R. N., Stănciuc, N., Bahrim, G. E., & Râpeanu, G. (2024). Bioactive Components, Applications, Extractions, and Health Benefits of Winery By-Products from a Circular Bioeconomy Perspective: A Review. *Antioxidants*, 13(1), 100. <https://doi.org/10.3390/antiox13010100>
- Djinovic-Stojanovic, J. M., Nikolic, D. M., Vranic, D. V., Babic, J. A., Milijasevic, M. P., Pezo, L. L., & Jankovic, S. D. (2017). Zinc and magnesium in different types of meat and meat products from the Serbian market. *Journal of Food Composition and Analysis*, 59, 50–54. <https://doi.org/10.1016/j.jfca.2017.02.009>
- EFSA (2010). Scientific Opinion on the safety of chromium picolinate as a source of chromium added for nutritional purposes to foodstuffs for particular nutritional uses and to foods intended for the general population - Panel on Food Additives and Nutrient Sources added to Food. *EFSA Journal* 8: 1–49.
- 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>
- García-Lomillo, J., & González-SanJosé, M. L. (2016). Applications of Wine Pomace in the food industry: Approaches and functions. *Comprehensive Reviews in Food Science and Food Safety*, 16(1), 3–22. <https://doi.org/10.1111/1541-4337.12238>
- Garrido, M. D., Auqui, M., Martí, N., & Linares, M. B. (2011). Effect of two different red grape pomace extracts obtained under different extraction systems on meat quality of pork burgers. *LWT*, 44(10), 2238–2243. <https://doi.org/10.1016/j.lwt.2011.07.003>
- Gerardi, C., D'amico, L., Migoni, D., Santino, A., Salomone, A., Carluccio, M. A., & Giovinazzo, G. (2020). Strategies for reuse of skins separated from grape pomace as ingredient of functional beverages. *Frontiers in Bioengineering and Biotechnology*, 8. <https://doi.org/10.3389/fbioe.2020.00645>
- Halagarda, M., Kędzior, W., & Pyrzyńska, E. (2018). Nutritional value and potential chemical food safety hazards of selected Polish sausages as influenced by their traditionality. *Meat Science*, 139, 25–34. <https://doi.org/10.1016/j.meatsci.2018.01.006>
- Jiang, S. L., Wu, J. G., Feng, Y., Yang, X. E., & Shi, C. H. (2007). Correlation Analysis of Mineral Element Contents and Quality Traits in Milled Rice (*Oryza sativa* L.). *Journal of Agricultural and Food Chemistry*, 55(23), 9608–9613. <https://doi.org/10.1021/jf071785w>
- Jiang, S. L., Wu, J. G., Feng, Y., Yang, X. E., & Shi, C. H. (2007). Correlation Analysis of Mineral Element Contents and Quality Traits in Milled Rice (*Oryza sativa* L.). *Journal of Agricultural and Food Chemistry*, 55(23), 9608–9613. <https://doi.org/10.1021/jf071785w>
- Kalli, E., Lappa, I., Bouchagier, P., Tarantilis, P. A., & Skotti, E. (2018). Novel application and industrial exploitation of winery by-products. *Bioresources and Bioprocessing*, 5(1). <https://doi.org/10.1186/s40643-018-0232-6>
- Kumar, A., Kumar, A., MMS, C., Chaturvedi, A. K., Shabnam, A. A., Subrahmanyam, G., Mondal, R., Gupta, D. K., Malyan, S. K., Kumar, S. S., Khan, S. A., & Yadav, K. K. (2020). Lead toxicity: health hazards, influence on food chain, and sustainable remediation approaches. *International Journal of Environmental Research and Public Health*, 17(7), 2179. <https://doi.org/10.3390/ijerph17072179>
- Lachman, J., Hejtmánková, A., Hejtmánková, K., Horníčková, Š., Pivec, V., Skala, O., Dědina, M., & Příbyl, J. (2013). Towards complex utilisation of winemaking residues: Characterisation of grape seeds by total phenols, tocols and essential elements content as a by-product of winemaking. *Industrial Crops and Products*, 49, 445–453. <https://doi.org/10.1016/j.indcrop.2013.05.022>
- Lidiková, J., Čeryová, N., Šnirc, M., Vollmannová, A., Musilová, J., Brindza, J., Grygorieva, O., & Fehér, A. (2021). Comparison of heavy metal intake by different species of the genus *Allium* L. *Biological Trace Element Research*, 199(11), 4360–4369. <https://doi.org/10.1007/s12011-020-02536-7>
- Monti, A., Di Virgilio, N., & Venturi, G. (2007). Mineral composition and ash content of six major energy crops. *Biomass and Bioenergy*, 32(3), 216–223. <https://doi.org/10.1016/j.biombioe.2007.09.012>
- Musilová, J., Fedorková, S., Podhorecká, K., Harangozo, L., Mesárošová, A., Vollmannová, A., Lidiková, J., Čeryová, N., Norbová, M., & Orsák, M. (2023). Carbohydrates and mineral substances in sweet chestnuts (*Castanea sativa* Mill.) from important growing areas in Slovakia. *European Food Research and Technology*. <https://doi.org/10.1007/s00217-023-04408-5>
- Nistor, E., Dobrei, A., Bampidis, V., & Ciolac, V. (2014). Grape pomace in sheep and dairy cows feeding. *Journal of Horticulture, Forestry and Biotechnology*, 18(2), 146–150. <https://www.cabdirect.org/abstracts/20143414985.html>
- Pereira, P., Palma, C., Ferreira-Pêgo, C., Amaral, O., Amaral, A., Rijo, P., Gregório, J., Palma, L., & Nicolai, M. (2020). Grape pomace: a potential ingredient for the human diet. *Foods*, 9(12), 1772. <https://doi.org/10.3390/foods9121772>
- Selim, S., Abdel-Megeid, N. S., Alhotan, R. A., Ebrahim, A., & Hussein, E. (2023). Grape Pomace: Agrifood By-Product with Potential to Enhance Performance, Yolk Quality, Antioxidant Capacity, and Eggshell Ultrastructure in Laying Hens. *Veterinary Sciences*, 10(7), 461. <https://doi.org/10.3390/vetsci10070461>
- Sousa, E. C., Uchôa-Thomaz, A. M. A., Carioca, J. O. B., De Moraes, S. M., De Lima, A., Martins, C. G., Alexandrino, C. D., Ferreira, P. a. T., Rodrigues, A. L. M., Rodrigues, S. P., Silva, J. D. 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>
- Stasiak, K., Stanek, M., Janicki, B., Roślewska, A., Cygan-Szczegielniak, D., & Stasiak, K. (2017). The content of selected minerals determined in the liver, kidney and meat of pigs. *Journal of Elementology*, 4/2017. <https://doi.org/10.5601/jelem.2017.22.1.1314>
- Stojanovic, B., Stojanovic, Z., Marjanovic, S., Jankovic, S., Antic, M., Balaban, M., & Antic, V. (2022). Canned meat products for members of the Serbian armed forces: Na, K, Ca, and Mg content and health risks/benefits. *Journal of Agricultural Sciences Belgrade*, 67(4), 415–431. <https://doi.org/10.2298/jas2204415s>
- Šnirc, M., Lidiková, J., Čeryová, N., Pintér, E., Ivanišová, E., Musilová, J., Vollmannová, A., & Rybníkář, S. (2023). Mineral and phytochemical profiles of selected garlic (*Allium sativum* L.) cultivars. *South African Journal of Botany*, 158, 319–325. <https://doi.org/10.1016/j.sajb.2023.05.024>
- Tan, B. L., Norhaizan, M. E., Liew, W., & Rahman, H. S. (2018). Antioxidant and Oxidative stress: A mutual interplay in Age-Related Diseases. *Frontiers in Pharmacology*, 9. <https://doi.org/10.3389/fphar.2018.01162>