DETERMINATION OF THE CHEMICAL AND MINERAL COMPOSITION OF APPLE POMACE IN RELATION TO ITS UTILISATION AS AN INNOVATIVE FEED RAW MATERIAL

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ABSTRACT

Globally, the food industry is one of the largest and fastest-growing industries. However, food production is also associated with the generation of tons of waste, which has a serious negative impact on the environment. Almost 50 % of fruits used for freshly squeezed juice production become waste. Animal husbandry and especially feed raw materials cultivation also has a serious ecological footprint on nature. The inclusion of these waste products in the feeding of farm animals could help to reduce economic losses, having a positive environmental effect as well.

In this regard, the aim of the present study was to determine the nutritional and mineral composition of waste products (pomaces) obtained from the production of freshly squeezed apple juice from two different apple varieties - red apple (*Malus domestica 'Red Delicious'*) and green apple (*Malus 'Granny Smith'*). In all samples, the following indicators were determined: dry matter (DM), moisture, crude protein (CP), crude fibre (CF), crude ash (CA), ether extract (EE), manganese (Mn), zinc (Zn), magnesium (Mg), calcium (Ca), phosphorus (P), sodium (Na), potassium (K), lead (Pb) and cadmium (Cd).

The results showed that variety affects nutritive value, and red apple pomace is a better source of nutrients. For both types of AP, crude fibre was the nutrient with the highest values and the heavy metals tested were below the maximum allowable concentrations.

Key words: apple pomace (AP), chemical composition, mineral composition, red apple (*Malus domestica 'Red Delicious')*, green apple *(Malus 'Granny Smith')*, feed material.

Introduction

Nowadays, more and more discussions arised in connection with feeding the population with foods with positive effects on the health status, as well as the production of those with a minimal ecological footprint. The type of food and the processing significantly affected both the health of people and the environment (Willett et al. 2019). In recent years, our society has increasingly adopted models of healthy eating, excluding traditional dairy and meat products from the population's diet, at the expense of increasing fruit and vegetable consumption (Chen et al. 2019, Bali and Naik 2023). The World Health Organization also reported an increase in the use of fruits (Bacarea et al. 2021), as according to FAO data from 2021, the COVID-19 pandemic increased it significantly. Greater consumption inevitably leads to the generation of more waste. Literature data showed that nearly 45% of the annual fruit production becomes a waste product (Chaudhary and Dangi 2022), with the juice industry believed to generate the largest amounts of waste (Kasapidou et al. 2015, Sahni and Shere 2017). These by-products had valuable nutritional properties and could be a source of essential nutrients for both humans and animals (Schieber et al.2001). Their use as raw material in the farm animals' rations could not only improve their productive qualities but will significantly reduce the pressure on the environment from the feed industry (Elferink et al. 2008, Kasapidou et al. 2015).

One of the most commonly grown and widely distributed fruits are apples (Agrahari and Khurdiya 2003, Beigh et al. 2015). According to FAO data for 2022, the world production of apples amounted to more than 96 million tons per year. The apple fruits belonged to the genus *Malus*, subfamily *Pomoideae* of the *Rosaceae* family (Hancock et al. 2008), and for Europe, one of the widespread species was *Malus domestica 'Red Delicious'* and *Malus 'Granny Smith*' (Way et al. 1991). A large part of the cultivated fruit (approximately 35%) was used for apple juice production (Malec et al. 2014) and about 25-35 % of the total amount became waste, amounting to over 3.0 - 4.2 million metric tons per year (Oreopoulou and Tzia 2007). The composition of the obtained waste product, also known as apple pomace (AP) (Sereti et al. 2024), included a large part of the peels, seeds and part of the apple pulp (Usman et al. 2020, Gadulrab et al. 2023). Many literature researches had primarily focused on the nutritional qualities of apple pomace as an excellent source of essential nutrients and minerals (Shalini and Gupta 2010, Dhillon et al. 2013, Lyu et al. 2020, Kauser et al. 2024), but also as an environmental pollutant (Kengoo et al. 2022). AP also could be used as a raw material in the food industry, as the main source of useful fibre (Gomez and Martinez 2018, Malenica and Bhat 2020, Younis and Ahmad 2020). Precisely because of its valuable nutritional qualities, AP found its greatest application in farm animals feeding and especially ruminants (Shalini and Gupta 2010, Aghsaghali et al. 2011, Sharoba et al. 2013). It has been proven that AP could successfully replace traditionally used fodder such as alfalfa hay, corn silage, soybean meal, etc. in the ration of polygastric animals and at the same time positively affected the fermentation processes in the rumen, the productive qualities as well as the quality of the final product (Gadulrab et al. 2023). According to Alarcon-Rojo et al. (2019), the inclusion of apple pomace in the sheep ration significantly improved meat quality, reducing fat oxidation. Another finding in other research was that dietary fibre (contained in apple waste), intake increased daily gain in beef cattle (Osaka 2001). A positive correlation was also observed between AP content and cow milk quality (Bae et al. 1994, Diao et al. 2003).

The aim of the present study was to determine the chemical and mineral composition of waste products obtained during red and green apple juice production in connection with their use as feed raw material.

Materials and methods

The research material was obtained after the production of cold-pressed apple juice by an industrial fresh-squeezed juice machine (GEA Vaculiq Vacuum Spiral Filter) and consisted of apple pulp, peels and seeds. The raw materials used were red apples (*Malus domestica 'Red Delicious')* and green apples *(Malus 'Granny Smith').* The final laboratory samples of the apple pomaces were obtained after preliminary reduction of the aggregate sample, composed of spot samples taken from each batch according to the requirements of Regulation (EC) 152/2009 and were as follows:

Green apple pomace – aggregate sample composed of 19 incremental samples taken from 19 tons batch of waste product.

Red apple pomaces – aggregate sample composed of 13 incremental samples taken from 8 tons batch of waste product.

The following indicators were analyzed: dry matter (DM), moisture, crude protein (CP), crude fibre (CF), crude ash (CA), ether extract (EE), manganese (Mn), zinc (Zn), magnesium (Mg), calcium (Ca), phosphorus (P), sodium (Na), potassium (K), lead (Pb) and cadmium (Cd).

The production factory of freshly squeezed fruit juices was located in the village of Musachevo, Western Bulgaria. All samples were collected using clean triers and were placed in poly-lined leak-resistant plastic bags. The plastic bags were sealed identified and transported to the laboratory in a cooler bag.

The indicators were determined to be available moisture and then recalculated to dry matter. The collection of aggregate samples was carried out according to the requirements of Regulation 152/2009 and then analyzed in an accredited laboratory. The moisture content in the samples was determined by drying 5 g of the samples at 103 °C to a constant weight. The crude protein content was determined based on the total nitrogen content, according to the Kjeldahl method, by successive combustion, distillation with sulfuric acid, distillation with boric acid, and titration. The samples were treated successively with boiling solutions of sulfuric acid and potassium hydroxide. The residue was separated by filtration, washed, dried, weighed, and ashed at a temperature of 475 to 500°C. The loss in weight due to ashing corresponded to the crude fibres. Crude ash was separated after burning the sample at 550°C in a muffle furnace. In the determination of crude fats (Ether extract), the sample was subjected to extraction with petroleum ether. The solvent was distilled off, then the residue was dried and weighed.

The mineral content was determined in dry ashed samples at 550°C in a muffle furnace (Ursamar RK 44) and dissolved in 6M HCL obtained from Hydrochloric acid fuming K 43922117 242 by Merck KGaA, Darmstadt, Germany according to the requirements of Regulation (EC) 152/2009 and ISO EN 15510:2017 Animal feeding stuff: Methods of sampling and analysis – Determination of calcium, sodium, phosphorus, magnesium, potassium, iron, zinc, copper, manganese, cobalt, molybdenum and lead by Atomic Absorption Spectrophotometer (Perkin Elmer 5000).

Results and discussion

Chemical composition

Table 1 presented the results obtained for the chemical composition of apple pomace from Red apples (*Malus domestica 'Red Delicious'*) fig. 1 and Green apples (*Malus 'Granny Smith'*) Fig. 2. It was well known that the waste products obtained during fruit juice production have high water content and low dry matter values (Bhushan et al. 2008, Kruczek et al. 2016, Malenica and Bhat 2020). This was seen as the main disadvantage of these products, as the high humidity could be a prerequisite for the development of microorganisms and acceleration of spoilage processes (Beigh et al. 2015, Kasapidou et al. 2015).

Figure 1: Red apple pomace

Figire 2: Green apple pomace

The data in Table № 1 demonstrated the presence of a large amount of water in the apple pomace as follows 83.53 ± 1.02 % for red apple and 80.31 ± 1.02 % for green one. These results exceed the values reported by other authors of 74.6% (Shalini and Gupta 2010) and 66.4–78.2% (Bhushan et al. 2008) respectively. The table also presented the remaining nutrients determined by Weende analysis - crude protein (CP), crude fibre (CF), crude ash (CA) and ether extract (EE). In both types of pomaces, the indicator in the largest quantity was crude fibre, with the green apple pomace containing 4.19 % more. Despite the high levels of CF, our results were significantly lower than those of Kengoo et al. (2022), who documented 33.52% crude fibre in apple pomace. Gadulrab et. al (2023), determined apple waste products as an excellent source of fibres, as shown by the summary data presented by Beigh et al. (2015). However, the authors also observed significant CF variations between 4.70–51.10% in dry matter. After CF, the nutrient in the largest amount was crude protein, followed by crude ash and ether extract (fats), and this regularity was observed in pomace from both varieties of fruit. Nevertheless, the values for CP, CA and EE were higher in favour of the *Malus 'Granny Smith'*. Depending on the variety of the fruits, their maturity and quality, as well as the agricultural practices, substantial variations in the nutritional value of apple pomace could be observed (Pirmohammadi et al. 2006). On the other hand, the type of juicing technology used could also affect the nutrient content and especially the amount of water (Wang et al. 2020).

Table 1: Chemical composition (%) of by-products of red and green apple (mg/kg to dry matter)

Type of raw material	Dry matter (DM)	Moisture	Crude protein (CP)	Crude fibre (CF)	Crude ash (CA)	Ether extract (EE)
Red apple (*Malus domestica 'Red Delicious'*)	**16.47±1.02**	**83.53±1.02**	**2.78±0.06**	**6.27±0.14**	**2.14±0.04**	**0.99±0.13**
Green apple *Malus 'Granny Smith'*	**19.69±1.02**	**80.31±1.02**	**4.10±0.11**	**10.46±0.17**	**2.52±0.04**	**1.62±0.05**

**The results for CP, CF, CA and EE are expressed on a dry matter basis*

Mineral composition

In addition to the nutrients already mentioned, apple pomace could be rich in some minerals (Aghsaghali et al. 2011, Lyu et al. 2020), the main source of which are apple seeds (Yu et al. 2007). Table 2 showed the mineral composition of red and green apple waste products, as the order of mineral levels pomaces samples was as followed K > P > Mg > Ca > Na > Zn > Mn = Pb > Cd. Despite the variation in mineral values, the order was the same for both types of AP. Potassium (K) was the macroelement in the largest amount - 6857 ± 109 mg/kg for *Malus domestica 'Red Delicious'* pomace and 4757 ± 97.01 mg/kg for *Malus 'Granny Smith'*, respectively. According to data from other studies K was also a dominant mineral in apple pomace (Carson 1990, Kruczek et al. 2017). Ezzat et al. (2022) found that after potassium, the predominant macro elements in apple pomaces were phosphorus and magnesium, and this regularity was also observed in the results presented in Table № 2. The most significant differences in AP mineral content were observed for calcium (Ca), as the level in the green apple by-product was 2.08 more compared to the calcium value found in the red apple one. The macro mineral with the lowest values in both wastes was sodium (Na) 17 ± 0.03 mg/kg for the red apple pomace and 22 ± 0.23 mg/kg for the green one.

To maintain normal vital functions, although in smaller quantities, micro minerals or trace elements must also be present in animal nutrition (Upadhaya and Kim et al. 2020). In the present study manganese (Mn) and zinc (Zn) were also investigated. Manganese was below the limit of detection (< 0.1 mg/kg) in both types of samples. Zinc is the trace element with the most essential biological role related to the function of many enzymes and metabolic processes in the human and animal body (Duffy et al. 2023). In the studied samples, it was found that the waste product from red apples was superior in Zn content compared to that from green apples. Zn levels in *Malus 'Granny Smith'* pomace 15.4 ± 0.41 mg/kg were in good agreement with those reported by Beigh et al. (2015), namely 15.00 mg/kg. An essential part of the safety of food of animal origin is minimizing the risk of heavy metals entering them through the feed raw materials used in animal nutrition (Elliott et al. 2017). In this regard, the EU imposes maximum permissible concentrations for some heavy metals such as cadmium (Cd) and lead (Pb) in plant feed raw materials as follows 1 mg/kg for Cd and 10 mg/kg for Pb (Regulation 1275/2013). The data provided in Table 2 showed that Cd and Pb concentrations in apple pomace samples were below the detection limits and did not exceed the limits laid down in European legislation. As already mentioned, the nutritional value of fruits, respectively of their waste products, could vary significantly. Similar differences could also be observed in AP mineral composition (Carson 1990). The amount of macro and micro minerals could be influenced by the soil composition and geographical area where the fruits were cultivated (Mattick and Moyer 1983, Kruczek et al. 2016). According to Choi et al. (2019), the size of the apples is important, as the fruit grows, the amount of minerals also increases.

Table 2: Mineral composition of by-products of red and green apple (mg/kg to dry matter)

Type of raw material	Mn	Zn	Mg	Ca	P	Na	K	Pb	Cd
Red apple -*Malus domestica 'Red Delicious'*	**< 0.1**	**2.5 ± 0.08**	**363 ± 12**	**206±11**	**657.72±42.1**	**17±0.03**	**6857±109**	**< 0.1**	**< 0.05**
Green apple- *Malus 'Granny Smith'*	**< 0.1**	**15.4 ± 0.41**	**468±41**	**429±24**	**724.83±33.23**	**22 ± 0.23**	**4757± 97.01**	**< 0.1**	**< 0.05**

Conclusion

In the present study, the chemical and mineral composition of apple pomace obtained from two apple cultivars (*Malus domestica 'Red Delicious'* and *Malus 'Granny Smith'*) was analyzed. Similar to other literature data, the obtained results showed that regardless of the variety, apple pomace contained essential nutrients and minerals. A high water content was found in both types of apple pomace. Crude fiber was the most abundant nutrient of all, followed by crude protein, crude ash, and EE. The analysis carried out showed that the variety affected the nutritional value, and red apple pomace was a better source of nutrients. Sensitive variations depending on the variety were also observed in the mineral composition, as the green apple pomace showed high levels of macro and microelements. An exception was K, which was 30.63 % less in the waste product from *Malus 'Granny Smith'*. In both types of apple pomace, Mn, Cd and Pb were of limit detection. The obtained results confirmed that AP could be successfully used as a feed raw material, as a source of essential nutrients, but should take into account the variations in composition depending on the apple variety. Given the high levels of CF, these waste products could participate in larger quantities in ruminant rations which could be the subject of more detailed research.

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