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Review

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Animal Evaluation Possibilities of Aronia (*Aronia melanocarpa* (Michx.) Elliot)

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A R T I C L E I N F O

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A B S T R A C T

The aronia plant, which is native to North America, has recently come to the forefront as a berry-like fruit that has attracted interest in terms of its usability in animal nutrition owing to its powerful antioxidant compounds such as anthocyanins, flavonoids, polyphenols and proanthocyanidins. However, studies conducted in our country and around the world have shown that aronia is more suitable for use as a feed additive in animal rations to increase the quality of animal products such as meat, milk and eggs rather than for direct use in animal nutrition. This is particularly evident when compared to quality forage sources such as alfalfa and sainfoin.

1. Introduction

According to the latest research in our country, the number of large cattle increased by 2.5% compared to the previous year, reaching 16 million 208 thousand (excluding buffalo), the number of sheep increased by 4.8% compared to the previous year, reaching 44 million 80 thousand 584 head, and the number of goats increased by 5.0% compared to the previous year, reaching 10 million 822 thousand 84 head (TÜİK 2024), Therefore, exploring new forage sources becomes essential, among which aronia emerges as a candidate. However, since this need cannot be met by the basic roughage sources of our country, which are meadows and pastures, legume-cereal forage crops, and the stems and straws of cereals, importance has been emphasizedto alternative roughage sources in order to increase both production and quality. For this purpose, in addition to legume and gramineous forage plants such as beet (*Beta vulgaris* L.), turnip (*Brassica rapa* L.), pomace, amaranth (*Amaranthus* sp.) and black chard (*Atriplex* sp.) (Tan and Temel 2012), some agricultural industrial by-products (beer pulp, grape pomace, anise pulp) have the opportunity to be evaluated as alternative feed sources (Özdüven et al., 2005). The idea of whether the aronia plant, which has become commercially widespread since 2017 and contains many bioactive compounds including anthocyanins, carotenoids, fatty acids, flavonoids, phenolic compounds and vitamins, will be evaluated in terms of animal husbandry has been on the agenda (Yılmaz et al., 2021).

Aronia fruit has become a well-known food in the field of health and nutrition in recent years. In particular, the bioactive components and nutritional value found in its fruit provide significant health benefits (Gümüştepe et al., 2022). In particular, the secondary compounds present in the fruit have a protective effect and can reduce the risk of people being exposed to diseases (Bayram and Öztürkcan, 2022). A plant belonging to the *Rosaceae* family, Aronia is the fruit of Aronia melanocarpa and has three species: *Aronia*

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arbutifolia (Ell.) Pers. (Red chokeberry), *Aronia melanocarpa* (Black chokeberry) and *Aronia prunifolia* (Marsh.) (Purple chokeberry) (Slimestad et al., 2005; Strigl et al., 1995). This plant, whose natural habitat is North America, is generally known as the Aronia Bush or Black Rosehip. In 1910, Russian scientist Ivan Mitschurin aimed to develop a sweet fruit by hybridizing Sorbus and Mespilus aronia species and for this purpose produced two new varieties called Likernaja and Desertnaja Michurina. After World War II, aronia cultivation spread rapidly in Europe and Russia as of 1946, and large-scale aronia gardens were established especially in the former Soviet Union republics such as Belarus, Moldova, the Siberian Federal District of Russia and Ukraine, and this process continued steadily. Following this, after 1950, it was widely produced in gardens, especially in Eastern Europe, especially in the east, and in European countries in general, especially in Germany (Šnebergrova et al., 2014).

2. Cultivation Areas in the World and Türkiye

In Russia, in 1910, Ivan Mitschurin, who hybridized Sorbus and Mespilus with North American aronia, started breeding studies on aronia and developed two cultivars, called Likernaja and Desertnaja Michurina (Walther and Müller, 2012). Aronia cultivation later became widespread in Europe and Russia from 1946 onwards and was first brought to Japan from the former Soviet Union in 1976. In the 1980s, aronia cultivation began to be active in the countries of the former Soviet Bloc (Czechoslovakia, Bulgaria, Poland, East Germany and Slovenia) and the Scandinavian countries (Denmark and Finland) (Walther and Müller, 2012; Kokotkiewicz et al., 2010). In 1996, Jan Mills Wayne brought important varieties for commercial aronia cultivation from Polish agricultural schools to the United States, and Poland began to supply approximately 90% of the world's aronia production. The planting areas and production values of the countries, including Poland, are given in Table 1, while the varieties commonly used by the countries are shown in Table 2 (Poyraz and Engin, 2019; Fidancı, 2015; Šnebergrová et al., 2014; Strigl et al., 1995).

Table 1. Aronia production values in the world

Countries	Production Areas (ha)	Production Quantities (tons)
Poland	6000	50000
USA	800	2500
Germany	853	1434
Türkiye	78	130
Finland	60	4

Table 2. Aronia varieties cultivated by country

Country	Cultivated Varieties
Denmark	Aron
Czech Republic	Nero
Finland	Viking
Sweden	Hugin
Hungary	Fertödi
Türkiye	Nero, Viking

In Türkiye, it stands out as a smaller producer with a production of 130 tons in an area of 78 hectares. According to 2021 data, aronia cultivation in Türkiye is most intensively carried out in the provinces of Kırklareli (40000 seedlings, 240 decares), Bursa (23500 seedlings, 141 decares) and Manisa (15500 seedlings, 90 decares), while production is more limited in other provinces (Table 3).

Table 3. Number of saplings and production areas in the provinces where Aronia cultivation is economically carried out in Türkiye.

Province	Number of Seedlings (Pieces)	Production Area (da)
Kırklareli	40.000	240
Bursa	23.500	141
Manisa	15.500	90
Kırşehir	8.000	48
Yalova	8.000	48
Çanakkale	7.000	42
Samsun	6.000	36
İzmir	5.000	30
Antalya	3.000	18
İstanbul	3.000	18
Ordu	3.000	18
Ankara	2.000	12

3. Systematics and Morphology

When examined from a botanical perspective, Aronia is defined as Aronia from the Angiosperms (Angiosperms) Division, Eudicolydon (Dicotyledons) Subdivision, Meloideae Class, Rosales Order, Rosaceae (*Rosaceae*) Family, Amygdaloideae Subfamily structure, Maleae Genus. Aronias are frequently confused with chokecherries, which is the common name of Prunus virginiana. Aronia berries and chokecherries both contain polyphenolic compounds such as anthocyanins, but these two plants are somewhat distantly related in the *Amygdaloideae* subfamily. Black chokeberry is a common shrub grown in Central Europe, where it is mostly used for food production (Ekiert et al., 2021).

Figure 1. General view of the aronia plant (https://www.berkefidancilik.com/50-adet-katya-kirmizi-aronya-aronia-fidesi--10-15-cm---brkfdnclk00605; https://www.sopeyzaj.com/aronia-melanocarpa/#prettyPhoto).

The genus Aronia is thought to have three species (Kulling and Rawel 2008; Ekiert et al., 2021). The most common and widely used is *Aronia melanocarpa* (black chokeberry), which originates from eastern North America. The lesser-known *Aronia arbutifolia* (red chokeberry) and the hybrid form of the above-mentioned species, *Aronia prunifolia* (purple chokeberry), were first cultivated in central and eastern North America (Ekiert et al., 2021).

Aronia is a perennial shrubby plant that can grow to 2-2.5 m in height, and the fruit diameter varies between 6-13 mm, while the fruit weight varies between 0.5-2 g. When the fruits are fully ripe, they can be consumed fresh (King and

Bolling, 2020). The aronia plant, which has hermaphroditic flowers, has 5 sepals, 5 petals and 10-30 stamens. The number of flowers in the cluster varies between 20 and 25. Aronia fruits ripen in 90-110 days, depending on the variety, pruning method and climate factors, and are harvested in late August or early September. While the fruit size varies between 1.2-1.7 cm, the water-soluble dry matter ratio is measured between 14-20 Brix and the acidity value is between 0.75-1.05 g citric acid/100 g (Ara, 2002; Kulling and Rawel, 2008; Ochmian et al., 2012; Anonymous, 2021; Ministry of Agriculture and Forestry 2022). Aronia plant produces 8-12 fruits in each bunch starting from the second year of planting, achieves the highest yield in the third year, and 500-1200 kg yield is achieved per decare in five years.

4. Nutritional and Chemical Content

It is known that the fruits in the berry group have rich antioxidant and anthocyanin amounts. Aronia is also included in the berry group and stands out as a plant with various phytochemicals and high antioxidant and anthocyanin capacity. Thanks to this rich variety of phytochemicals, it attracts the attention of researchers and is expressed as a functional product on which studies are concentrated (Yurtkulu, 2022, Eskimez and Polat, 2023). Its fruit is known for its high antioxidant content, rich in vitamin C, fiber and many other vitamins and minerals (Table 4, 5). Particularly, its richness in antioxidants is considered a key factor supporting its health benefits.

Table 4. Nutritional Content of Aronia Fruit

Contents	Value	Reference
Dry Matter (%)	16,7-28,8	Lehmann 1990
Glucose+Fructose (g/kg)	130–176	Lehmann 1990
Oil (%)	0,14	Tanaka and Tanaka 2001
Protein (%)	0,7	Tanaka and Tanaka 2001
Vitamin C (mg/kg)	13-270	Lehmann 1990
Vitamin B1 (µg/kg)	180	Tanaka and Tanaka 2001
Vitamin B2 (µg/kg)	200	Tanaka and Tanaka 2001
Vitamin B6 (µg/kg)	280	Tanaka and Tanaka 2001
Vitamin K (µg/kg)	242	Tanaka and Tanaka 2001
Folate (µg/kg)	200	Stralsjo et al. 2003
l-Malic Acid (g/kg)	13,1	Tanaka and Tanaka 2001
Citric acid (g/kg)	2,1	Tanaka and Tanaka 2001
-β-Carotene (mg/kg)	16,7	Razungles et al. 1989
β-Cryptoxanthin (mg/kg)	12,2	Razungles et al. 1989

Table 5. Chemical Content of Aronia Fruit

Components		Value	Reference
Minerals	Na	26	Tanaka and Tanaka 2001
	K	2180	Tanaka and Tanaka 2001
	Ca	322	Tanaka and Tanaka 2001
	Mg	162	Tanaka and Tanaka 2001
	Fe	9,3	Tanaka and Tanaka 2001
	Zn	1,47	Tanaka and Tanaka 2001
Anthocyanins	Cyanidin-3-arabinoside	14,6- 39,9-58,2	Slimestad et al. 2005; Wu et al. 2004, Oszmianski and Wojdylo 2005
	Cyanidin-3-galactoside	23,7 -99-128,2	Zheng and Wang 2003; Wu et al. 2004, Oszmianski and Wojdylo 2005
	Cyanidin-3-glucoside	1-3,76- 4,2	Slimestad et al. 2005; Wu et al. 2004, Oszmianski and Wojdylo 2005
	Cyanidin-3-xyloside	1-4,7-5,3	Slimestad et al. 2005; Zheng and Wang 2003; Oszmianski and Wojdylo 2005

	Pelargonidin-3-arabinoside	0,23	Wu et al. 2004
Flavonols	Quercetin-3-galactoside	3,7	Oszmianski and Wojdylo 2005
	Quercetin -3-glucoside	2,73	Zheng and Wang 2003
	Quercetin -3-rutinoside	1,5	Oszmianski and Wojdylo 2005
	(–)-Epicatechin	2,7	Oszmianski and Wojdylo 2005
	Chlorogenic acid	30,2	Oszmianski and Wojdylo 2005
	Neochlorogenic acid	29,1	Oszmianski and Wojdylo 2005

5. Ecological Features

Aronia, which can be grown in many parts of the world, has a wide adaptability and the regions where it develops best are temperate areas (Yurtkulu, 2022). Adapted to high altitudes, the plant blooms late in spring and is also resistant to late spring frosts. Aronia blooms late in spring and is quite resistant to late spring frosts (Strik et al., 2003; Cujic et al., 2018; Jurendic and Scetar, 2021). Although it is cultivated at temperatures down to -29 and -350 C (Tolić et al., 2017; Cujic et al., 2018; Jurendic and Scetar, 2021), the plants are sensitive to frost in late April/early May, when flower formation occurs. For this reason, the plant is planted in early spring, but if mulching is possible, the plant can also be planted in autumn (Ekiert et al., 2021).

The plant, which has good productivity and quality in sunny areas (Yurtkulu, 2022), shows vegetative development at minimum 60 C, maximum 350 C and average 15-250 C temperatures (Tolić et al., 2017). Although the exact cooling requirement is not fully determined, it has been reported to be approximately 800–1000 hours according to Engin et al. (2018). The air temperatures where the plant is grown, sunlight status and rainfall amounts significantly affect the phenolic and flavonoid ratios especially in the fruit content (Kalt, 2005; Tolić et al., 2017). The water requirement of the plant is no different from other plants and it is of great importance that the rainfall decreases during the vegetation period. The plant, which has the opportunity to grow in places with an annual rainfall of 500-600 mm, can be subjected to drip and irrigation, especially in the months (July and August) when there is water shortage during the fruit growth periods (Yurtkulu, 2022).

Although the perennial and bush-like grape plant with high adaptability can grow in almost all types of soil, the most preferred soils are those that do not have drainage problems, are moist, have medium texture, are rich in organic matter and have a pH value of 6-6.5 (Çelik et al., 2022; Yurtkulu, 2022). The addition of organic substances such as 4-5 tons of compost and well-rotted barn manure to the soil a year before significantly increases the yield of the plant. When necessary, chemical fertilization is also done in order to increase the vegetative development of the plant, and it would be appropriate to divide the amount into two in June and July and give 2.0 and 2.5 kg da^{-1} N and 5-6 kg da^{-1} P_2O_5 in the first year before planting.

6. Areas of Use in Animal Husbandry

In recent years, the global interest in healthy and natural nutrition has significantly increased, leading to a heightened focus on the use of alternative sources in animal production. For this purpose, the idea of aronia plant as a quality roughage source or usability in animal production has come to the fore thanks to both its polyphenol content and biologically active components that support digestion, and the studies conducted on the subject are briefly given below under subheadings.

Use in the meat industry

Today, many products are used to reduce the negative situations in processed meat products and to support their nutritional value (Shan et al. 2017). In particular, changes in color, taste and odor that lead to oxidation are the most important negative factors in the preference of meat and meat products by consumers (Bellucci et al., 2022). Although these negative effects that cause oxidation can be prevented with antioxidants such as synthetic propyl gallate (PG), tert-butylhydroquinone (TBHQ), butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) (Granato et al., 2017; Lorenzo et al., 2019), they can have negative effects on the health of consumers. For this reason, the use of natural antioxidants instead of synthetic antioxidants has recently come to the fore in order to regulate lipid and protein oxidation. (Nikmaram et al., 2018). For this purpose, blueberries, blackberries, cranberries and the aronia plant,

which has attracted great attention recently, stand out with their rich antioxidant content.

Use in the dairy industry

Today, in recent years, there has been a significant increase in people's demand for functional foods in their dietary preferences, which have significant effects on their health, mental state or physical performance (Rincón-León, 2003). These natural functional foods, which possess antimicrobial, antioxidative, antihypertensive, antidiabetic, immunomodulatory, and antithrombotic activities, may represent an economical and accessible approach to promoting sustainable well-being (Terpeu et al., 2019). Blackberry, raspberry, blackcurrant, blueberry and elderberry are the most preferred and developed bioactive products in fruit-added dairy products (such as fermented milks, kefir and yogurt) within the functional groups (Ozdemir & Ozkan, 2020). Similarly, aronia fruit and its extract, pulp, juice, powder, tea, yogurt, kefir and fermented milk are widely used by people today due to its antioxidant, anti-inflammatory, antidiabetic, anticarcinogenic, antimutagenic, antibacterial, hypolipidemic, cardioprotective and hepatoprotective properties.

Use in improving the growth and meat quality of weaned piglets

Weaning of piglets, which significantly affects intestinal development and growth performance, causes oxidative reactions that lead to economic losses and deterioration in meat quality (Bai et al., 2020). In order to eliminate these negativities, the use of aronia plant, which has a rich polyphenol content, as a feed additive has been recorded to increase both the average daily feed intake (ADFI) and average daily gain (ADG) of weaned piglets and improve meat quality (Liu et al., 2021).

Use in improving egg quality in chickens

Since it is highly preferred by humans worldwide in terms of the protein, lipid, amino acid and minerals it contains, it has been recorded that oxidative stress occurs due to the continuous egg laying of laying hens during the peak laying period and as a result, the egg laying rate and cycle in chickens decreases (Zmrhal et al. 2023). However, in many studies, it has been suggested that some substances with different antioxidant content can increase the egg laying rate in chickens in order to eliminate such negative effects (Frizzell et al., 2017; Gao et al., 2020.; Chen et al., 2021). In fact, in the study conducted by Jing et al. (2024), it was stated that aronia used in the diets of laying hens both increases the antioxidant capacity of the chickens and positively affects the quality of the eggs and meat obtained.

Use of Aronia pulp

In our country, especially in the Eastern Anatolia Region, the use of products as silage has a special importance in terms of meeting the need for quality roughage of animals. While the use of corn, alfalfa, sainfoin, vetch, sorghum and meadow grasses as silage is widespread, the use of agricultural residues as silage has recently become widespread. In particular, due to its high bioactive compounds, polyphenol, carotenoid and fiber content (Lalas et al., 2019; Zhou et al., 2019), fruit pulps obtained from many plant materials such as apple, peach (Büyükkılıç Beyzi et al., 2018) as well as the aronia plant, the remaining part of which is evaluated as silage after the juice is extracted, are widely used for this purpose (Koç et al,. 2023).

7. Conclusion

According to the studies, although the plant leaves contain sufficient fiber and protein, they have lower nutritional content compared to quality roughage sources such as alfalfa and vetch, which are traditionally used in animal nutrition. Consequently, it is increasingly recognized that the most promising application of aronia lies not in its use as a primary forage source, but rather as a functional additive incorporated into animal feeds and products. Such utilization has the potential to significantly enhance the nutritional value, health benefits, and overall quality of animal-derived products, including meat, milk, and eggs. Furthermore, future research is warranted to optimize the inclusion rates, evaluate long-term effects, and explore the economic feasibility of aronia-based additives in diverse livestock production systems.

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