

## The Effects of Different Package Weights on the Fermentation Characteristics and Aerobic Stability of Aronia Pomace Silage

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### Article info

Received: 14.08.2025  
Accepted: 25.02.2026

Article type: Research

### Keywords:

Aronia pomace, silage,  
temperature sensor,  
aerobic stability

### Abstract

This study evaluated the effects of different package weights on the fermentation characteristics and aerobic stability of aronia pomace silage. Aronia pomace was ensiled for 30 days in packages weighing 200, 400, and 600 g. After fermentation, the silages were exposed to air for 7 days to assess aerobic stability. Dry matter (DM), pH, lactic acid (LA), water-soluble carbohydrates (WSC), and microbial populations were determined after fermentation and on days 1, 3, and 7 of aerobic exposure. In addition, silage temperature was continuously monitored using a temperature sensor. Research findings showed that increasing package weight reduced dry matter losses and led to a decrease in pH values. Higher package weights were associated with increased residual WSC levels as well as higher lactic acid bacteria (LAB) and yeast populations. Throughout the aerobic stability period, silage temperatures remained below ambient temperature, and no visible signs of spoilage were observed in any treatment. This resistance to aerobic deterioration may be associated with the natural phenolic and antioxidant compounds of aronia pomace in addition to improved silage compaction.

Citation: Erten, K., Koç, F. (2026). The effects of different package weights on the fermentation characteristics and aerobic stability of aronia pomace silage. *International Journal of Food, Agriculture and Animal Sciences*, 6 (1), 01-10.

## Farklı Paket Ağırlığında Silolamanın Aronya Posası Silajlarının Fermantasyon Özellikleri ve Aerobik Stabilitesi Üzerine Etkisi

### Makale bilgileri

Geliş Tarihi: 14.08.2025  
Kabul Tarihi: 25.02.2026

Makale türü: Araştırma


### Anahtar kelimeler

Aronya posası, silaj  
sıcaklık sensörü, aerobik  
stabilite

### Öz

Bu çalışmada, farklı silaj paket ağırlığında silolanan aronya posalarının fermantasyon kalitesi ve aerobik stabilite üzerine etkisi incelenmiştir. Aronya posaları 200, 400 ve 600 g ağırlıklarda 30 günlük fermantasyona bırakılmıştır. Fermantasyon sonunda açılan silajlara 7 günlük aerobik stabilite testi uygulanmıştır. Fermantasyon sonrası ve aerobik stabilitenin 1, 3 ve 7. günlerinde elde edilen yem materyallerinin kuru madde (KM), pH, laktik asit (LA), suda çözünebilir karbonhidrat (SÇK) ve mikrobiyolojik analizleri yapılmıştır. Ayrıca aerobik stabilite süresince sıcaklık sensörü ile ölçümler yapılmıştır. Araştırma bulguları, paket ağırlığının artmasının KM kaybını azalttığını, pH değerini düşürdüğünü göstermiştir. Paket ağırlığındaki artış, SÇK miktarı LAB ve maya sayısını artırmıştır. Aerobik stabilite süresince tüm gruplarda silaj sıcaklıklarının ortam sıcaklığının altında kalması ve bozulma belirtilerinin gözlenmemesi, aronya posasının yüksek antioksidan kapasitesi ile ilişkilendirilmiştir.

Atf: Erten, K., Koç, F. (2026). Farklı paket ağırlığında silolamanın aronya posası silajlarının fermantasyon özellikleri ve aerobik stabilitesi üzerine etkisi, *Uluslararası Gıda, Tarım ve Hayvan Bilimleri Dergisi*, 6 (1), XX-XX.

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## Introduction

Mistakes made in silage applications cause silage to spoil and increase management losses. Application factors such as particle size, plastic cover colour, and wrapping layer count significantly affect silage fermentation parameters (Kavalcıoğlu, 2008; Toruk et al., 2010; Samarasinghe et al., 2019; Günal and Koç, 2020). The ensiling procedure should therefore be optimized to minimize such mistakes, particularly to guarantee a prolonged aerobic stability period for silage. One of the most important factors affecting the aerobic stability period is silage density (Çayıroğlu et al., 2016). Insufficiently compacted silage material retains oxygen and subsequently deteriorates, while properly compacted silage has higher density, lower oxygen permeability, and enhanced fermentation stability. Ensuring appropriate density contributes to a stable fermentation process and extends the aerobic stability period by maintaining optimal anaerobic conditions (Koç and Erdoğan, 2020).

Many additives, including bacterial inoculants, organic acids, and enzymes, are commonly used in silage materials to maintain nutrient quality and improve aerobic stability (Koç and Erdoğan, 2020; Erten et al., 2022). In recent years, medicinal and aromatic plants with high antioxidant capacity have also been evaluated as potential silage additives (Soycan Önenç et al., 2017).

Among these, aronia (*Aronia melanocarpa*) has received increasing attention due to its rich phytochemical composition. Aronia berries possess strong antioxidant, antibacterial, antiviral, antilipidemic, anti-inflammatory, and antidiabetic properties (Jurikova et al., 2017; Koc et al., 2024; Koc et al., 2025). They contain more than 40 volatile compounds, predominantly flavonoids such as anthocyanins and procyanidins (Kokotkiewicz et al., 2010). The procyanidin content ranges from 0.66% to 5.18% and the anthocyanin content from 0.60% to 2.00% on a dry weight basis, indicating a high total phenolic concentration (1752 mg/100 g) (Wu et al., 2004; Kokotkiewicz et al., 2010). This rich phenolic profile contributes to the strong antioxidant potential of aronia.

Aronia pomace, a by-product of juice processing, still retains a considerable amount of these bioactive compounds. Despite its relatively low water-soluble carbohydrate content, its moderate dry matter level allows it to be ensiled effectively when properly compacted and sealed under anaerobic conditions (Koc et al., 2024).

Considering these characteristics, this study was conducted to determine the effects of different package weights (silage densities) on the fermentation characteristics and aerobic stability of aronia pomace silages. It was hypothesised that increasing the package weight would enhance compaction, improve fermentation quality, and extend aerobic stability by limiting oxygen exposure and microbial deterioration.

## Material and Method

The aronia pomace used in this experiment was obtained from the Tekirdag Viticulture Research Institute. Approximately 50 kg of fresh material was transported to the laboratory immediately after processing. The pomace was vacuum-packed into polyethylene bags (Petkim, İzmir, Turkey) measuring 250 × 400 mm with a film thickness of 75 µm, oxygen permeability of 41 cc/m<sup>2</sup>/day, and CO<sub>2</sub> permeability of 160 cc/m<sup>2</sup>/day. Three different package weights, 200, 400, and 600 g, were prepared to represent varying silage densities, corresponding approximately to 0.55, 0.70, and 0.85 g/cm<sup>3</sup>, respectively.

Each treatment included five replicate silage bags, which were stored for 30 days in a dark environment at  $20 \pm 2$  °C, protected from direct sunlight. After the fermentation period, the silage bags were opened and subjected to a 7-day aerobic stability test under controlled laboratory conditions ( $22 \pm 1$  °C and 65% relative humidity). In addition, temperature changes in silage samples and ambient temperature were monitored for 7 days (hobo pentant data logger) during the aerobic stability period (Chen et al., 1994). Aerobic stability analyses were performed on days 1, 3, and 7 after bags opening (Figure 1).



**Figure 1.** Aronia pulp, ensiling, and aerobic stability

### ***Chemical and microbiological analyses***

Dry matter (DM), crude ash (CA), crude protein (CP), ether extract (EE), and crude fiber (CF) analyses of the nutrient composition of aronia pulp were performed according to the method reported by AOAC (2005). pH analysis was performed according to the method reported by Chen et al. (1994), and water soluble carbohydrates (WSC) analyses were performed according to the method reported by Dubois et al. (1955). Lactic acid (LA) analysis of aronia pomace was determined using the spectrophotometric method reported by Koç and Coşkuntuna (2003). Lactic acid bacteria (LAB) and yeast counts in aronia pomace were performed according to the methods reported by Seale et al. (1990).

### ***Phenolic compound analyses***

Analyses of phenolic compounds in aronia pulp were performed at the Trakya University Technology Research and Development Centre (TUTAGEM) using an HPLC device. Aronia extracts were analysed using liquid chromatography-mass/mass spectrometry (LC-MS/MS) with triple quadrupole performance. During the analysis process, standard compounds were prepared at five points between concentrations of 5-100 ng/ml, and a calibration curve was created. The areas of the peaks obtained as a result of the analysis were plotted against the concentration of the added standard in the sample. In the study where the Acidic Hydrolysis Method was used, 200 µl of 2 M HCl solution was added to 100 µl of sample and vortexed for 30 seconds. After being kept in an ultrasonic bath at 90 °C for 40 minutes, 700 µl of extraction solution (79% ultra-pure water + 20% methanol + 1% formic acid) was added. The samples were centrifuged at 9000 rpm for 5 minutes, and the clear filtrate was transferred to glass vials for injection. The analysis of phenolic compounds was performed using Agilent 1260 Infinity liquid chromatography and Agilent 6460 Triple Quadrupole MS/MS System (Jet Stream Electrospray ion source) (Kelebek et al., 2018).

### ***Statistical analyses***

The statistical analyses of the obtained data were performed using the SPSS 27 software package. One-way analysis of variance was used for the statistical analysis of the data and to assess differences between groups, while Tukey's multiple comparison test was used to compare group effects (Genç and Soysal, 2018).

### **Results and Discussion**

A total of 18 phenolic compounds were identified in the aronia extract (Table 1). Among these, quercetin exhibited the highest concentration (84,108.31 ng/mL), followed by caffeic acid (83,568.61 ng/mL), protocatechuic acid (74,901.93 ng/mL), and chlorogenic acid (70,254.30 ng/mL).

**Table 1.** Phenolic compounds in aronia fruit

Phenolic Compounds	RT	Response	Result ng/mL
Gallic Acid	1.736	16761	4069.60
Protocatechuic Acid	1.922	119272	74901.93
2,5-Dihydroxybenzoic Acid	2.326	4279	6423.51
Caffeic Acid	3.756	200861	83568.61
Chlorogenic Acid	3.685	220563	70254.29
Salicylic Acid	3.868	1020	396.60
Catechin	3.972	1339	1772.38
p-Coumaric Acid	4.112	2099	3691.60
Rutin	4.071	496	98.73
Hesperidin	4.054	215	58.97
Trans Ferulic Acid	4.179	616	4133.15
Mirisetin	4.284	2383	863.45
Quercetin	4.386	617128	84108.31
Luteolin	4.428	5418	523.84
Abscisic Acid	4.447	1212	1489.47
Naringenin	4.488	811	378.10
Kaempferol	4.496	3331	8504.04
Isoquercetin	4.511	161288	7233.12

### ***Results related to the initial material of aronia pulp***

The characteristics of the initial material of aronia pulp before silage are presented in Table 2. The initial material of aronia pulp had a relatively high dry matter content (47.11%) and low pH (4.14). It also contained moderate levels of CP and CF, and a limited amount of WSC, which is consistent with previous reports indicating the low WSC content of aronia berries (Andrzejewska et al., 2015; Denev et al., 2018; Yang et al., 2019).

**Table 2.** The values related to the initial material of aronia pulp

Parameters	Value
pH	4.14
DM, %	47.11
CP, DM%	7.47
CA, DM%	2.53
EE, DM%	3.97
CF, DM%	14.67
WSC, g/kg DM	6.22
LA, g/kg DM	32.18
LAB, cfu/g DM	5.95
Yeast, cfu/g DM	6.38
Mold, cfu/g DM	0.00

DM: Dry matter, CP: Crude protein, CA: Crude ash, EE: Ether extract, CF: Crude fiber, WSC: Water soluble carbohydrates, LA: Lactic acid, LAB: Lactic acid bacteria

### ***Results Related to Fermentation Parameters of Aronia Pulp***

The results related to fermentation parameters of aronia pulp stored in bags of different weights are given in Table 3. The DM values of aronia pulp storage ranged from 40.84% to 42.89%. The highest DM value was observed in aronia pulp weighed at 400 g, while the lowest DM value was detected in aronia pulp weighed at 200 g ( $P < 0.001$ ). The highest DM value was observed in aronia pomace silaged at 400 g, while the lowest DM value was determined in aronia pomace silaged at 200 g ( $P < 0.05$ ). According to some researchers, DM values decreased compared to the initial material with the silage of pomace (Özdüven et al., 2005; Ülger et al., 2020; Kordi and Naserian, 2021), while others have reported that DM values increase with silage compared to the initial material (Canbolat et al., 2014). In this study, it was determined that aronia pomace has a lower DM value with silage compared to the initial DM value. Krüger et al. (2020) noted that as ensiling density increased in corn silage, DM values decreased initially, but this density had a positive effect on silage quality. In a similar study, Erdoğan and Koç (2020) emphasised that DM ratios increased with the prolongation of aerobic stability.

There was statistically no significant difference in pH values between groups after the 30-day fermentation period of aronia pulp ( $P > 0.05$ ). However, silage pH values tended to decrease with increasing package weight. This reduction in pH is likely associated with higher packing density, which limited oxygen availability and maintained a more stable anaerobic environment during fermentation. Although the same compaction procedure was applied to all groups, the heavier packages naturally resulted in greater material density per unit volume, improving silage preservation conditions. Similar findings were reported by Erdoğan and Koç (2020), who observed that pH stability was better maintained in well-compacted silages.

The content of WSC increased with the package weight of silage. The highest WSC content was found in aronia pulp weighing 600 g (4.70 g/kg, DM), and the lowest WSC content was found in aronia pulp weighing 200 g (3.28 g/kg, DM) ( $P < 0.001$ ). As the packaged weight of silage increased, the WSC content increased, and this increase showed a positive correlation with the number of LAB. This indicates that fermentative bacteria increase substrate supply, leading to more efficient LA production. Günal and Koç (2020) stated that the increase in WSC content supported LAB growth directly and contributed positively to fermentation quality.

Coşkuntuna et al. (2022) also reported that WSC content decreased during aerobic stability, which was associated with an increase in LAB count.

**Table 3.** The fermentation parameters of aronia pomace stored in silos at different package

Parameters	Silage package weight (g)			SEM	P
	200	400	600		
DM %	40.84 <sup>b</sup>	42.89 <sup>a</sup>	42.71 <sup>a</sup>	0.368	0.018
pH	4.04	3.96	4.00	0.021	0.325
WSC, g/kg DM	3.28 <sup>b</sup>	3.30 <sup>b</sup>	4.70 <sup>a</sup>	0.236	0.000
LA, g/kg DM	37.76 <sup>a</sup>	35.97 <sup>b</sup>	36.12 <sup>b</sup>	0.332	0.032
LAB, cfu/g DM	5.01 <sup>b</sup>	4.78 <sup>c</sup>	5.37 <sup>a</sup>	0.085	0.000
Yeast, cfu/g DM	4.61 <sup>c</sup>	5.71 <sup>b</sup>	6.16 <sup>a</sup>	0.231	0.000

DM: Dry matter, WSC: Water soluble carbohydrates, LA: Lactic acid, LAB: Lactic acid bacteria, SEM: Standard error of mean.

<sup>a-c</sup>The difference between groups containing different letters in the same row is statistically significant.

The LA content of the groups changed between 35.97-37.76 g/kg, DM. The highest LA content was observed in aronia pulp silaged at 200 g, while the lowest LA content was determined in aronia pulp silaged at 400 g. LA content decreased in aronia pulp packets depending on packet weight ( $P < 0.05$ ).

The yeast counts of aronia pomace ensiled at different package weights ranged from 4.61 to 6.16 cfu/g DM. The highest yeast population was observed in the 600 g treatment, whereas the lowest value was recorded in the 200 g treatment. Yeast counts increased with increasing package weight. A similar trend was observed for LAB populations, which also increased with package weight. This pattern may be related to the higher residual WSC content in heavier packages, providing a greater substrate supply for microbial growth. Previous studies have reported that the availability of fermentable carbohydrates can stimulate both LAB and yeast populations during fermentation (Günel & Koç, 2020). Although higher silage density is generally expected to reduce oxygen availability, microbial responses may also be influenced by substrate concentration and microenvironmental conditions within the silage mass (Samarasinghe et al., 2019). Therefore, the variation in yeast populations observed in this study appears to be more closely associated with nutrient availability than with density alone. LAB populations showed a pattern partially consistent with WSC availability, suggesting that microbial dynamics during fermentation were influenced not only by density but also by substrate concentration and microenvironmental conditions within the silage mass. Therefore, while increased density can enhance anaerobic conditions, microbial responses may vary depending on nutrient availability and the competitive balance between microbial groups.

### ***Results Related to Aerobic Stability Parameters of Aronia Pulp***

The results of aerobic stability parameters on the 1<sup>st</sup>, 3<sup>rd</sup>, and 7<sup>th</sup> days of aerobic stability for aronia pulp stored in silos of different weights are given in Table 4.

The DM levels of aronia pomace varied between 44.17% and 61.94% during aerobic stability. The highest DM content was determined on the 7<sup>th</sup> day of aerobic stability in the aronia pomace stored at 400 g weight, while the lowest DM content was detected on the 3<sup>rd</sup> day of aerobic stability in the aronia pomace stored at 200 g weight. An increase in the duration of aerobic

stability increased the DM content (except for 600 g) ( $P<0.001$ ). According to the data obtained, an increase in silage package weight decreased the DM amount ( $P<0.001$ ). Erdoğan and Koç (2020) reported in their study that the DM amount of silage increased with the increase in aerobic stability period. Similarly, Koç et al. (2020) found similar results. Krüger et al. (2020) reported a negative effect between silage density and DM in their study on corn silage.

The pH value of aronia pomace during aerobic stability ranged from 3.76 to 4.26. The highest pH value was determined on the 7<sup>th</sup> day of aerobic stability in aronia pomace stored in 200 g silos, while the lowest pH value was determined on the 1<sup>st</sup> day of aerobic stability in aronia pomace stored in 600 g silos. The pH value increased with the increase in aerobic stability duration ( $P<0.001$ ). The pH value of silage during aerobic stability decreased with the increase in silage package weight ( $P<0.001$ ). The increase in temperature and pH value in silage materials is explained as an indicator of aerobic spoilage along with yeast and mold growth (McDonald et al., 1991). In accordance with the pH value of the silage, it was determined that yeast quantities increased with the increase in aerobic stability time and decreased with the increase in silage package weight ( $P<0.001$ ).

**Table 4.** Aerobic stability parameters of aronia pomace silaged at different weights

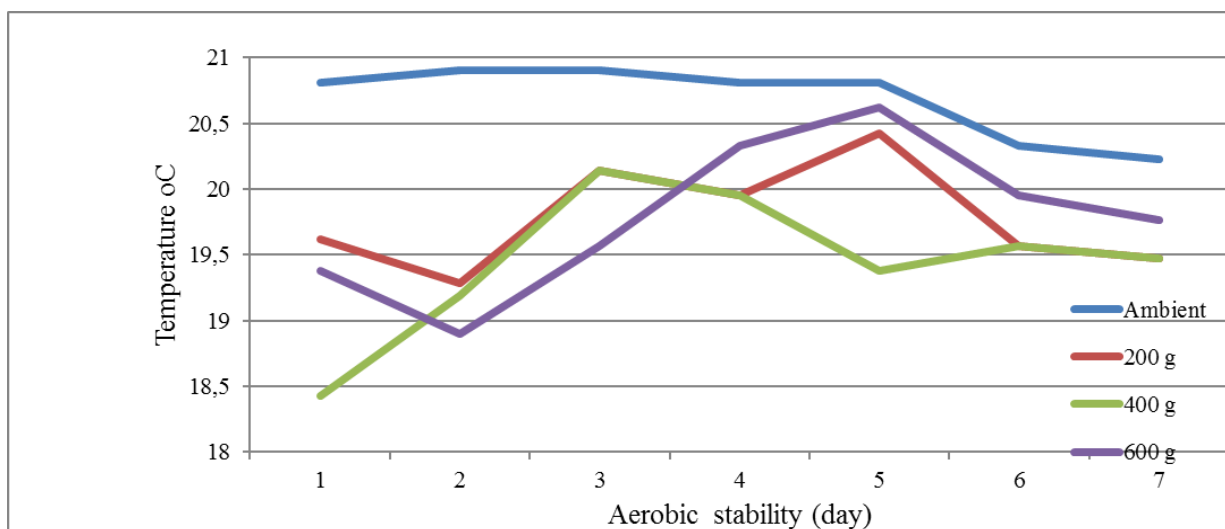
Silage package weight (g)	AS day	Parameters					
		DM %	pH	WSC g/kg DM	LA g/kg DM	Yeast cfu/g DM	LAB cfu/g DM
200	1	47.14 <sup>c</sup>	4.00 <sup>e</sup>	2.67 <sup>f</sup>	31.65 <sup>a</sup>	5.56 <sup>f</sup>	4.60 <sup>g</sup>
	3	44.17 <sup>c</sup>	4.15 <sup>bcd</sup>	3.07 <sup>d</sup>	34.00 <sup>a</sup>	6.08 <sup>d</sup>	5.04 <sup>f</sup>
	7	60.21 <sup>a</sup>	4.26 <sup>a</sup>	1.91 <sup>h</sup>	24.33 <sup>b</sup>	6.30 <sup>b</sup>	5.40 <sup>cd</sup>
400	1	44.24 <sup>c</sup>	4.00 <sup>e</sup>	3.09 <sup>c</sup>	33.29 <sup>a</sup>	5.45 <sup>g</sup>	5.26 <sup>e</sup>
	3	54.99 <sup>b</sup>	4.09 <sup>de</sup>	3.55 <sup>b</sup>	27.19 <sup>b</sup>	5.74 <sup>e</sup>	6.08 <sup>a</sup>
	7	61.94 <sup>a</sup>	4.20 <sup>abc</sup>	1.86 <sup>i</sup>	24.04 <sup>b</sup>	6.33 <sup>a</sup>	5.39 <sup>d</sup>
600	1	44.28 <sup>c</sup>	3.76 <sup>f</sup>	4.08 <sup>a</sup>	32.93 <sup>a</sup>	6.30 <sup>b</sup>	4.30 <sup>h</sup>
	3	46.31 <sup>c</sup>	4.24 <sup>ab</sup>	2.80 <sup>e</sup>	32.16 <sup>a</sup>	6.20 <sup>c</sup>	5.75 <sup>b</sup>
	7	46.02 <sup>c</sup>	4.13 <sup>cd</sup>	2.51 <sup>g</sup>	32.20 <sup>a</sup>	6.32 <sup>a</sup>	5.41 <sup>c</sup>
SEM		1.335	0.029	0.133	0.749	0.065	0.101
Silage package weight (g)		0.000	0.000	0.000	0.000	0.000	0.000
AS (day)		0.000	0.000	0.000	0.000	0.000	0.000
Silage package weight* AS		0.000	0.000	0.000	0.000	0.000	0.000

DM: Dry matter, AS: Aerobic stability, WSC: Water-soluble carbohydrate, LA: Lactic acid, LAB: Lactic acid bacteria, cfu: Colony forming unit, SEM: Standard error of mean

<sup>a-h</sup>: Differences between groups with different letters in the same column are statistically significant

The WSC content in aronia silage changed between 1.86 and 4.08 g/kg DM. The highest WSC content was determined on the first day of aerobic stability in aronia pulp silage weighing 600 g, while the lowest WSC content was measured on the seventh day of aerobic stability in aronia pulp silage weighing 400g. An increase in the aerobic stability period was associated with a decrease in WSC content in aronia silage ( $P<0.001$ ). An increase in silage package weight was associated with an increase in WSC content ( $P<0.001$ ). This finding was also consistent with LAB values. Increases in package weight and aerobic stability period in aronia silage have increased LAB content ( $P<0.001$ ). Coşkuntuna et al. (2022) reported in their study that silage and aerobic stability period increases were associated with decreases in WSC content. Similarly, Erdoğan and Koç (2020) reported in their study that the amount of WSC decreased and the number of LAB increased in silage due to the increase in aerobic stability period.

The LA content of aronia pomace during aerobic stability ranged from 24.04 to 34.00 g/kg DM. The highest LA content was determined on the 3<sup>rd</sup> day of aerobic stability in aronia pomace packed at 200 g, while the lowest LA content was determined on the 7<sup>th</sup> day of aerobic stability in aronia pomace packed at 400 g. An increase in the aerobic stability period reduced the LA content in aronia pulp ensiled at 200 and 400 g. However, the LA content did not decrease in aronia pulp ensiled at 600 g. Coşkuntuna et al. (2022) reported that the LA content decreased with an increase in the aerobic stability period. In this research, aerobic stability data recorded by temperature sensors are presented in Figure 2. Aerobic stability is defined as the duration of time that an opened silage remains without spoiling or heating up (Erdoğan and Koç, 2020). In studies, an increase in silage temperature above 2 °C above ambient temperature is considered aerobic spoilage (Barmaki et al., 2018; Da Silva et al., 2019; Carvalho et al., 2021). The aerobic stability of silage is closely related to the activity of yeast, mold, and other oxygen-dependent microorganisms. Temperature recordings in the study revealed that all silage groups remained below ambient temperature and showed no signs of aerobic spoilage. This may be associated with the high phenolic content and potential antioxidant properties of aronia pulp. Jurikova et al. (2017) reported that aronia fruit is rich in phenolic compounds and anthocyanins, which can inhibit microbial growth and prevent spoilage. Koç et al. (2024) emphasized that aronia pulp has a protective effect on microbial stability when used as a feed additive.



**Figure 2.** The aerobic stability data of aronia pomace ensiled in different package weights

## Conclusions

This study evaluated the fermentation properties and aerobic stability of aronia pulp silages prepared at different package weights (200, 400, and 600 g). The results clearly demonstrated that silage density, determined by package weight, plays a decisive role in both the fermentation process and aerobic stability. Increasing package weight improved compaction, reduced dry matter losses, provided lower and more stable pH values, and limited yeast activity. Furthermore, higher density silages exhibited higher WSC content and LAB populations, indicating a more favorable fermentation environment.

During the aerobic stability period, silage temperatures in all treatment groups remained below ambient temperatures, and no visible signs of spoilage were detected for seven days. This resistance to aerobic spoilage was attributed, in part, to the naturally high antioxidant capacity

of aronia pulp, which may have suppressed oxidative and microbial activity. However, the primary factor determining fermentation success was silage density, not aronia's additive potential. Therefore, it can be concluded that higher-density silage effectively improves fermentation quality and prolongs aerobic stability by minimizing oxygen exposure and nutrient degradation. When considering aronia pulp as silage material, the use of higher packaging weights (higher densities) is recommended to reduce feed nutrient losses and maintain storage stability.

## References

- Andrzejewska, J., Sadowska, K., Kloska, L. & Rogowski, L. (2015). The effect of plant age and harvest time on the content of chosen components and antioxidative potential of black chokeberry fruit. *Acta Scientiarum Polonorum. Hortorum Cultus*, 14 (4).
- AOAC. (2005). Official methods of analysis of the Association of Analytical Chemists International (18<sup>th</sup> ed.). Arlington, VA: Washington, DC, USA.
- Barmaki, S., Alamouti, A. A., Khadem, A. & Afzalzadeh, A. (2018). Effectiveness of chopped lucerne hay as a moisture absorbent for low dry-matter maize silage: Effluent reduction, fermentation quality and intake by sheep. *Grass and Forage Science*, 73 (2), 406-412.
- Canbolat, Ö., Kamalak, A. & Kara, H. (2014). The effects of urea supplementation on pomegranate pulp (*Punica granatum* L.) silage fermentation, aerobic stability and *in vitro* gas production. *Ankara University Faculty of Veterinary Medicine Journal*, 61 (3), 217-223.
- Carvalho, B. F., Sales, G. F. C., Schwan, R. F. & Ávila, C. L. S. (2021). Criteria for lactic acid bacteria screening to enhance silage quality. *Journal of Applied Microbiology*, 130 (2), 341-355.
- Chen, J., Stokes, M. R. & Wallace, C. R. (1994). Effects of enzyme-inoculant systems on preservation and nutritive value of haycrop and corn silages. *Journal of Dairy Science*, 77 (2), 501-512. [https://doi.org/10.3168/jds.S0022-0302\(94\)76978-2](https://doi.org/10.3168/jds.S0022-0302(94)76978-2)
- Coşkuntuna, L., Erten, K. & Koç, F. (2022). Toplam rasyon karışımının silolanmasının aerobik stabilite özellikleri üzerindeki etkisi. *Türk Tarım ve Doğa Bilimleri Dergisi*, 9 (4), 933-942.
- Çayiroğlu, H., Coşkun, İ. & Şahin, A. (2016). Silajın aerobik stabilitesini etkileyen faktörler ve iyileştirme stratejileri. *Alinteri Dergisi*, 31 (B), 91-97.
- Da Silva, N. C., Nascimento, C. F., Campos, V. M., Alves, M. A., Resende, F. D., Daniel, J. L. & Siqueira, G. R. (2019). Influence of storage length and inoculation with *Lactobacillus buchneri* on the fermentation, aerobic stability, and ruminal degradability of high-moisture corn and rehydrated corn grain silage. *Animal Feed Science and Technology*, 251, 124-133.
- Denev, P., Kratchanova, M., Petrova, I., Klisurova, D., Georgiev, Y., Ognyanov, M. & Yanakieva, I. (2018). Black chokeberry (*Aronia melanocarpa* (Michx.) Elliot) fruits and functional drinks differ significantly in their chemical composition and antioxidant activity. *Journal of Chemistry*, Article ID 9574587. <https://doi.org/10.1155/2018/9574587>
- Dubois, M., Giles, K., Hamilton, J. K., Rebes, P. A. & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, 28, 350-356. <https://doi.org/10.1021/ac60111a017>
- Erdoğan, A. & Koç, F. (2020). Saha şartlarında aerobik stabilite süresince mikrobiyal kompozisyondaki değişikliklerin termal kamera görüntüleme tekniği ile değerlendirilmesi. *Hayvansal Üretim*, 61 (1), 9-16.
- Erten, K., Kaya, A. & Koç, F. (2022). Effects of re-ensilage with bacterial inoculant and organic acid addition on aerobic stability and *in vitro* gas production parameters of corn silage. *Journal of the Institute of Science and Technology*, 12 (4), 2568-2580.
- Genç, S. & Soysal, M. İ. (2018). Parametrik ve parametrik olmayan çoklu karşılaştırma testleri. *Black Sea Journal of Engineering and Science*, 1(1), 18-27.
- Günel, S. & Koç, F. (2020). Fiğ-buğday silajlarının fermantasyon ve aerobik stabilite özellikleri üzerine plastik rengi, depolama ortamı ve depolama süresinin etkileri. *Uluslararası Anadolu Ziraat Mühendisliği Bilimleri Dergisi*, 2 (3), 1-8.

- Jurikova, T., Mlcek, J., Skrovankova, S., Sumczynski, D., Sochor, J., Hlavacova, I., Snopek, L. & Orsavova, J. (2017). Fruits of black chokeberry (*Aronia melanocarpa*) in the prevention of chronic diseases. *Molecules*, 22 (6), 944. <https://doi.org/10.3390/molecules22060944>.
- Kavalcıoğlu, S. (2008). Yonca balya silajında parça boyu, plastik rengi ve sarma katının silaj yem kalitesine etkisi. Tekirdağ Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü Yüksek lisans Tezi.
- Kelebek, H., Diblan, S., Kadiroğlu, P., O, Kola. & Selli, S. (2018). Effects of drying treatments on phenolic compounds, antioxidant capacity and some other important quality criteria of figs (*Ficus carica L.*). *Çukurova Journal of Agricultural and Food Sciences*, 33 (2), 127-136.
- Koç, F., Ağma Okur, A. & Okur, E. (2020). The effects of sodium diacetate and sodium benzoate addition on the aerobic stability characteristics of high moisture corn grain. *Journal of Agriculture Faculty of Ege University*, 57 (2), 289-302.
- Koç, F., & Coşkuntuna, L. (2003). The comparison of the two different methods on the determination of organic acids in silage fodders. *Journal of Animal Production*, 44 (2), 37-46.
- Koc, F., Erten, K. & Coşkuntuna, L. (2024). Possibilities of using aronia pulp in animal nutrition. *Turkish Journal of Agricultural and Natural Sciences*, 11 (1), 267-278.
- Koc, S. T., Kök, S., Atalay, S. & Ersoy, O. (2024). Effects of microencapsulated and non-encapsulated aronia extract on serum lipid profile and liver histology in Sprague-Dawley rats fed a high fat diet. *Journal of Elementology*, 29 (4), 769-788.
- Kokotkiewicz, A., Jaremicz, Z. & Luczkiewicz, M. (2010). Aronia plants: A review of traditional use, biological activities, and perspectives for modern medicine. *Journal of Medicinal Food*, 13 (2), 255-269. <https://doi.org/10.1089/jmf.2009.0062>.
- Kordi, M. & Naserian, A. A. (2021). Nutritive value, qualitative characteristics, in situ rumen dry matter degradability and *in vitro* gas production parameters of citrus pulp silage supplemented with barley grain. *Slovak Journal of Animal Science*, 54 (02), 66-74.
- Krüger, A. M., Lima, P. D. M. T., Abdalla Filho, A. L., de Geus Moro, J., De Carvalho, I. Q., Abdalla, A. L. & Jobim, C. C. (2020). Dry matter concentration and corn silage density: Effects on forage quality. *Tropical Grasslands-Forrajes Tropicales*, 8 (1), 20-27.
- McDonald, P., Henderson, A. R. & Heron, S. J. E. (1991). The biochemistry of silage (2nd ed.). Chalcombe Publications.
- Özdüven, M. L., Coşkuntuna, L. & Koç, F. (2005). Üzüm posası silajının fermentasyon ve yem değeri özelliklerinin saptanması. *Trakya Üniversitesi Fen Bilimleri Dergisi*, 6 (1), 45-50.
- Samarasinghe, M. B., Larsen, M., Johansen, M., Waldemar, P. & Weisbjerg, M. R. (2019). Effects of shredding on silage density and fermentation quality. *Grass and Forage Science*, 74 (2), 244-253.
- Seale, D.R., Pahlow, G., Spoelstra, S.F., Lindgren, S., Dellaglio, F. & Lowe, J.F., (1990). Methods for the Microbiological Analysis of Silage. Proceedings of the Eurobac Conference, 147-164, Uppsala, Sweden.
- Soycan Önenç, S., Coşkuntuna, L., Koç, F., Özdüven, M. L. & Gümüş, T. (2017). Effects of essential oils of oregano and cinnamon on fermentation quality and *in vitro* metabolic energy of field pea silages. *Journal of Animal Production*, 58 (2).
- Toruk, F., Koç, F. & Gönülol, E. (2010). Color changes of package silage period of aerobic stability. *Journal of Tekirdag Agricultural Faculty*, 7 (1), 23-30.
- Ülger, İ., Beyzi, S. B., Kaliber, M. & Konca, Y. (2020). Chemical, nutritive, fermentation profile and gas production of citrus pulp silages, alone or combined with maize silage. *South African Journal of Animal Science*, 50 (1), 161-169.
- Wu, X., Gu, L., Prior, R.L. & McKay, S. (2004). Characterisation of anthocyanins and proanthocyanidins in some cultivars of Ribes, Aronia, and Sambucus and their antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 52 (26), 7846-7856.
- Yang, H., Kim, Y. J. & Shin, Y. (2019). Influence of ripening stage and cultivar on physicochemical properties and antioxidant compositions of Aronia grown in South Korea. *Foods*, 8 (12), 598.