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REGULAR ARTICLES

Nutritive value of ensiled *Amaranthus powellii* Wild. treated with salt and barley

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Abstract

Silages or ensiled plant parts are important to feed materials for ruminal fermentation and contributed to the feeding of ruminant animals in large share. The current study was conducted to determine the nutritive value of ensiled *Amaranthus powellii* Wild. (AP) treated with salt and barley. Experimental silages were (1) no supplemented AP forage (control), (2) 1% salt–added AP, (3) 1% salt + 5% barley–added AP, (4) 5% barley-added AP, (5) 1% salt + 7.5% barley–added AP, and (6) 7.5% barley–added AP silages. Silages were analyzed to determine their nutritional contents, physical properties, and microbiota. The DM (g/kg), OM, CP, ADF, NDF, ADL, and ash contents (g/100 g DM) of AP silage were determined as 331.20, 29.84, 12.62, 37.22, 57.72, 42.23, and 3.28, respectively. DM and OM contents were increased by both salt and barley additions while CP and ADF values decreased by these additions ($P < 0.01$). DDM and RFV values were improved by both salt and barley additions with alone and together usage, reaching the highest levels by 7.5% barley addition ($P < 0.01$). While salt itself did not affect RFQ, 5%, 7.5% barley, and 1% salt with 5% barley additions decreased this value ($P < 0.01$), most likely, due to the nutritional content of added barley. The physical properties of AP silage were not affected by any treatment ($P > 0.05$), except a* and Fleig score ($P < 0.01$, $P < 0.05$). Salt caused loss natural red coloring in AP silage compared with control silage, while the other additions saved the natural coloring ($P < 0.01$). Expectedly, all treatments increased lactic acid bacteria count compared with control ($P < 0.01$). To conclude, AP had the potential to be a good silage with respective to its nutritional contents, feed value, and physical properties with appropriate microbiological status. Salt and barley both can be used to improve the nutritional status of AP silages. Further studies are needed to determine its in vitro digestibility and preference by animals in vivo.

Keywords *Amaranthus powellii* · Fleig score · Relative feed value · Relative feed quality · Silage additives

Introduction

Silages or ensiled plant parts are important feed materials for ruminal fermentation and contributed to the feeding of ruminant animals in large share. Mainly, in ruminant farms, silages are made of corn. Recently, the alternative silage materials plant and plant parts such as grain crops, millet varieties, Sudan grass, clover, sainfoin, sugar beet, sunflower, tree branch, and leaves have been studied constantly by researches (Yıldırım 2015). Instead of corn that requires a higher amount of water for vegetative growth, the alternative silage plants that can grow in arid conditions, also, contribute to the fight against drought (Kır and Dursun 2019). A drought-resistant Amarant, which was cultivated by Aztecs 7000 years ago, is a plant that has more than 60 species and is called the pseudograin belonging to the *Amaranthus* genus and the *Amaranthaceae* family (Svirskis 2003; Písaříková et al. 2005; Ammann and Gressel 2007). *Amaranth* is a C_4 dicotyledonous plant that can grow in dry climate condition with having high energy and protein content (Brennan et al. 2012; Seguin et al. 2013; Assad et al. 2017). In general, its seeds and leaves are consumed as supplemental food by human beings due to their higher nutrient contents (Rodríguez et al. 2011; Caselato-Sousa and Amaya-Farfán 2012) and as

Highlights
- The silages of *Amaranthus powellii* Wild. have acceptable nutrient contents.
- Salt and barley additions improve the nutritional value of *Amaranthus powellii* Wild. silage.
- *Amaranthus powellii* Wild. silage can be used for feeding ruminants.

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feed material by farm animals such as rabbits, pigs, poultry, and ruminants (Sleugh et al. 2001; Zralý et al. 2004; Písaøíková et al. 2006; Pospišil et al. 2009; Abbasi et al. 2012; Seguin et al. 2013; Alegbejo 2013; Rezaei et al. 2013, 2014; Kambashi et al. 2014; Molina et al. 2015) even though it contains oxalic acid and nitrates whose levels might cause poisoning for human beings and farm animals (Arellano et al. 1993; Karimi Rahjerdi et al. 2015). In order to prevent oxalic acid and nitrate poisoning in farm animals, some studies were conducted to evaluate *Amaranthus* as a silage material (Rezaei et al. 2009, 2013, 2014, 2015; Karimi Rahjerdi et al. 2015; Abbasi et al. 2018). In addition, the leaves of some *Amaranthus* species were used as roughage (*Amaranthus cruentus*: Pond and Lehmann 1989; *Amaranthus caudatus*: Peiretti 2018) in ruminant nutrition. *Amaranthus* has 85-t fresh forage yield per hectare; it corresponds to 16.7-t dry matter (Abbasi et al. 2012). *Amaranthus cruentus* (Olorunnisomo 2010), *Amaranthus hypochondriacus* (Rezaei et al. 2009, 2013, 2014, 2015; Karimi Rahjerdi et al. 2015; Abbasi et al. 2018), and *Amaranthus mantegazzianus* (Dumanoğlu and Geren 2019) were preferred as silage materials. Filik et al. (2018) determined the nutrient contents of *Amaranthus powellii* Wild. (AP) forage as DM, EE, ash, CP, ADF, NDF, and ME values as 93.75%, 4.95, 12.44, 8.75, 64.81, 49.52, and 2148.23 kcal/kg DM, respectively. Up to now, there has been no study to evaluate AP silage nutritionally. In the present study, therefore, AP silages added with salt and barley in different ratios were investigated nutritionally to improve its quality. Salt is crucial for enhancing fermentation while barley would compensate the energy requirements of bacteria due to the high-protein-contained AP. It was expected that the current AP silages may be the preferable silages for ruminant feeding with respect to nutritional, organoleptic, and microbiological.

Material and methods

Vegetative parts of AP were obtained from the experimental field crop area in the Kırşehir province in Turkey (39°10′ N latitude, 34°22′ E longitude, at an altitude of 988 m above mean sea level). When the AP seeds reached the dough level, the whole plant was harvested from the bottom with pruning shears. The AP plant, which was rested for a day before silage, was chopped about 3 cm long.

The chopped plants were divided into six different groups homogeneously with and without additives. Experimental silages were (1) no supplemented AP (control), (2) 1% salt–added AP, (3) 1% salt + 5% barley–added AP, (4) 5% barley-added AP, (5) 1% salt + 7.5% barley–added AP, and (6) 7.5% barley–added AP silages. Each experimental silage was blended and air-vacuumed in double-layer plastic bags having a capacity of 3 L volume. Experimental silages were prepared as 4 replicates and 24 silages in total. The prepared silages were observed for 90 days in the Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Agricultural Biotechnology, Feed Biotechnology Laboratory. Samples were taken from three different locations of AP silage when opened at the end of the 90th day. The 5th silage AP silage treated with 1% salt and 7.5% barley was discarded from the experiment due to the high rate of mold growth. The ensiled samples were dried in a ventilated drying oven at 55 °C for 48 h. Then, the dried samples were ground (Ultra-Centrifugal Mill ZM 200-Retsch) in a 1-mm sieve grinder before analysis.

Dry matter or moisture (DM or M method 925.40), organic matter (OM method 934.01), crude protein (CP, method 984.13), ether extract (EE, method 920.39), ash (ash, method 942.05 (4.1.10)), hemicellulose (HCel, BFM79), total carbohydrates (TC, BFM156), and non-fiber carbohydrates (NFC, BFM121) contents of AP silages were determined according to the AOAC procedures (2006). The acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) were determined according to the Ankom procedures (Ankom Technology 2016, 2017a, b, c). The organic matter of neutral detergent fiber (NDFom) and the organic matter of acid detergent fiber (ADFom) were determined with the Ankom 200 Fiber Analyzer (Ankom Technology Corp., Macedon, NY, USA), based on the method of Van Soest et al. (1991). The metabolizable energy (ME), and relative feed value (RFV) and relative forage quality (RFQ) of AP silages were calculated according to the method given by Filik (2020).

Before the silage packages were opened, the temperatures of the silage samples from three different regions were determined with the Digital Dip Thermocouple Thermometer (Loyka 9263 + Plus Rod Thermometer).

For pH measurement, a 20-g sample size was taken from the opened silage for each group and mixed with 100 ml pure water for 3 min at 2000 rpm until homogeneous. The mixture content was filtered, and the pH value was measured three times by a pH meter (Eutech pH 700, Eutech Instruments Pte. Ltd., Singapore). The water-soluble carbohydrates (WSC) value (Brix degree 0–25°) was measured with a refractometer (Çayıroğlu et al. 2020).

Fleig score (FS), as silage quality parameter, was calculated from DM and pH values by using the following the formula (Kılıç 1986)

$$FS = 220 + (2 \times DM\% - 15) - 40 \times pH$$

According to Kılıç (1986), Fleig scores for silages that were between 0 and 20 are considered poor quality, 21 to 40 was low quality, 41 to 60 was medium, 61 to 80 was good, and between 80 and 100 was considered reflective of very good silage.

After the silage samples were opened, the color values were measured from three different parts of the silage with the Konica-Minolta CR-410 color meter. The CIELAB method L *, a *, and b * values are based on the principle of determining the closest color to the human eye on the coordinate system with the help of values of pigment sensitivity, color tone, color saturation, and tone angle. CIELAB are given results in values of L^* (lightness-0, black; 100, white), a^* (redness + a, red; − a, green), and b^* (yellowness − b, blue; + b, yellow). ΔE^*, h (hue angle), and C^* (chroma or saturation) values were calculated using L^*, a^*, and b^* values. The total color difference (ΔE^*) between two samples value is calculated as the square root of the sum of the squares of L^*, a^*, and b^* values ($\Delta E^* = (L^2 + a^2 + b^2)^{1/2}$). The h value was calculated as the arctan of the portion of the a^* value to the b^* value ($\theta = \tan^{-b/a}$). Chroma or saturation value is the square root of the sum of the squares of a^* and b^* values ($(a^2 + b^2)^{1/2}$) (CIE 1986; Pérez-Magariño and González-Sanjosé 2003; Kopřiva et al. 2014; Çayıroğlu et al. 2020).

The microorganism counts were determined by the plate count method of Cai et al. (1999). A 10-g silage sample was mixed in sterile 90 ml of 0.85% NaCl solution. The mixtures were diluted to be 10^{-1} and 10^{-8} in a 0.85% NaCl solution. A 1 ml dilution was transferred to previously prepared sterile Petri dishes.

For determination of total live bacteria count PCA solution (plate count agar acc. Merck, ISO 4833, ISO 17410, and FDA-BAM) was cooled to 45 °C and poured into 15-ml sterile Petri dishes. After the Petri dishes were incubated at 30–32 °C for 24–48 h, the total number of bacteria was reached by counting the developing colonies (Harrigan 1998).

For counting lactic acid bacteria MRS agar (Merck Lactobacillus Agar acc. to de Man, Rogosa, and Sharpe for microbiology VM694860 533) was poured into 15-ml sterile Petri dishes after cooling at 45 °C. After the Petri dishes were incubated at 30 °C for 2 days (under anaerobic conditions), the number of *Lactobacillus* spp. were found according to the number of colonies developing (Harrigan 1998).

The nutritional contents of experimental silages were calculated from the chemical analysis on a DM basis. The RFV and RFQ were calculated using the chemical analysis results. The experimental silages were statistically compared with each other by using the SAS statistical software (SAS 2001).

Results

The nutritional contents of AP silage were 331.20 DM g/kg, 29.84 OM %, 12.62 CP %, 37.22 ADF %, 52.72 NDF %, 42.23 ADL % in DM, and 285.20 g/kg NFC. DM content of AP silage was increased by either salt or barley addition when added solely or combined each other as seen in Table 1 ($P < 0.01$), except 1% barley addition. But, even 1% barley addition increased DM content of silage but not statistically. OM's was increased in all treated silages compared with control silage ($P < 0.001$). CP content of AP silage was started to decrease by 1% barley addition but not statistically and decreased by the other additions ($P < 0.01$). Ether extract and ash content of AP silage were not affected by any additions ($P > 0.05$). ADF content of AP silage was decreased by both salt and barley additions either solely or combined ($P < 0.001$). While ADL content of AP silage was decreased only by 5% barley addition ($P < 0.05$), its NDF content was increased by the same rate barley addition ($P < 0.01$), compared with control and other treated silages. Like ADL, NFC was decreased by 5% barley addition ($P < 0.05$).

In vitro analysis showed that TDN values were decreased in 5% barley, 1% salt + 5% barley, and 7.5% barley–added AP silages compared with control and 1% salt–added silages ($P < 0.01$). DCP was started to decrease by 1% salt treatment without statistical significance. This became significant in other treatment silages compared with control silage ($P < 0.01$). The same tendency was seen in DE, ME, and NE values ($P < 0.01$).

Dry matter digestibility was increased by both salt and barley additions when either alone- and combined-added ($P < 0.001$), like RFVs ($P < 0.01$). However, RFQ values were decreased in treated silages compared with control silage ($P < 0.01$). According to present RFVs, 7.5% barley–added AP silage was considered second-class silage with a value of 131.51, while other groups were found to be of third-class silage quality (Table 2).

According to Table 3, temperature °C, WSC, L^*, b^*, ΔE^*, h, and C values were not statistically affected by any additions ($P > 0.05$). There was a linear statistical decrease in the treatment groups compared with the pH value of control silage ($P < 0.01$). Fleig score was increased by salt and barley addition when added both either alone or combined in different ratios ($P < 0.05$). When the experimental silages were evaluated microbiologically, the highest LABc proliferation occurred in the 5% barley–added AP silage (124.5 $\log 10^{-6}$ cfu/g DM) (Fig. 1).

Discussion

This study is the one of the nutritional studies on AP silage being recently investigated. According to nutritional contents of control AP silage, it can be said that AP silage would take the place in TMR (total mixed ration) of ruminant animals in the event that it is an obtained sustainable manner. However, there have not been found out any sufficient study to compare our results exactly. Fortunately, it can be easily seen that salt or barley addition solely or their combination improved the

Table 1 Nutritional contents of *Amaranthus powellii* Wild. silages

Parameters[4]	Control	1% salt–added AP	5% barley–added AP	1% salt + 5%–barley added AP	7.5% barley–added AP	SD	*P* values
DM[1]	331.20b	354.50b	384.60a	400.70a	407.20a	3.50	0.0039
OM[2]	29.84d	32.49c	36.98b	34.66c	39.54a	0.28	0.0007
CP[2]	12.62a	12.12a	9.95b	8.07bc	7.49c	0.25	0.0038
EE[2]	2.87	3.42	2.46	3.75	3.05	0.19	0.3491
ADF[2]	37.22a	29.17b	20.76c	28.18b	18.25c	0.31	0.0001
ADFom[3]	33.94a	25.92b	17.28c	24.84b	14.76c	0.32	0.0001
NDF[2]	52.72bc	51.27c	59.67a	54.21b	52.84bc	0.33	0.0031
NDFom[3]	49.44b	48.01b	56.19a	50.87b	49.35b	0.35	0.0040
ADL[2]	42.23a	42.85**a**	30.80b	39.16a	40.84a	0.73	0.0164
HCel[2]	15.51e	22.10d	38.91a	26.03c	34.60b	0.45	0.0001
TC[1]	812.40b	812.10b	841.10a	848.50a	859.80a	2.90	0.0108
NFC[1]	285.20b	299.40ab	244.40c	306.40ab	331.40a	4.40	0.0113
Ash[2]	3.28	3.26	3.48	3.34	3.49	0.03	0.1503

Mean values within the same column with no common letters differ significantly ($P < 0.01$)

AP Amaranthus powellii Wild. silage, *DM* dry matter (g/kg), *OM* organic matter (%), *CP* crude protein (%), *EE* ether extract (%), *ADF* acid detergent fiber (%), *NDF* neutral detergent fiber (%), *HCel* hemicellulose (%), *TC* total carbohydrates (g/kg), *NFC* non-fiber carbohydrates (g/kg), Ash (%)

[1] g/kg of natural material

[2] (%) of dry matter

[3] ADFom = ADF − ash, NDFom = NDF – ash

[4] Data represents the mean value of four applications of each treatment

Table 2 Nutritive values of *Amaranthus powellii* Wild. silages

Parameters[1,2]	Control	1% salt–added AP	5% barley–added AP	1% salt + 5% barley–added AP	7.5% barley–added AP	SD	*P* values
TDN	61.48a	61.00ab	59.19b	56.79c	56.27c	0.26	0.0047
DCP	7.69a	7.24a	5.27b	3.55bc	3.03c	0.04	0.0038
DE	2.71a	2.69ab	2.61b	2.50c	2.48c	0.01	0.0043
ME	2.22a	2.21ab	2.14b	2.05c	2.04c	0.01	0.0043
NE_L	0.63a	0.63ab	0.61b	0.58c	0.57c	0.00	0.0043
NE_M	0.68a	0.67ab	0.65b	0.62c	0.61c	0.00	0.0045
NE_G	0.35a	0.35ab	0.32b	0.29c	0.28c	0.00	0.0045
NE_m	1.36a	1.34ab	1.28b	1.20c	1.19c	0.01	0.0039
NE_g	0.78a	0.77ab	0.71b	0.64c	0.62c	0.01	0.0040
DDM	59.91c	66.18b	72.73a	66.95b	74.69a	0.00	0.0001
DMI	2.28ab	2.34a	2.01c	2.22b	2.27ab	0.01	0.0027
RFV	105.71c	120.08b	113.42b	114.95b	131.51a	0.83	0.0015
RFQ	113.81a	116.08a	96.81b	102.23b	103.91b	0.92	0.0050

Mean values within the same column with no common letters differ significantly ($P < 0.01$)

DCP digestible crude protein (%), *TDN* total digestible nutrients (%), *DE* digestible energy (Mcal/kg), NE_L net energy–lactation (Mcal/lb. to Mcal/kg), NE_M net energy–maintenance (Mcal/lb. to Mcal/kg), NE_G net energy–gain (Mcal/lb. to Mcal/kg), NE_m net energy–maintenance (Mcal/kg), NE_g net energy–gain (Mcal/kg), *DDM* digestible dry matter (%), *DMI* dry matter intake, *LW* live weight (%), *RFV* relative feed value, *RFQ* relative forage quality, *AP Amaranthus powellii* Wild. silage

[1] % of dry matter

[2] Data represent the mean value of four applications of each treatment

Table 3 Color and quality of *Amaranthus powellii* Wild. silages

Parameters	Control	1% salt–added AP	5% barley–added AP	1% salt + 5% barley–added AP	7.5% barley–added AP	SD	*P* values
Temperature, °C	20.73	20.80	20.48	20.83	21.03	0.06	0.1165
pH	5.38a	4.99ab	4.60b	4.68b	4.81b	0.06	0.0069
WSC (°Brix)	12.50	13.25	15.25	13.00	13.13	0.34	0.1465
Fleig score	56.93c	76.30bc	97.80a	98.15a	94.04ab	2.46	0.0118
*L**	28.49	29.81	28.95	30.28	30.89	0.37	0.2758
*a**	2.74a	2.16b	2.96a	2.54ab	2.97a	0.07	0.0086
*b**	9.20	9.30	8.85	9.74	9.65	0.19	0.5707
*ΔE**	30.07	31.3	30.42	31.91	32.51	0.40	0.3132
h	73.42	76.87	71.19	75.41	72.78	0.58	0.0553
*C**	87.44	88.84	82.47	98.24	96.53	0.18	0.6084

^{a,b,c} Mean values within the same column with no common letters differ significantly ($P < 0.01$)

AP Amaranthus powellii Wild. silage, *°C* Celsius degree, *WSC* the water-soluble carbohydrates value (Brix degree 0–25°), *L** lightness, *a** redness, *b** yellowness, *ΔE** the total color difference, *h* hue angle, *C** chroma or saturation

nutritional contents of AP silage (Table 2). These increases can be easily explained salt's accelerating effect on fermentation and barley's being carbohydrate source of lactic acid bacteria.

Apart from our experimental *Amaranth* species, Tan et al. (2012) used *Amaranthus retroflexus* (AR) silages. This makes our findings more required. In 1% salt and 5% barley–added AR silages, DM and CP contents increased, but ADF and NDF values decreased compared with their control silage (Tan et al. 2012). In the current study, DM (1% salt and 5% barley–treated) and NDF (5% barley–treated) increased while CP and ADF% values decreased in both silages.

Our CP values (control and 1% salt–treated) were similar to those of Rezaei et al. (2013, 2014, 2015) in *Amaranthus hypochondriacus* silages. A 5% barley treatment decreased silage crude protein content (9.95% vs. 12.12%) compared with 1% salt treatment. The decrease in crude protein value by barley shows that CP would have been used by silage microorganisms in silage fermentation. The addition of 1% salt + 5% barley increased the decrease in crude protein value in AP silage. Since the presence of salt in the silage increases the osmotic pressure of the plant cells, the resulting water-soluble molecules and the increase in the amount of crude protein provided a suitable environment for lactic acid bacteria (Koç et al. 1999). Therefore, energy and protein decreases were statistically significant in parallel with the addition of barley and salt in all groups ($P < 0.01$). When the results of *Amaranthus cruentus* silage by Olorunnisomo (2010) are compared with the results of chemical analysis of AP silages, the results are generally similar. CP values decreased linearly in AP silages due to the increase in barley amount. This result shows that the energy needed by the microorganisms in the silage is provided with barley. Abbasi et al. (2018) reduced CP in the silage of Maria *Amaranthus hypochondriaus* variety

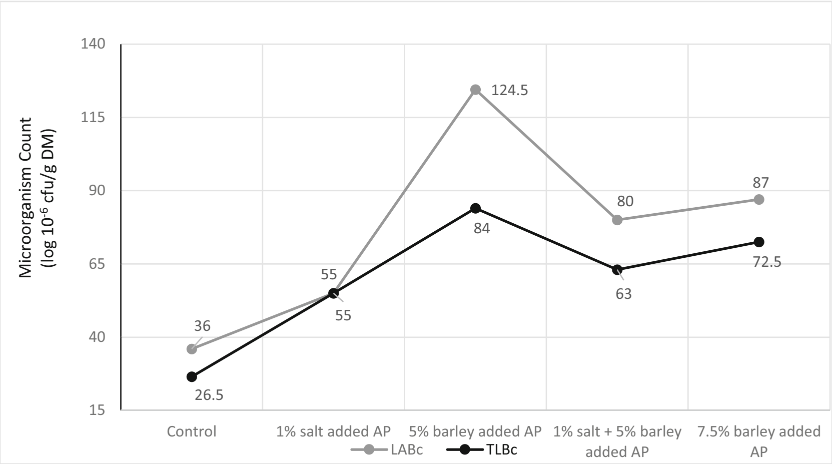

Fig. 1 Microorganism count of *Amaranthus powellii* Wild. silages. AP, *Amaranthus powellii* Wild. silage; LABc, lactic acid bacteria count; and TLBc, total live bacteria count

prepared by *Lactobacillus plantarum*, molasses, and mixtures, and the results support our study. Decreased CP in the silage samples with Kharkovskiy and Sem *Amaranth* varieties in the study of Karimi Rahjerdi et al. (2015) were similar to the control and 1% salt–added AP groups in our study. Researchers determined that CP value decreased in silages used for energy purposes mixed with corn such as barley in our study. The results showed that the corn or barley provides the energy needed by silage microorganisms and also supports the silage fermentation (Rezaei et al. 2009). Also, the main reason of CP decreases by salt and barley additions can be explained by the increased protein or N requirements of lactic acid bacteria for their body composition (Koç et al. 2017).

ADF content of AP silage was decreased by treatment since cellulose and lignin are dynamic to hydrolysis during silage fermentation. The results were thought to meet the nutrient requirements required for the development of lactic acid bacteria in silage and cause deformation even in the lignin, which is a structural component (Rezaei et al. 2009). The amount of ADL was decreased only by 5% barley addition, this contributed to an increase in DDM (72.73% vs. 59.91%) and RFV values (113.42 vs. 105.71) positively, and this reflected to RFQ value (96.81 vs. 113.81) compared with control silage as expected. According to the RFQ value, which classifies the feed used in the feeding of dairy cattle, 5% barley with AP silage group shows that other groups can be used for feeding 18- to 24-month heifers ($P < 0.01$). The highest of barley, compared with control and other additions, improved RFV ($P < 0.01$). A 7.5% barley–added AP silage had 7.49% crude protein, 3.05% ether extract, 74.69% digestible dry matter, 131.51% relative feed value, and 103.91% relative forage quality which was the superior in among experimental silages. A 7.5% barley–added AP silage becomes a second-class silage with respect to RFV 131.51.

Except Fleig score and *a value, the physical properties of AP silage were not affected by any additions. Although salt addition caused a loss of the natural red coloring in AP ($P < 0.05$), the other additions saved the natural red coloring in AP silages. In our current study, the other quality criteria of salt- and barley-mixed silages were found to be of very good quality silage according to Fleig score, which was used in silage evaluation, with the value of 1% salt + 5% barley–added AP silage. There was no study in AP silage exactly on the effects of salt and barley additions on the literature. In the study on *Amaranthus retroflexus*, it was determined that the silage prepared with 1% salt and 5% barley–folded mixtures at the beginning and end of the blooms is a middle-class silage according to the physical properties (Tan et al. 2012). However, they did not determine Fleig score. They classified their *Amaranthus retroflexus* silage quality as below the middle in general. They also found out that this quality jumped to middle class by barley addition.

The pH values (4.56–4.68, respectively) of Seguin et al. (2013) in Plainsman and D136 culture *Amaranthus* silages and pH value (3.94, 3.99) of Rezaei et al. (2013, 2015) in *Amaranthus hypochondriacus* silages support our current study. The pH values of silage prepared with *Amaranthus retroflexus* flowering beginning and end with 1% NaCl and 5% barley–folded mixes decreased compared with the control group (5.14); the results support our current study (Tan et al. 2012). Abbasi et al. (2018) who studied the silage of Maria *Amaranthus hypochondriaus* variety prepared by *Lactobacillus plantarum*, molasses, and mixtures of pH values support our present study. The lowest pH value ($P < 0.01$) and the highest LABc value were determined in the 5% barley–added AP silage. Lactic acid bacteria might have increased lactic acid concentration and, consequently, decreased pH value (Yang et al. 2019; Guo et al. 2020). Microbiological analysis showed that there was no incidence in any yeast and mold growth during ensiling, resulting quite healthy AP silages that were either controlled or added with salt and/or barley.

The amount of water-soluble carbohydrate (WSC) in AP silage was tended to increase by 5% barley addition. This value was 12.50–15.25 in the present study without any statistical difference between control and additions. This can be explained that WSC usage was not affected by any additions. The water-soluble carbohydrate value of *Amaranthus hypochondriacus* silage (12.7) was similar to that of our study (Rezaei et al. 2015).

As a result, plants with high-water requirements such as corn are used in silage production, which is of great importance for animal feeding. Instead of corn, it is important to investigate other plants in dry conditions to be an alternative to the nutrient content of corn. The *Amaranthus* plant, on the other hand, is not a very new plant in terms of animal nutrition but is again a popular plant. Investigation of wild varieties other than *Amaranthus* culture species is of great importance. In the current study, the usability of the AP plant, which is a wild variety, in two different additives and mixtures such as salt and barley, was investigated in the feeding of ruminant animals. Due to the high protein value of *Amaranthus*, the use of barley in silages had a positive effect on microorganism development. The pressure created by salt addition on the cell walls caused changes in WSC values. According to RFV, 7.5% barley–added AP (131.51) silage; RFQ, all groups except 5% barley–added AP (96.81 < RFQ) silage; and FS, 5% barley–added AP (97.80) and 1% salt + 5% barley–added AP (98.15) silages were determined as the best silages, respectively. To conclude, AP has an ensiling potential by using different additives in various doses. Also, further studies are needed to investigate its in vitro digestibility and the effects on preference and performance of animals in vivo.

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Author contributions Ayşe Gül Filik and Gökhan Filik designed and conducted the experiments. Ayşe Gül Filik conducted the laboratory analyses. Ayşe Gül Filik supervised and coordinated the experiments. Gökhan Filik evaluated experimental data statistically. The manuscript was written and revised by Ayşe Gül Filik and Gökhan Filik.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethics in animal experiments committee approval The study complied with an ethics document taken from the Animal Experiments Local Ethics Committee of Kırşehir Ahi Evran University, dated and numbered 08/08/2018-15-3.

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