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Chemical composition, organic matter digestibility and energy content of apple pomace silage and its combination with corn plant, sugar beet pulp and pumpkin pulp*

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Abstract

The objective of this research was to investigate and compare the quality of apple pomace silage ensiled with corn plant, sugar beet pulp, and pumpkin pulp for nutrient compositions. Fresh samples of apple pomace, corn plant, sugar beet pulp, pumpkin pulp, and their combinations were fermented in glass jars. The treatment groups included i) 100% apple pomace as control, ii) 100% corn plants, iii) 100% sugar beet pulp, iv) 100% pumpkin pulp, v) 50% apple pomace and 50% sugar beet pulp, vi) 50% apple pomace and 50% pumpkin pulp, and vii) 50% apple pomace and 50% whole corn plant. The silage pH was different among treatment groups, ranging from 3.60 to 4.15, being lowest with a combination of apple pomace and pumpkin pulp, and highest with sugar beet pulp. Dry matter (DM) and crude protein (CP) contents of the silages were also different among groups, with corn silage being the highest for both values, namely 29.17% for DM and 9.92% of DM for CP. Although acid detergent fibre (ADF) and crude cellulose (CC) values differed among silages (ADF and CC contents varied between 24.47 and 38.55% of DM and 21.58–28.98% of DM among silages, respectively), neutral detergent fibre (NDF) contents remained similar. *In vitro* organic matter digestibility of sugar beet pulp silage (74.41% of DM) was highest among all silages, whilst corn silage (55.35% of DM) had the lowest digestibility. Sugar beet pulp silage had the highest metabolizable energy (ME) (2.67 Mcal/kg DM) and net energy lactation (NEL) (1.61 Mcal/kg DM) values among all silages. The results of the current study suggested that nutritive values of the apple pomace silage were comparable with the silages from the other plant sources. In summary, apple pomace silage is a promising feed.

Keywords: Ensiling, fruit juice, gas production technique, nutritive value, roughage
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Introduction

To increase the profit in animal production systems, economical feed sources, including agro-industrial residuals, should be regarded as part of ruminant feeding. The use of unconventional feed sources is also a useful way of overcoming the shortage of animal feedstuffs and has been intensively addressed by researchers worldwide (Dixon & Egan, 1987; Ali *et al*., 2017; Shah *et al*., 2017a; Shah *et al*., 2017b; Shah *et al*., 2018). Apple pomace is a by-product of the fruit juice industry. It contains 26.4% DM, 4.0% DM CP, 3.6% DM sugar, 6.8% DM crude cellulose, 0.38% DM crude ash (CA) (Vasil'ev *et al*., 1976), 30–48.2% DM NDF, 25–42% of DM ADF (Wolter *et al*., 1980; Singhal *et al*., 1991), and 7.7–9.1 MJ/kg DM metabolizable energy (Mafakher *et al*., 2010). Apple pomace is also an agro-industrial waste, which can be used as animal feed as a way of disposal. Using unconventional silages such as apple pomace in ruminant diets could be a source of low-cost nutrients. Because of the seasonal availability of fresh fruits, ensiling may offer a good solution to preserving their by-products. Pumpkin pulp is a by-product of pumpkin *(Cucurbita pepo),* which is grown in

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Turkey for seed production. Ensiling apple pomace with pumpkin pulp could be another economic source of animal feed. Ensiling apple pomace with dry sugar beet *(Beta vulgaris L.)* pulp also seems an interesting solution. A mixture of common silage maize (*Zea mays*) and apple pomace may also offer a cheaper source for admixtures.

A few studies have investigated the use of apple pomace silage in ruminant diets (Fontenot *et al*., 1977; Toyokawa *et al*., 1977; Tümer, 2001; Ahn *et al*., 2002). Feeding trials with apple pomace silage in the literature showed positive results. The results of a study showed that feeding dairy cows with apple pomace silage containing 10% wheat straw, 10% alfalfa hay, and 10% rice hulls resulted in an increase in milk yield and milk protein content (Toyokawa *et al*., 1984). Another study revealed that apple pomace silage could be added to the diet of lactating cows up to 30% (Ghoreishi *et al*., 2007). However, the combination of apple pomace silage and other types of silage has not been studied adequately. Therefore, the objective of this study was to investigate and compare the quality of apple pomace ensiled with corn plant, sugar beet pulp and pumpkin pulp for nutrient composition and digestibility.

Materials and Methods

Fresh apple pomace and fresh sugar beet pulp were provided by a local fruit juice factory and a sugar factory in Kayseri Province, Turkey. Fresh pumpkin pomace was provided from the field just after harvest for seeds in Develi District in Kayseri Province. Corn was harvested from the fields of the experimental farm of Erciyes University, Kayseri, Turkey. All material was collected on the same day and brought to the laboratory for ensiling processes. Fresh silage materials (1000 g for each silage) were stuffed in 1 litre glass jars and closed tightly for ensiling for 60 days. Before ensiling, the jars were placed upside down to drain water from the holes in the cap of the jar for 24 hours. There were seven treatment groups: i) 100% apple pomace as control, ii) 100% corn plant, iii) 100% sugar beet pulp, iv) 100% pumpkin pulp, v) 50% apple pomace and 50% sugar beet pulp (w/w), vi) 50% apple pomace and 50% pumpkin pulp (w/w), and vii) 50% apple pomace and 50% whole corn plant (w/w). Each treatment contained three jars of the same material.

The jars were opened after 60 days of fermentation. The silage pH was measured right after opening. A total of 25 g of silage from each jar was sampled for pH measurement in 100 ml of distilled water. The content was homogenized in a blender for five minutes. The homogenized sample was filtered through a double layer of cheesecloth and the solution was re-filtered through a filter paper until it became totally clear. The filtrated liquid was used to determine silage pH directly with a digital pH meter.

The DM, CA, CP and EE contents were analysed according to the methods described by AOAC (1990). The ADF and NDF were analysed by a method described by Goering & Van Soest (1970). Crude cellulose (CC) was determined by the method of Bulgurlu & Ergül (1978). Hemicellulose (HC) was calculated by the equation suggested by Rinne *et al*. (1997) as follows:

$$HC\ (\%\ of\ DM) = NDF - ADF$$

Where: HC is hemicellulose (% of DM)
NDF is neutral detergent fibre (% of DM)
ADF is acid detergent fibre (% of DM) values

The amount of 0.2 g of samples was used for gas production analysis according to Menke & Steingass (1988). The samples were placed in glass tubes containing 10 ml rumen fluid and 20 ml medium. Rumen fluid was collected from two ruminally fistulated sheep fed twice daily with a diet containing alfalfa hay (60%) and concentrate (40%). Rumen fluid was collected approximately two hours after the morning feeding and transported immediately to the laboratory for use. The medium was prepared by mixing 500 ml distilled H_2O, 0.1 ml micro-mineral solution, 200 ml buffer solution, 200 ml macro-mineral solution, and 1 ml resazurin solution (0.1%). The buffer solution contained 4 g ammonium bicarbonate (NH_4HCO_3) and 35 g sodium bicarbonate ($NaHCO_3$) in 1 L of distilled water. The macro-mineral solution contained 9.45 g sodium dihydrogen phosphate dodecahydrate ($Na_2HPO_4.12H_2O$), 6.2 g monopotassium phosphate (KH_2PO_4), and 0.6 g magnesium sulphate heptahydrate ($MgSO_4.7H_2O$) in 1 L of distilled water. These were prepared freshly before use. The micro mineral solution contained 13.2 g calcium chloride dihydrate ($CaCl_2.2H_2O$), 10.0 g manganese dichloride tetrahydrate ($MnCl_2.4H_2O$), 1 g cobalt dichloride hexahydrate ($CoCl_2.6H_2O$), and 8 g ferric chloride hexahydrate ($FeCl_3.6H_2O$) in 1 L of distilled water.

Metabolizable energy (ME) and net energy lactation (NEL) values of silages were estimated using equations suggested by Blümmel & Ørskov (1993) and in vitro organic matter digestibility (IVOMD) was calculated using the equation of Menke *et al.* (1979) as follows:

$$ME\ (MJ/kg\ DM) = 2.20 + (0.1357 \times GP) + (0.0057 \times CP) + (0.0002895 \times EE^2)$$

NEL (MJ/kg DM) = (0.1149 × GP) + (0.0054 × CP) + (0.0139 × EE) – (0.0054 × CA) – 0.36
IVOMD (% of DM) =14.88 + (0.889 × GP) + (0.45 × CP) + (0.0651 × CA)

Where: GP is 24 h net gas production (ml/200 mg)
CP is crude protein (% of DM)
EE is ether extract (% of DM)
CA is crude ash (% of DM) values
Then energy unit converted to Mcal/kg DM

All data were analysed using analysis of variance (ANOVA), and means were compared using Duncan's multiple range test and least significant difference test at *P* <0.05 if ANOVA showed a significant effect. These analyses were carried out using SPSS (Statistical Package for the Social Sciences, version 14.0, SPSS Inc., Chicago IL, USA) software.

Results

The pH varied among silages (*P* <0.05), being lowest with a combination of apple pomace and pumpkin pulp (3.60) and highest with sugar beet pulp (4.15) (see Table 1). The DM contents of the silages were also different (*P* <0.05), being highest with corn silage (29.17%). Noticeably, pumpkin pulp silage had highest ash content (14.38% DM) among all silages (*P* <0.05). Corn silage had the highest CP content (9.92% of DM) among all silages (*P* <0.05). Additionally, EE content ranged from 1.79% of DM (sugar beet pulp silage) to 8.28% of DM (pumpkin pulp silage) among silages (*P* <0.05).

Table 1 pH, dry matter, crude ash, crude protein and ether extract values of silages

Silage	pH	DM[1]	CA[2]	CP[3]	EE[4]
		% as fed	% of DM		
100% apple pomace silage (AP)	3.79^{cd}	13.65^{d}	3.44^{e}	6.14^{e}	4.30^{c}
100% corn silage (CS)	4.03^{ab}	29.17^{a}	6.91^{c}	9.92^{a}	2.73^{de}
100% sugar beet pulp silage (SBP)	4.15^{a}	17.93^{c}	5.25^{d}	9.71^{ab}	1.79^{e}
100% pumpkin pulp silage (PS)	3.76^{cd}	9.33^{f}	14.38^{a}	8.75^{bc}	8.28^{a}
50% AP + 50% CS	4.00^{ab}	21.32^{b}	5.18^{d}	8.01^{cd}	3.40^{cd}
50% AS + 50% PS	3.60^{d}	11.52^{e}	8.95^{b}	7.50^{d}	6.45^{b}
50% AP + 50% SBP	3.87^{bc}	15.12^{d}	4.35^{de}	7.95^{cd}	2.98^{cde}
SEM[5]	0.04	1.41	0.79	0.29	0.50
P-value[6]	0.011	0.010	0.023	0.021	0.017

[1]DM: dry matter
[2]CA: crude ash
[3]CP: crude protein
[4]EE: ether extract
[5]SEM: standard error of means
[6]P-value: probability value
[a-f]Means in the same column followed by different superscripts are significantly different (*P* <0.05)

The ADF and calculated hemicellulose contents of silages differed among silages (*P* <0.05; Table 2). Pumpkin pulp silages contained the highest ADF (38.55% of DM). Although CC values differed among silages (*P* <0.01), NDF contents remained similar (*P* >0.05).

Table 2 Fibre components of silages

Silage	ADF[1]	NDF[2]	CC[3]	HC[4]
	% of DM[5]			
100% apple pomace silage (AP)	34.91[ab]	46.07	22.43[bc]	11.16[c]
100% corn silage (CS)	28.46[c]	51.90	26.19[ab]	23.45[a]
100% sugar beet pulp silage (SBP)	24.47[d]	49.27	21.58[c]	24.80[a]
100% pumpkin pulp silage (PS)	38.55[a]	52.19	28.98[a]	13.64[c]
50% AP + 50% CS	31.29[bc]	48.32	24.78[abc]	17.04[b]
50% AS + 50% PS	36.52[a]	49.11	25.99[abc]	12.59[c]
50% AP + 50% SBP	29.86[c]	47.97	22.35[bc]	18.11[b]
SEM[6]	1.09	0.61	0.70	1.15
P-value[7]	0.023	0.243	<0.001	0.018

[1] ADF: acid detergent fibre
[2] NDF: neutral detergent fibre
[3] CC: crude cellulose
[4] HC: hemicellulose
[5] DM: dry matter
[6] SEM: standard error of means
[7] P-value: probability value
[a-d] Means in the same column followed by different superscripts are significantly different (*P* <0.05)

In vitro organic matter digestibility of sugar beet pulp silage (74.41% of DM) was highest (*P* <0.05), while corn silage (55.35% of DM) had the lowest digestibility (Table 3). Sugar beet pulp silage had both highest ME (2.67 Mcal/kg DM) and NEL (1.61 Mcal/kg DM) values (*P* <0.05). Corn silage contained the lowest ME (1.99 Mcal/kg DM) and NEL (1.10 Mcal/kg DM) values.

Table 3 *In vitro* organic matter digestibility, metabolizable energy and net energy lactation values of silages

Silage	IVOMD[1]	ME[2]	NEL[3]
	% of DM[4]	Mcal/kg DM	
100% apple pomace silage (AP)	62.32[b]	2.32[bc]	1.30[bc]
100% corn silage (CS)	55.35[b]	1.99[d]	1.10[c]
100% sugar beet pulp silage (SBP)	74.41[a]	2.67[a]	1.61[a]
100% pumpkin pulp silage (PS)	60.65[b]	2.41[ab]	1.24[c]
50% AP + 50% CS	57.94[b]	2.12[cd]	1.17[c]
50% AS + 50% PS	60.32[b]	2.33[bc]	1.24[c]
50% AP + 50% SBP	69.42[a]	2.53[ab]	1.48[ab]
SEM[5]	1.55	0.06	0.04
P-value[6]	0.035	<0.001	0.017

[1] IVOMD: in vitro organic matter digestibility
[2] ME: metabolizable energy
[3] NEL: net energy lactation
[4] DM: dry matter
[5] SEM: standard error of means
[6] P-value: probability value
[a-d] Means in the same column followed by different superscripts are significantly different (*P* <0.05)

Discussion

The ranges of pH (3.60–4.15) obtained from the experimental silages in the present work were in agreement with the study by Mafakher *et al.* (2010), who reported that high-quality silage should have a pH ranging from 3.80 to 4.30. The pH of corn silage in the present work (4.03) was similar to the pH of corn silage at 3.97 at the end of 8 weeks and 3.93 at the end of 16 weeks reported by Bal (2006). The pH of apple pomace silage (3.79) in the present work was within the ranges of pH for apple pomace silage from 3.40 to 4.10 reported by other researchers (La Van Kinh & Phuong, 1997; Pirmohammadi *et al*., 2006; Yalçınkaya *et al*., 2012). The pH values for apple pomace silages from the present work and from the literature (La Van Kinh & Phuong, 1997; Pirmohammadi *et al*., 2006; Yalçınkaya *et al*., 2012) differ because of the varieties of apple pomace from different sources and different technologies (McDonald, 1981).

The DM of apple pomace silage (13.65% as fed) in the present work was in agreement with the DM reported as 12.37 and 14.92% by Yalçınkaya *et al.* (2012) and La Van Kinh & Phuong (1997). High-quality silage should have 20–35% dry matter (Ergül, 1988). However, combining apple pomace silage with corn silage (50:50) in the present study yielded a DM of 21.32%, which is close to that of good-quality silage. The results of the present work suggest that the DM of apple pomace should be increased to yield good silage. This can be achieved by adding 50–60% corn silage or a proper amount of dry forages such as straw or alfalfa hay (Gürbüz & Kaplan, 2008). Combining the apple pomace silage with pumpkin pulp (50:50) in the current work decreased the DM content of the silage (11.52%), being far from high-quality silage. The DM of corn silage (29.17%) of the present work was parallel with those who reported similar values of DM from corn silage (Idukut *et al*., 2009; Arslan & Çakmakçı, 2011).

Ash content of the apple pomace silage of the present work (3.44% of DM) was similar to the values (2.33–3.44% of DM) reported by other researchers (Ahn *et al*., 2002; Gürbüz *et al*., 2004; Abdollahzadeh *et al*., 2010). Ash content as an indicator of the mineral content of the feed material (Arslan & Çakmakçı, 2011) increased in the present work when apple pomace was combined with corn silage, pumpkin pulp, and sugar beet pulp silages. The CP content of the apple pomace silage (6.14% of DM) was similar to values (5.6–7.2% of DM) reported by other researchers (Ahn *et al*., 2002; Pirmohammadi *et al*., 2006; Abdollahzadeh *et al*., 2010). To increase the CP content of apple pomace silage, nitrogen sources should be added during ensiling. In addition, the EE content of the apple pomace silage (4.30% of DM) was similar to the values (4.70–5.49% of DM) reported in the literature (Ahn *et al*., 2002; Abdollahzadeh *et al*., 2010). Collectively, the ash, protein, and fat contents of apple pomace silage are similar to average silage quality from other plant sources.

The ADF and NDF contents of the apple pomace silage measured in the present work (34.91 and 46.07% of DM, respectively) were in accordance with the reported values for ADF (34.13–46% DM) and NDF (39.12–56.7% DM) (Ahn *et al*., 2002; Pirmohammadi *et al*., 2006; Abdollahzadeh *et al*., 2010). Wide variations among the reported values were probably due to apple types and processing technologies. In addition, the CC content of the apple pomace was in accordance with those reported in the literature (Gürbüz *et al*., 2004; Pirmohammadi *et al*., 2006).

Combining apple pomace with corn silage and pumpkin pulp (50:50) resulted in an increase in the CC content of the silage. Moreover, combining apple pomace with corn silage and sugar beet pulp (50:50) resulted in an increase in HC content of the silage. The fibre components of the apple pomace silage measured in the present work (ADF, NDF, CC, and HC) were close to those of corn silage.

*In vitro o*rganic matter digestibility of apple pomace silage was reported to be 57.5% of DM (Pirmohammadi *et al*., 2006) and 71.4% of DM (Mirzaei-Aghsaghali *et al*., 2011), which are both in agreement with the results of the present work (62.32% of DM). In the current work, the ME of apple pomace silage was 2.32 Mcal/kg DM (8.37 MJ/kg DM), which is similar to the values of ME for apple pomace silage (9 MJ/kg DM and 10.73 MJ/kg DM) reported by Pirmohammadi *et al.* (2006) and Mirzaei-Aghsaghali *et al.* (2011). The findings of the present work for NEL (4.18 MJ/kg DM) also agree with values (6.50 MJ/kg DM) reported by other researchers (Pirmohammadi *et al.*, 2006; Mirzaei-Aghsaghali *et al*., 2011). Combining apple pomace with sugar beet pulp (50:50) resulted in an increase in the energy content of the silage. In general, IVOMD, ME, and NEL values of the apple pomace silages were comparable with those of the silages from the other plant sources.

The different values reported here in the present work and from the literature are mostly due to the varieties of apple pomace from different apple sources with different technologies. However, independently of the sources of apple types and harvesting technologies, apple pomace silage has the suitable nutrient composition to be used as an economic source of feed compared with silages from other plant sources. Also combining apple pomace and other agro-industrial residue materials such as pumpkin pulp and sugar beet pulp is a useful way to obtain good-quality silages in animal husbandry enterprises.

Conclusion

The results of the present study suggested that DM of apple pomace should be increased to yield good silage. In general, EE, CP, IVOMD, ME, and NEL values of the apple pomace silage were comparable to the silages from the other plant sources. In other words, apple pomace silage is a promising feed.

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Authors' Contributions

İÜ contributed to the project idea, design and execution of the study. MK was in charge of project assistance, executing the study. TA was involved in statistical analysis. OK was responsible for supervision and writing the manuscript.

Conflict of Interest Declaration

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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