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Possible ensiling of pumpkin (*Cucurbita pepo*) residues

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Abstract: The aim of the current study was to determine the feasibility of ensiling pumpkin residues alone and with forage. For this purpose, chemical composition, nutritive values, and in vitro gas production of pumpkin residue silages were investigated. Pumpkin residue (PR), maize fodder (M), sugar beet pulp (SBP), and pomegranate pulp (PP) were ensiled alone, and pumpkin residues were ensiled with maize (PRM), sugar beet pulp (PRSB), and pomegranate pulp (PRP) in 50% (50:50 w:w) of each, as well as with 5% wheat straw (PRS) and alfalfa hay (PRA). After 2 months of storage, chemical compositions and Fleig scores of the silages were determined. Metabolic energy (ME), net energy lactation (NEL), and organic matter digestibility (OMD) values were determined with the aid of 24-h net gas production. It was concluded that pumpkin residues could be used as a quality silage source, and that sugar beet pulp and pomegranate pulp supplementation might improve the basic chemical composition and quality of the silage. Furthermore, 5%–10% alfalfa hay could be supplemented into pumpkin silage to increase DM level.

Key words: Silage, pomegranate pulp, sugar beet pulp, chemical composition, metabolizable energy

1. Introduction

Parallel to a rapid increase in population, food demand throughout the world increase with each passing day. Plant and animal products per person are decreasing because of climate change, unproductive use of soil resources, natural disasters, and other factors. Additionally, in recent years, there has been an increasing search for alternative feed sources for animals. Agricultural wastes and postharvest residues of vegetables, fruits, and crops may be good sources for animal feeding. Recent research has mostly focused on the potential use of agricultural wastes and postharvest residues, especially through ensilage of these waste materials [1–4].

Following the harvest and separation of seeds, pumpkin (*Cucurbita pepo*) residues (PR) are commonly left in the fields in a considerable quantity (95% of the fresh fruit skin, fleshy part, inner fibers, and minor seeds) [5]. Pumpkin fruits contain various carbohydrates. Postharvest residues are quite rich in vitamins, minerals, and carotenoids, and are easily digested by ruminants [6–8]. Pumpkin can be utilized in animal feeding in fresh form, as dry solids, and as silage. Pumpkin fields are also grazed by ovine in some places [9]. Through grazing activities, possible environmental pollution is also prevented [4,10]. Ensilage may offer a reliable means of preservation of such residues. Pumpkin fruits contain quite large amount of water; thus, it is hard to preserve such material for long periods, and mold develops shortly after harvest. Therefore, pumpkin residues should be consumed within a short time following the harvest season. In cases where they cannot be consumed shortly after harvest, such residues can be ensiled for later use. In this way, pumpkin postharvest residues may offer a valuable feedstuff especially for dairy cattle, have positive impacts on palatability of the diet, and improve the dietetic value of the milk [11].

Although high water content increases the suitability of pumpkin for ensiling, it does not allow pumpkin to be ensiled alone [7]. Wheat straw and alfalfa hay are commonly used to reduce the moisture content of silage materials with high water content [12,13]. Dried sugar beet (*Beta vulgaris* L.) pulp could be supplemented into pumpkin silage [14]. Pomegranate (*Punica granatum* L.) pulp also offers a quite good admixture for pumpkin silage. A mixture of common silage maize (*Zea mays*) and pumpkin may offer a cheaper source for admixtures.

There have been a limited number of studies carried out on nutritive values of pumpkin and ensilage of pumpkin residues. Church [15] reported the nutritional composition of pumpkin as follows: 9% dry matter (DM), 16% crude protein (CP), 14% ether extract (EE), 0.24% Ca, 0.43% P, 3.32% K, and 58% total digestible nutrients (TDN). In another study, Mokhtarpour [16] reported the

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nutritive values of pumpkin residues (PR) before ensilage as follows: 12.5% DM, 11.3% CP, 1.4% EE, 19.7% crude fiber (CF), and 17.6% ash, with a pH of 5.9. Hashemi and Razzaghzadeh [5] indicated that PR (skin and flesh) had a considerably high carbohydrate content, provided sufficient amounts of easily digestible carbohydrates required for silage formation, and thus offered a good source for animal feed with ensilage. In another study, Razzaghzadeh et al. [17] used 0%, 20%, 40%, and 60% pumpkin silage supplementation to dry hay in feeding buffalo calves and reported that such supplementation rates did not have significant impacts on feed quality parameters (dry matter intake, daily live weight gain, and feed conversion ratio); they concluded that 60% pumpkin silage supplementation could be used without any negative effects on feed quality attributes and animal performance.

The present experiments were conducted to evaluate the nutritional and quality attributes of pumpkin silages ensiled alone and with maize fodder, sugar beet pulp, pomegranate pulp, wheat straw, and alfalfa hay.

2. Materials and methods

Pumpkins (*Cucurbita pepo*) grown in the experimental fields of the Agricultural Research Center of Erciyes University (Kayseri, Turkey) were harvested in late September 2014. The postharvest residues (fleshy part of the fruit that remains after seeds were collected) were then used to prepare silages at the Animal Science Department of Erciyes University Agricultural Faculty. The maize (*Zea mays*) to be used in silages was harvested at the milk stage in early October 2014; alfalfa (*Medicago sativa*) and wheat (*Triticum aestivum*) straw were also harvested from the experimental fields of the same center. Pomegranate (*Punica granatum* L.) pulp to be used in silage was supplied from a commercial fruit juice facility in the region. Sugar beet (*Beta vulgaris* L.) pulp was supplied from a commercial sugar facility. Basic chemical composition of these raw materials is provided in Table 1.

Representative plants and postharvest residues were chopped into 2–4-cm pieces and ensilaged in plastic containers (5 kg capacity) in 3 replicates. Experimental silages are listed in Table 2.

Experimental silages were stored for 2 months. Silage pH values were determined with a pH meter. Silage samples were dried at 105 °C for 24 h to obtain DM contents. Samples were ashed in an oven at 525 °C for 8 h to obtain ash contents. The ether extract present in the feed was extracted by petroleum ether using a Soxhlet apparatus. Kjeldahl's method was used to determine the nitrogen (N) contents of the samples [18]. The resulting N contents were multiplied by 6.25 (N × 6.25) to get crude protein (CP) contents. Goering and Van Soest's [19] method was used to determine NDF and ADF contents of the samples. The AOAC [18] method was used to determine crude fiber (CF) contents of the samples. Fleig scores were calculated in accordance with Kilic [20]: Fleig score = 220 + (2 × DM% − 15) − (40 × pH). Silage quality is classified based on Fleig scores as follows: very good for Fleig scores of 85–100; good for Fleig scores of 60–84; moderate for Fleig scores of 40–59; satisfactory for Fleig scores of 20–39; worthless for Fleig scores of <20.

For gas production (GP), silages were incubated in vitro with rumen fluid supplied in glass syringes in accordance with the principles specified in Menke and Steingass [21]. Rumen fluid was obtained from a slaughterhouse from 2 cows that had been fed a diet of at least 60% roughage. Then, 100-mL syringes were supplemented with 0.200 g of dry samples. The syringes with only the rumen fluid were incubated and used as controls. Incubations were performed in 3 replicates. Prewarmed syringes (39 °C) were injected with 30 mL of rumen fluid–buffer mixture and incubated in a water bath at 39 °C. Gas production

Table 1. Chemical composition of raw materials.

	Components, %						
Raw materials	DM	Ash	CP	EE	CF	ADF	NDF
PR	8.98	15.31	8.17	8.51	31.84	38.84	53.09
M	26.87	9.74	8.29	2.19	32.17	35.98	57.04
SBP	22.14	5.14	4.18	2.87	18.02	25.71	40.18
PP	37.29	4.84	12.61	11.18	32.37	33.02	42.57
WS	91.70	7.66	4.04	1.54	45.75	57.55	83.39
AA	90.30	10.02	18.11	2.61	28.71	36.64	46.17

PR: pumpkin residues; M: maize fodder; SBP: sugar beet pulp; PP: pomegranate pulp; WS: wheat straw; AA: alfalfa hay; DM: dry matter; CP: crude protein; EE: ether extract; CF: crude fiber; ADF: acid detergent fiber; NDF: neutral detergent fiber.

Table 2. Silage combinations.

	Raw materials, %					
Silages	PR	M	SBP	PP	WS	AA
PR	100	-	-	-	-	-
M	-	100	-	-	-	-
SBP	-	-	100	-	-	-
PP	-	-	-	100	-	-
PRS	95	-	-	-	5	-
PRA	95	-	-	-	-	5
PRM	50	50	-	-	-	-
PRSB	50	-	50	-	-	-
PRP	50	-	-	50	-	-

PR: 100% pumpkin residue silage; M: 100% maize fodder silage; SBP: 100% sugar beet pulp silage; PP: 100% pomegranate pulp silage; PRS: 95% PR + 5% WS; PRA: 95% PR + 5% AA; PRM: 50% PR + 50% M silage; PRSB: 50% PR + 50% SBP silage; PRP: 50% PR + 50% PP silage; WS: wheat straw; AA: alfalfa hay.

readings were performed before incubation (0) and 24 h after incubation. Resultant GP values were corrected for control and hay standards. The following equations were used to calculate metabolic energy (ME), net energy lactation (NEL), and organic matter digestibility (OMD) values of the silage samples, from Menke et al. [21] and Blümmel et al. [22]:

$$\text{ME (Mcal/kg DM)} = (2.20 + 0.1357 \times GP + 0.057 \times CP + 0.00285 \times EE^2) / 4.184$$

$$\text{NEL (Mcal/kg DM)} = (1.64 + 0.269 \times GP + 0.00078 \times GP^2 + 0.0051 \times CP + 0.01325 \times EE) / 4.184$$

$$\text{OMD (\%)} = 14.88 + 0.889 \times GP + 0.45 \times CP + 0.0651 \times Ash$$

Data were subjected to analysis of variance (ANOVA) using the General Linear Model of SPSS for Windows [23]. Significant differences between individual means were identified using Tukey's multiple range tests [24]. Differences were considered to be significant if $P < 0.05$ or $P < 0.001$.

3. Results and discussion

The pH, DM contents, Fleig scores, and quality classifications of the studied silages are provided in Table 3.

Silage pH values varied between 3.56 and 4.34 and the differences in pH values of the experimental silages were found to be significant ($P < 0.05$). Pumpkin residues supplemented with alfalfa hay (PRA) had significantly higher pH values than the others. The value was greater than the value specified for quality silage (3.80–4.30) [25]. Pomegranate pulp (PP) silages had a lower pH value (pH 3.56), similar to the findings of Canbolat et al. [26]. The pH values of pumpkin residue (PR) and pumpkin residues supplemented with sugar beet pulp (PRSB) silages were

Table 3. Effect of ensiling on pH, DM, Fleig score, and qualities of the silages.

Silages	pH	DM, %	Fleig score	Silage quality
PR	3.86^{bc}	9.39^{e}	54^{d}	Moderate
M	4.18^{b}	27.69^{b}	78^{b}	Good
SBP	3.75^{c}	23.97^{bc}	88^{ab}	Very good
PP	3.56^{c}	39.04^{a}	100^{a}	Very good
PRS	4.17^{b}	15.59^{d}	54^{d}	Moderate
PRA	4.34^{a}	17.20^{cd}	51^{d}	Moderate
PRM	4.07^{ab}	23.47^{bc}	74^{bc}	Good
PRSB	4.01^{abc}	18.55^{c}	66^{c}	Good
PRP	3.95^{abc}	25.97^{b}	84^{ab}	Very good
SEM	0.14	1.88	1.17	-
P	**	***	***	-

PR: 100% pumpkin residue; M: 100% maize fodder; SBP: 100% sugar beet pulp; PP: 100% pomegranate pulp; PRS: 95% PR + 5% wheat straw; PRA: 95% PR + 5% alfalfa hay; PRM: 50% PR + 50% M; PRSB: 50% PR + 50% SBP; PRP: 50% PR + 50% PP silage; SEM: standard error of means; P: significance; **: $P < 0.05$; ***: $P < 0.001$; Means indicated with the same letter in the same column are not significantly different.

also similar to the values found by Łozicki et al. [27]. Similar to current findings for M and pumpkin residue supplemented with maize fodder (PRM) silages, Fonseca et al. [28] reported the pH of 37 maize silage samples as 3.36–4.33. The pH values of PRA and pumpkin residue supplemented with wheat straw (PRS) silages were similar to the values reported by Hashemi and Razzaghzadeh [5]. The pH of SBP silage was 3.75, which was in agreement with the values (pH 3.50–4.36) reported by Sahin et al. [29]. The high pH values of PRA silage were mainly attributed to greater soluble protein contents and greater NH_4^+ generation in PRA silage [26]. Such high pH levels were also attributed to the high buffering capacity of alfalfa.

The DM contents of experimental silages ranged between 9.39% and 39.04% (Table 3); there were significant differences in DM content of silages ($P < 0.001$). The PP silage had higher DM contents than the other silages, while PR silage had the lowest DM content. Current DM contents of pomegranate silages were greater than the values determined by Canbolat et al. [26] (25.67%–26.30%).The differences were mainly because of different presilage dry matter contents (±13.25%) of pomegranate pulp supplied from different facilities. On the other hand, similar to the present study, Scharrer et al. [30] reported DM content of fresh pumpkin and pumpkin residue silages respectively as 8.01% and 8.81%. With straw and alfalfa supplementation of pumpkin residues, DM content of PRA and PRS silages increased respectively to 17.20% and 15.59% compared to PR silage alone (9.39%). However, 5% supplementation was found to be insufficient. Furthermore, PP and M supplementation into PR increased silage DM contents sufficiently (approximately +15%), and SBP supplementation increased DM content of silage (just about +9%).

The Fleig scores of silages ranged from 51 to 100; differences in Fleig scores of the experimental silages were found to be significant ($P < 0.001$). Based on Fleig scores, the present silages (except for PR, PRA, and PRS) were of very good or good quality. Present findings revealed improved silage quality with maize fodder, sugar beet, and pomegranate pulp supplementations compared to PR silage (Table 3).

Silage chemical compositions are provided in Table 4. The differences in ash, CP, CF, EE, ADF, and NDF contents of the silages were found to be significant ($P < 0.001$).

The CA content of silages ranged from 4.33% to 14.44%. While the greatest CA content was observed in pumpkin residue silage (PR), the lowest values were seen in SBP and PP silages. Entire supplements to pumpkin residues decreased CA content of silages ($P < 0.001$). CP contents varied between 4.79%–13.11% ($P < 0.001$). The PP silage had greater CP contents than the other silages. Present findings agree with the results of Ots and Kart [31]. The CP contents of PR and M silages were similar to the values of Fonseca et al. [27] and Niewczas et al. [8]. While wheat straw (WS) supplementation decreased CP content, alfalfa hay (AA) supplementation increased the values because of the CP content of alfalfa. The CP content of SBP silage was in agreement with the values reported by Kilic and Saricicek [32]; application of the sugar beet

Table 4. Effect of ensiling on chemical composition of the silages.

Silages	CA, %	CP, %	CF, %	EE, %	ADF, %	NDF, %
PR	14.44^{a}	8.86^{c}	29.54^{b}	8.33^{ab}	38.13^{b}	52.14^{b}
M	8.98^{bc}	8.93^{bc}	29.35^{b}	2.04^{d}	35.26^{bc}	56.10^{b}
SBP	4.59^{d}	4.79^{d}	16.89^{d}	2.70^{cd}	24.66^{d}	39.10^{d}
PP	4.33^{d}	13.11^{a}	29.87^{b}	10.37^{a}	31.47^{c}	41.17^{cd}
PRS	10.34^{b}	5.52^{d}	34.94^{a}	4.94^{bc}	43.66^{a}	63.33^{a}
PRA	10.65^{b}	9.66^{b}	28.88^{b}	5.08^{b}	36.59^{b}	49.56^{bc}
PRM	10.75^{b}	8.92^{bc}	25.29^{c}	3.57^{c}	36.99^{bc}	54.59^{b}
PRSB	8.63^{bc}	6.84^{cd}	25.65^{c}	6.76^{b}	31.54^{c}	42.94^{c}
PRP	7.14^{c}	10.09^{b}	28.36^{b}	9.66^{a}	34.29^{bc}	44.29^{cd}
SEM	0.63	0.94	1.33	0.71	1.45	1.94
P	***	***	***	***	***	***

PR: 100% pumpkin residue; M: 100% maize fodder; SBP: 100% sugar beet pulp; PP: 100% pomegranate pulp; PRS: 95% PR + 5% wheat straw; PRA: 95% PR + 5% alfalfa hay; PRM: 50% PR + 50% M; PRSB: 50% PR + 50% SBP; PRP: 50% PR + 50% PP silage; SEM: standard error of means; P: significance; **: $P < 0.05$; ***: $P < 0.001$. Means indicated with the same letter in the same column are not significantly different.

pulp decreased CP content of the ensiled material. The CF contents of the silages varied between 16.89%–34.94%. While wheat straw supplementation increased CF values of the silages because of higher cellulose contents, M, SBP, and PP supplementations reduced the CF content of the silages (P < 0.001).

Ether extract (EE) contents of experimental silages varied between 2.04% and 10.37% (P < 0.001). The lowest EE content was obtained from M silage. Current findings are in agreement with the values reported by Canbolat et al. [26]. Similar EE contents were also reported by Özdüven et al. [33] for M silages; M addition decreased the EE content of ensiled material. The present EE contents for PR silages agreed with the results of Halik et al. [14]. WS and AA supplementations decreased the EE content of PR silages. Present EE contents for SBP silages agreed with the results of Sahin et al. [29], but they were lower than the values of PR silage.

ADF contents of experimental silages varied between 24.66% and 43.66% (Table 4), and differences in ADF contents of silage samples were found to be significant (P < 0.001). PRS silage had higher ADF content than the others (P < 0.001). The present ADF content of M silage (35.26%) was comparable with the values of Anil et al. [34]. On the other hand, ADF content of PP silage was lower than PR and M silages but higher than SBP silage; the values obtained from PP (31.47%) and SBP (24.46%) silages were similar to the values of Canbolat et al. [26] and Ülger et al. [35]. Furthermore, addition of WS increased the ADF content of ensiled material because of the high ADF content of raw wheat straw. The NDF content of silages ranged from 39.10% to 63.33% (P < 0.001), and PRS silage had significantly greater NDF content that the other silages due to NDF content of raw WS. The lowest NDF contents were obtained from SBP and PP silages, which were in agreement with the values reported by Ülger et al. [35] and Canbolat et al. [26]. The PP and SBP supplementations decreased the NDF content of ensiled material. The NDF value of M silage was higher than that of PR silage and similar to the values of Fonseca et al. [28].

The 24-h gas production (GP), OMD, ME, and NEL values of pumpkin residue silages ensiled with different supplementations are provided in Table 5. The differences in all of these parameters of the silages were found to be significant (P < 0.01).

The GP values of the silages varied between 32 and 80 mL/200 mg DM (P < 0.001). The SBP silage had significantly greater GP values than the other silages (P < 0.001), mostly because of greater soluble carbohydrate content. Therefore, SBP supplementation into pumpkin residues increased water-soluble carbohydrate (WSC) contents of the silages, and decreased NDF and ADF contents (Table 4); thus, in vitro gas production was higher in PRSB silage than in PR silage. The lowest GP value was obtained from PP silage and the value was greater than the values of Canbolat et al. [25] but were in agreement with the values of Ebrahimi et al. [36] and Taher-Maddah et al. [37]. The OMD values of the silages varied between 42.98% and 83.40%, with the highest value in SBP silage (P < 0.001). The SBP increased 24-h gas production and WSC

Table 5. 24-h gas production (mL/200 mg DM), OMD, ME, and NEL values of silages.

Silages	**GP, mL/24 h**	**OMD, %**	**ME, Mcal/kg**	**NEL, Mcal/kg**
PR	56.0^{c}	63.86^{c}	2.35^{c}	1.47^{c}
M	36.5^{e}	47.01^{e}	1.72^{e}	0.92^{e}
SBP	80.0^{a}	83.40^{a}	3.12^{a}	2.12^{a}
PP	32.0^{f}	42.98^{f}	1.58^{f}	0.84^{f}
PRS	41.0^{ef}	49.86^{de}	1.83^{de}	1.06^{de}
PRA	46.5^{d}	55.52^{d}	2.05^{d}	1.21^{d}
PRM	48^{c}	54.14^{d}	2.11^{d}	1.24^{d}
PRSB	65^{b}	71.07^{b}	2.64^{b}	1.72^{b}
PRP	45^{d}	54.06^{d}	2.01^{d}	1.19^{d}
SEM	3.47	3.19	0.12	0.10
P	***	***	***	***

PR: 100% pumpkin residue; M: 100% maize fodder; SBP: 100% sugar beet pulp; PP: 100% pomegranate pulp; PRS: 95% PR + 5% wheat straw; PRA: 95% PR + 5% alfalfa hay; PRM: 50% PR + 50% M; PRSB: 50% PR + 50% SBP; PRP: 50% PR + 50% PP silage; SEM: standard error of means; P: significance; ** = P < 0.05; *** = P < 0.001; Means indicated with the same letter in the same column are not significantly different.

content and reduced NDF and ADF contents; thus, PRSB silage had higher OMD than PR silage. While ME contents of silages varied between 1.58 and 3.12 Mcal/kg DM, NEL values varied between 0.84 and 2.12 Mcal/kg DM ($P < 0.001$). The highest ME and NEL values were obtained from SBP silages because of high 24-h gas production value used in ME and NEL calculations.

4. Conclusions

It was concluded in the present study that pumpkin residues could be used as a quality silage source, and SBP supplementation significantly improved nutritional values and GP, ME, and NEL values of the silages. Pomegranate supplementation also improved chemical composition and quality of the silages. It was also concluded that a sum of 5%–10% AA could be supplemented into silages to increase DM levels.

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