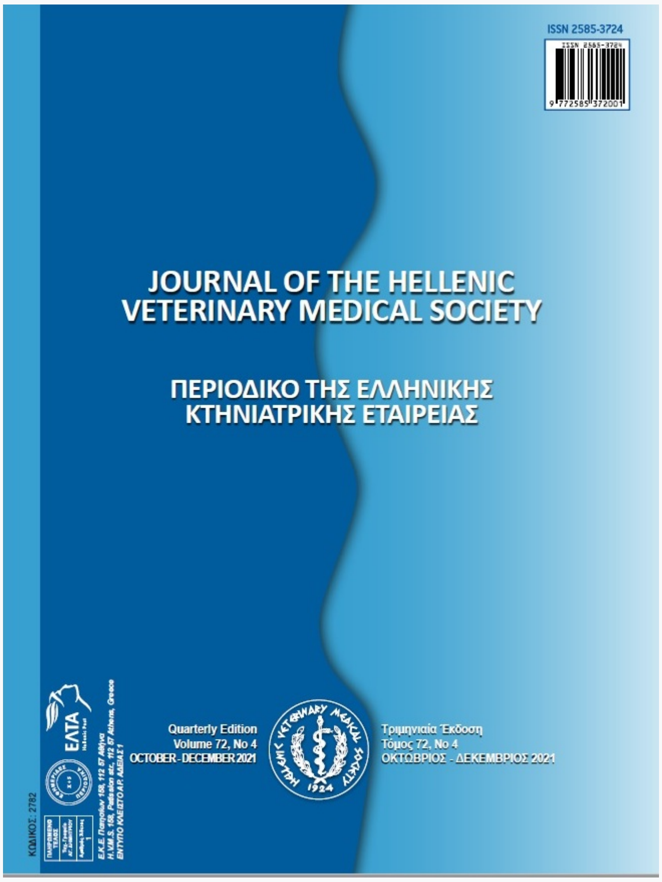
Journal of the Hellenic Veterinary Medical Society

Vol 72, No 4 (2021)



Digestibility and Silage Quality of Potato Pulp Silages Prepared with Different Feedstuff

HH ŞENYÜZ, MA KARSLI

doi: 10.12681/jhvms.29381

J HELLENIC VET MED SOC 2021, 72(4): 3383-3390
ΠΕΚΕ 2021, 72(4): 3383-3390

Research article
Ερευνητικό άρθρο

Digestibility and Silage Quality of Potato Pulp Silages Prepared with Different Feedstuff

H.H. Şenyüz[1], M.A. Karslı[2]

[1]International Center for Livestock Research and Training Mamak, Ankara, Turkey

[2]University of Kirikkale, Departmant of Animal Nutrition and Nutritional Disease, Yahsihan, Kirikkale, Turkey

ABSTRACT: The objective of this study was to determine silage quality and digestibility of potato pulp ensiled with different feedstuffs (straw, alfalfa hay and wheat bran). A total of 5 different potato pulp silages (PPS) were prepared with 5% ground barley straw, ground alfalfa hay, wheat bran alone or combination of 2.5 % wheat bran+ground straw, and wheat bran+ground alfalfa hay on a fed basis.These silages were ensiled in 2-L jars. After 49d of ensiling, all silages were opened and the chemical composition, pH, organic acids, ammonia-N contents, *in situ* organic matter (OM) and starch degradabilities and *in vitro* OM digestibility (IVOMD) of the silages were determined. Then, energy values were calculated.The highest dry matter (DM) and OM concentrations were observed in PPS prepared with wheat bran alone ($P<0.05$). Potato pulp silage containing ground barley straw alone had the lowest crude protein (CP) concentration ($P<0.05$) and silage containing wheat bran alone had the lowest neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations among PPS ($P<0.05$). Potato pulp with wheat bran alone had the highest lactic acid concentrations among all silages ($P<0.05$). Acetic acid concentrations of silages were similar ($P>0.05$). The *in situ* OM degradability and IVOMD were significantly different ($P<0.05$) among all silages. However, in situ starch digestibility was similar among PPS ($P>0.05$). It can be concluded that PPS prepared with different feedstuffs at a 5% level had good fermentation properties and high degradability values. Even a high quality PPS can be obtained with the addition of 5% ground barley straw alone.

Keywords: *In vitro* digestibility; potato pulp; silage quality.

Corresponding Author:
Hasan Hüseyin Şenyüz, International Center for Livestock Research and Training Mamak, Ankara, Turkey
E-mail address: hasansenyuzvet@yahoo.com

Date of initial submission: 25-09-2020
Date of acceptance: 24-01-2021

INTRODUCTION

The highest cost of animal husbandry expenses in Turkey constitutes feed costs (Boğa and Çevik, 2012). Among the feed costs, the most serious problem is experienced in obtaining high quality roughage at the right price.

Potato farming has been successfully carried out in Turkey for many years. However, there is no clear data on how much of the potatoes are consumed fresh and how much of them are processed in Turkey. In recent years, Turkey's potato industry has developed rapidly and potatoes are offered for consumption as chips and frozen potatoes. In addition, another usage field of potatoes is starch production and quantity of waste pulp (Yang et al., 2018; 2019). Hundreds thousands of tonnes potato pulp produced every year in the world from starch factories (Kurnik et al., 2015). The production of starch from potato in Turkey started in a factory established in Konya by private sector initiative. The factory was established in 2013, made trial production in 2014 and potato starch production started in 2015 by contracting planting with the farmers in the region. Potato pulp, a by-product obtained after potato starch production, has the potential to be a feed source that can be utilized by animals (Cheng et al., 2019).

By-products obtained from potato enterprises (chips products, frozen potato products, potato shells) were generally reported to contain 3.7% to 27.1% CP, 3% to 55.9% starch, 20% to 65.2% NDF, 6.2% to 31.2% ADF, 2.9% to 6.9% ether extract (EE) on DM basis (Okine et al., 2005; Aibibula et al., 2007; Nelson et al., 2010; Valadares et al., 2019).

Potato processing products (especially potato pulp) is not much known in Turkey. However in countries where potato production is high, these are considered as animal feed (Wang et al., 2010). Indeed; Wang et al. (2010) have utilized potato pulp fermented in solid form as a poultry feed, Aibibula et al. (2007) have used PPS instead of ground corn in ruminants. These studies display that this product can make a significant contribution to the national economy if properly utilized in animal nutrition.

The preservation of potato pulp, which is a wet product, is possible by either drying or silage making. However, drying is probably not an economically viable alternative due to the high energy cost (Okine et al., 2005). Silo water loss is the main problem in ensiling of high moist materials. This problem can be eliminated by adding absorbent to PPS. Indeed, it has previously been reported that absorbents have been used successfully in ensiling of high moist roughage to reduce DM loss and increase silage quality (Jones et al., 1990; Zhang et al., 2012; Mohamadian et al., 2016).

In the light of available information, it was aimed to determine silage quality and digestibility of potato pulp by ensiling with different feedstuffs (barley straw, alfalfa hay and wheat bran) used as moist absorbent.

MATERIALS AND METHODS

The potato pulp used in the trial was obtained from Konya sugar potato starch production facilities owned by Konya Sugar Company. Barley straw, ground alfalfa hay and wheat bran used as an absorbent in silage making were obtained from the Ankara region. The nutrient contents of pulp and absorbent substances are given in Table 1.

The samples taken from Konya sugar potato starch production facilities with plastic bags were brought to Lalahan International Center for Livestock Research and Training (ICLRT) and mixed thoroughly to prevent water loss during transportation due to high humidity of potato pulp. In this way, 5 different potato pulp silage were prepared in 2-L jars using potato pulp brought to ICLRT.

For this purpose; (treatment)

the mixtures of 7600 gr potato pulp, 200 gr wheat bran and 200 gr barley straw (BSP), 7600 gr potato pulp, 200 gr wheat bran and 200 gr ground alfalfa hay (BAP), 7600 gr potato pulp, 400 gr ground alfalfa hay (AP), 7600 gr potato pulp, 400 gr wheat bran (BP), 7600 gr potato pulp, 400 gr barley straw (SP) were prepared, then 4 replicates have been ensiled for each treatment groups in 2-L jars.

Table 1. Nutrient contents of PP and different feedstuff used in the experiment, DM %

Items	DM	CA	CP	NDF	ADF
Potato pulp	16.05	3.18	5.04	35.08	17.33
Barley Straw	91.8	6.1	3.4	72.3	55.4
Alfalfa hay	89.3	9.39	19.49	33.97	28.85
Wheat bran	91.5	2.62	12.6	29.63	7.96

DM: Dry matter, CA: Crude ash, CP: Crude protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber.

These mini silos were opened at the end of 49 days ensiling period and silage pH were determined. For this purpose, 25 g samples were mixed with 100 ml distilled water for 5 minutes in the mixer. pH measurement was made from silage filtrate (Bingöl et al., 2008). The silage filtrates were stored at -18 °C until ammonia nitrogen and organic acid analyzes were performed. In order to determine the DM of silage samples, 1 kg sample was weighed in clean aluminium containers and left to dry for 6 days at 49 °C until samples were completely dried (Kutlu, 2008). After DM determination of the samples, the samples were ground to pass 2 mm screen and prepared for the subsequent analysis.

To determine the *in situ* nutrient degradation of silages, 3 Holstein cattles (8 year-old, about 600 kg live weight) with rumen cannula were used (International Center for Livestock Research and Training Ethics Committee, 30.11.2015/117). Before initiation of the experiment, animals were treated with Detomax® and Anaverm® to eliminate the internal and external parasite. Cattles consumed alfalfa hay 10 days before the initiation of the experiment until the end of experiment. Cattles had free access to clean water and vitamin-mineral blocks throughout the experiment.

Approximately 4 grams of silage samples, which were dried and ground to pass 2 mm scren, were placed in nylon (Dacron) bags with a pore size of approximately 45µ. Each sample were placed into the rumen of each animal as duplicate for each given times. The mouth of the bags was tightly tied with the package rubber and placed into 20x40 nylon nets with a pore size of 0.3 cm, containing marbles to keep the bags in the ventral part of the rumen. Samples were incubated in the ventral part of rumen for 0, 2, 4, 8, 12, 24 and 48-hours (Tuncer et al., 1989). At the end of incubation time, the bags were removed from the rumen and washed in running tap water to remove the remaining feed particles from the bags. The bags were kept under running water until the color of the water became clear. Then, the bags were dried at 65 °C for 24 hours (Çetinkaya, 1992), the weight of samples remaining in the bags was recorded. OM and starch contents of the residue were determined. Nutrient degradability (OM and starch) of feed was calculated according to the following formula (Orskov and Shand, 1997);

Nutrient degradability (OM and starch) = $a+b(1-e^{ct})$

a=Represents the immediately soluble fraction
b=The insoluble but slowly rumen degradable fraction
a+b =The potential degradation
c=The rate constant of degradation of b
t=The time of incubation

Silage samples were run to determine dry matter (DM), ash, and crude protein (CP; AOAC, (1990)) neutral detergent fiber (NDF; Van Soest and Robertson, (1979) and acid detergent fiber (ADF; Goering and Van Soest, (1970)). *In vitro* organic matter (OM) digestibility of silage samples were determined according to Tilley and Terry (1963) method modified by Marten and Barnes (1979) using Daisy incubator (ANKOM®, USA). Energy contents of samples were calculated according to formulas reported by Bingöl et al. (2008)

Organic acid contents of silages were analyzed by HPLC according to Tjardes et al., (2000). Ammonia nitrogen determination of samples was made by distillation method as indicated by Filya (2003).

The data obtained in the study were subjected to variance analysis according to completely randomized design SAS (1995). The difference between the means was determined by Duncan test (Steel and Torrie, 1980).

$$Yin = \mu + Ai + ei$$

Y_{in} = observation in trial i.
μ = the overall mean.
A_i = the fixed effect of trial i.
E_i = random error.

RESULTS

The nutrient content of 5 potato pulp silages prepared with different feedstuffs is presented in Table 2. When the table was examined, it was noted that PPS containing wheat bran alone had higher DM, OM, and starch levels compared to PPS silages containing alfalfa and barley straw alone (P<0.05). At the same time, PPS containing wheat bran alone had lower ash, NDF and ADF levels compared to PPS silages containing alfalfa and straw alone (P<0.05). The CP contents of silages containing wheat bran and alfalfa alone were similar and this value was higher than silage containing straw alone (P<0.05).

Data on fermentation parameters of silages are given in Table 3. The silage pH was the highest in PPS containing alfalfa hay alone (4.18) and the lowest in PPS containing straw + bran (4.01; P<0.05). The level of lactic acid was higher in silages containing bran alone than others, while propionic acid was the highest in PPS containing bran and alfalfa (P<0.05).

The acetic acid, butyric acid and ammonia nitrogen levels of silages were statistically similar (P>0.05).

The data regarding OM degradation of PPS are given in Table 4 and OM fractions are given in Table 5. Based on these tables; PPS containing bran alone had the highest OM degradation values at 0-h (water-soluble fraction) and after 48-h ruminal incubation (P<0.05). Therefore, PPS containing bran alone has the highest water-soluble OM and the lowest non-degradable and potentially degradable OM fractions compared to other silages. The highest level of non-degradable OM fraction was observed in silage containing straw alone. While the levels of starch degradation after 48h ruminal incubation were similar (P>0.05), the highest water soluble and the lowest potentially degradable starch fractions were observed in groups containing bran and straw alone (Tables 6 and 7; P<0.05).

In vitro OM digestibility values of silages varied between 76.75% - 80.76%. The highest *in vitro* OM digestibility and energy values were observed in silage containing wheat bran alone (Table 8; P<0.05).

Table 2. Nutrient contents of PPS prepared with different feedstuff, DM %

Items	DM	CA	OM	CP	NDF	ADF	Starch
PBS	25.03±0.079^{b}	4.01±0.093^{ab}	95.99±0.093^{ab}	7.24±0.196^{b}	49.66±2.355^{a}	18.32±0.482^{ab}	47.82±073^{b}
PBA	25.29±0.158^{b}	4.01±0.07^{ab}	95.99±0.07^{ab}	8.37±0.254^{a}	49.95±3.75^{a}	18.08±0.642^{ab}	47.67±0.86^{b}
PA	25.38±0.285^{b}	4.96±0.104^{a}	95.04±0.104^{b}	8.51±0.163^{a}	49.11±4.013^{a}	20.52±0.915^{a}	46.52±0.92^{b}
PB	26.32±0.009^{a}	3.87±0.031^{b}	96.13±0.031^{a}	8.41±0.139^{a}	35.26±1.206^{b}	15.53±0.185^{b}	49.62±0.16^{a}
PS	25.34±0.153^{b}	4.61±0.35^{a}	95.39±0.035^{b}	6.69±0.183^{c}	52.35±2.614^{a}	19.53±0.51^{a}	47.29±0.69^{b}

DM: Dry matter, CA: Crude ash, OM: Organic matter, CP: Crude protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b, c}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Table 3. Fermentation parameters of PPS prepared with different feedstuff, DM %

Items	pH	LA	AA	PA	BA	NH_3-N
PBS	4.01±0.0091^{c}	4.702±0.0878^{b}	1.281±0.383	-	-	0.55±0.068
PBA	4.04±0.0075^{bc}	4.226±0.2357^{c}	0.897±0.06	0.247±0.1372^{a}	-	0.56±0.017
PA	4.18±0.0123^{a}	4.261±0.2958^{c}	0.936±0.08	0.073±0.0707^{b}	0.033±0.033	0.55±0.016
PB	4.04±0.0126^{bc}	4.813±0.097^{a}	0.825±0.087	-	0.0057±0.0034	0.55±0.016
PS	4.06±0.0048^{b}	4.228±0.042^{c}	0.852±0.0377	-	0.0058±0.0058	0.52±0.0043

LA: Lactic acid, AA: Acetic acid, PA: Propionic acid, BA: Butyric acid, NH_3-N: Ammonia nitrogen
PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b,c}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Table 4. *In situ* OM degredation of PPS prepared with different feedstuff, OM %.

Items	0. h	2. h	4. h	8. h	12. h	24. h	48. h
PBS	28.35±0.749^{b}	32.54±1.881^{ab}	31.53±1.498^{ab}	54.43±0.816^{ab}	63.05±3.092	79.6±1.639	85.45±0.457^{bc}
PBA	31.65±0.655^{b}	32.31±2.124^{ab}	34.19±2.694^{ab}	51.44±2.398^{bc}	59.7±3.23	79.4±2.157	85.78±1.591^{bc}
PA	30.78±1.364^{b}	29.61±1.736^{b}	26.74±5.754^{b}	45.68±1.46^{c}	64.63±2.506	78.97±2.427	87.78±0.294^{ab}
PB	35.47±0.828^{a}	35.38±2.059^{a}	38.92±2.144^{a}	55.22±2.787^{a}	63.47±2.73	79.77±3.104	89.34±0.297^{a}
PS	30.03±1.21^{b}	28.81±1.455^{b}	34.3±1.428^{ab}	49.41±1.149^{bc}	60.19±0.22	77.45±2.437	84.17±0.425^{c}

PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b,c}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Tabe 5. Organic matter fractions of PPS prepared with different feedstuff, OM%

Items	Water Soluble	Potantially Degradable	None- Degradable
PBS	28.35±0.749^{c}	57.10±0.631^{a}	14.45±0.457^{ab}
PBA	31.65±0.655^{b}	54.13±0.913^{ab}	14.22±1.591^{ab}
PA	30.78±1.364^{bc}	57.00±0.833^{a}	12.22±0.294^{bc}
PB	35.47±0.828^{a}	46.13±0.563^{b}	10.66±0.297^{c}
PS	30.03±1.21^{bc}	54.14±0.613^{ab}	15.83±0.425^{a}

PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b,c}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Table 6. *In situ* starch degredation of PPS prepared with different feedstuff, Starch %

Items	0. h	2. h	4. h	8. h	12. h	24. h	48.h
PBS	28.06±2.18 ^{b}	35.06±3.91	35.02±3.48	64.87±1.54	75.02±5.12	93.18±1.34	97.22±0.21
PBA	30.77±1.63 ^{b}	31.63±5.26	33.24±6.69	56.31±5.28	65.58±6.76	91.20±2.26	96.29±1.01
PA	29.89±3.38 ^{b}	28.20±4.33	38.39±3.10	50.49±3.26	73.97±4.52	93.00±1.98	97.62±0.14
PB	33.14±2.10 ^{a}	33.34±5.20	33.29±5.74	58.46±6.33	68.24±5.82	89.05±4.11	96.92±0.21
PS	33.33±2.82 ^{a}	30.26±3.49	39.97±3.20	59.80±2.23	73.71±6.03	92.63±1.95	97.27±0.18

PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Table 7. Starch fractions of PPS prepared with different feedstuff, Starch %

Treatments	Water Soluble	Potantially Degradable	None- Degradable
PBS	28.06±2.18 ^{b}	69.16±2.04 ^{a}	2.78±0.21
PBA	30.77±1.63 ^{b}	65.53±2.00 ^{ab}	3.71±1.01
PA	29.89±3.38 ^{b}	67.73±3.39 ^{ab}	2.38±0.14
PB	33.14±2.10 ^{a}	63.77±2.88 ^{b}	3.08±0.21
PS	33.33±2.82 ^{a}	63.94±2.82 ^{b}	2.73±0.18

PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

Table 8. *In vitro* OM digestibility and energy values of PPS prepared with different feedstuff

Items	IVOMD, %OM	ME, Mcal/kg	NEL, Mcal/kg
PBS	76.75±0.381 ^{d}	3.384±0.0168 ^{d}	1.76±0.009 ^{d}
PBA	79.9±0.521 ^{ab}	3.523±0.023 ^{ab}	1.838±0.013 ^{ab}
PA	77.29±0.613 ^{cd}	3.408±0.027 ^{cd}	1.774±0.015 ^{cd}
PB	80.76±0.129 ^{a}	3.561±0.006 ^{a}	1.859±0.003 ^{a}
PS	78.59±0.354 ^{bc}	3.465±0.016 ^{bc}	1.806±0.009 ^{bc}

IVOMD: *In vitro* organic matter digestibility, ME: Metabolic energy, NEL: Net energy for lactation
PBS: potato pulp+bran+straw, PBA: potato pulp+bran+alfalfa, PA: potato pulp+alfalfa, PB: potato pulp+bran, PS: potato pulp+straw, $^{a, b,c,d}$: letters with differet superscript at same column indicate statistical differences (P<0.05).

DISCUSSION

Since DM level of potato pulp alone was very low for silage making, different feedstuff used as water absorbers to improve DM content of PPS in this study. Among the potato silages prepared with different water absorbers, the PPS containing wheat bran alone had the highest DM level with 26.32%. In the study, it was noted that the DM level of PPS varied according to feedstuffs used as absorbent. It seemed that wheat bran additions into silages relatively increased the DM level. In the literature, DM levels of PPS prepared alone or with different feedstuff ranged from 15.9 to 27.69% (Okine et al., 2005; Aibibula et al., 2007; Nelson, 2010). The DM levels obtained in the current study were close to the upper edge of the values reported in the literature. The reason for the DM differences between the studies was thought to be due to differences in levels of feedstuff and initial DM levels of the potato pulps used in the silages.

In terms of OM content of silages, the highest OM level was observed in PPS containing wheat bran alone with 96.13 (P<0.05). OM values observed in the current study were similar to those of Sugimato et al. (2008, 2009, 2010), higher than that of Pen et al. (2005), however less than those of Okine et al. (2005), Sugimoto et al. (2007), and Zunong et al. (2009). These differences in OM levels were thought to be due to excessive amount of soil and field residues and not doing a good pre-wash. Again, it seemed that the OM levels of feedstuff used as absorbent also affected the OM content of PPS.

The lowest CP content was observed in PPS containing barley straw alone with 6.69% whereas the highest CP content was found in silage containing alfalfa hay with 8.51 in the study. This was due to the low CP content of the feedstuffs. Silages containing bran and alfalfa hay alone had higher CP content than silage containing straw alone (P <0.05). Again, it was thought that the CP contents of alfalfa hay and bran were higher than that of straw (NRC, 2001). Crude protein values of the current study were similar to the data reported by Zhang et al. (2012), but higher than those of Okine et al. (2005), Sugimoto et al. (2007), and Zunong et al. (2009). These differences were thought to be due to the ratio of the other feedstuff and the protein contents of the other feedstuff used for silage making in the studies.

When the NDF and ADF of the silages were examined, the lowest NDF and ADF contents were observed in silage with wheat bran alone (P <0.05). The NDF and ADF contents of silages except silage containing wheat bran alone were similar to that of Zhang et al. (2012), higher to Omer et al. (2011) and Dhingra et al. (2013) but the NDF and ADF content of silage with wheat bran alone was lower than that of Omer et al. (2011), Zhang et al. (2012), Dhingra et al. (2013) and Ncobela et al. (2017). Since the NDF and ADF content of wheat bran was much lower than that of straw and alfalfa hay (NRC, 2001), these low levels of NDF and ADF resulted from wheat bran in silage containing wheat bran.

The starch content of silages ranged from 46.52% to 49.62%. Since wheat bran contains some starch, it was thought that PPS prepared with wheat bran alone has a higher starch content than others. In previous studies, PP has been reported to contain starch between to 17.7 and 43% levels (Aibibula et al., 2007; Ncobela et al. 2017). This confirms the low levels of starch in the current study.

In the study, the pH values of silages were in the range of 4.01-4.18 and the highest pH values were observed in the group containing alfalfa hay alone (P<0.05). These pH values were very close to the values (pH: 3.5 - 4) previously reported in the literature (Sugimoto et al., 2007, 2008; Zhang et al., 2012) for PPS prepared with different additives. The pH values obtained in the study were in the 3.8-4.2 pH range, which is considered ideal for silage (Ergün et al., 2002) indicating very good fermentation. The high pH level of alfalfa hay silage was thought to be due to a higher CP content of alfalfa hay. As it is known, ammonia is alkaline and has high buffering power. Therefore, the pH level of silages made from legumes is generally higher than silages made from cereal grains.

While the silage containing wheat bran alone had the highest lactic acid content (4.813; P<0.05), acetic acid contents were similar in all silages (P>0.05). The level of butyric acid, which is important for silage quality and indicates poor fermentation, was either absent or negligible levels in all silages. The fact that 70% or more of the total amount of organic acid in all silages was lactic acid and the amount of butyric acid was not at significant levels, suggesting a good fermentation. The amount and profile of organic acid released by lactic acid bacteria as a result of fermentation in silages were related to the sugar and moisture contents, and buffering capacity of the silage product (Rotz and Muck, 1994). Zhang et al. (2012) have reported the lactic acid values of 3.22%, 2.73%, 2.74%, and acetic acid values of 0.54%, 0.42% and 0.55% in the PPS prepared with 20% rice straw, corn cob and bean cob. Both lactic acid and acetic acid levels obtained in this study were lower than the values obtained in the current study. The reason for the difference between the studies may have been due to type and the levels of feedstuff used in the silages.

Silage ammonia nitrogen was similar in all groups and ranged from 0.52 to 0.56% DM (P>0.05). Zhang et al. (2012) reported the ammonia nitrogen values in the range of 1.71 - 2.5% of total nitrogen for PPS prepared with rice straw, corn residue, and dried bean residue, which was lower than ammonia nitrogen values observed in the current study, but the ammonia nitrogen levels (1.06 %M) reported by Baytok et al. (2005) for maize silage was higher than the ammonia nitrogen levels in the current study.

In situ OM degradation values of all PPS used in the study were calculated in the range of 82.32-89.34% after 48 hours of ruminal incubation. Among PPS, the highest *in situ* OM degradation values were observed in PPS with wheat bran alone (P<0.05). Percentage of DM degradation for PPS prepared with different feedstuff ranged from 56.1 to 75.5% in the literature (Sugimato et al., 2006; Sugimato et al., 2007; Sugimato et al., 2008; Zunong et al., 2009; Sugimoto et al.,2010). Organic matter degradation values obtained in the current study was similar to that of Zunong et al.,(2009) but higher than those of Sugimato et al., (2006, 2007, 2008, 2009, 2010). The difference between the studies was thought to be due to the differences in the nutrient content of the pulp and the additives involved and also levels of additives used in PPS.

Among the OM fractions, water soluble OM level was the highest (35.47%) in wheat bran-added silage, while it was the lowest in wheat bran+straw-added PPS with 28.35%. Potentially degradable OM fractions of PPS were similar. The non-OM fractions in PPS ranged from 10.66% to15.83 (P<0.05).

When the *in situ* starch degradation values were examined, it was observed that the starch degradation values were similar in all silages and were at approximately 97% level after 48 hours incubation. It was an expected result since the source of starch in silages was PP, except the bran added silage. Starch present in wheat bran has a high digestibility like starch in potato so that degradation rate in silage containing wheat bran was also similar.

In vitro OM digestion values for PPS varied from 76.75 to 80.76%. Among the PPS, the highest OM digestion and energy values were observed in wheat bran-added silage, while wheat bran + straw-added silage had the lowest OM digestion and energy values. Since, energy values were calculated based on OMD values, energy values were also parallel with OMD values. In a study conducted by Zunong et al (2009), the DM digestion of PPS was 75.5%. The OM digestion values obtained for PPS in the current study were similar to that reported by Zunong et al. (2009). The level of digestion of PPS is expected to vary depending on the nature of the additive involved.

CONCLUSIONS

The result of the study, the nutritional content of the PP was very good in terms of carbohydrates, which was demonstrated by the high starch content. Although silages did not contain enough DM for ideal silage production, all of the silages have very good fermentation properties. In particular, the lactic acid levels in all silages was more than 70% of the total organic acids and the butyric acid level was either negligible or absent, which was a desirable form of fermentation in silages. It can be thought that due to the good compressibility of the potato pulp and its high digestible carbonhydrate content. All these positive properties were reflected in both *in situ* and *in vitro* digestion values, and thus, highly digestible silages have been obtained.

It can be concluded that PPS prepared with different feedstuffs at 5% level had good fermentation properties and high digestion and degradation values. Even PPS prepared by adding barley straw at 5% level has very high digestibility, indicating that can be good alternative feedstuff for ruminant animals.

ACKNOWLEDGEMENTS

This study is a summary of the first author's PhD thesis and was presented in the International Congress on Agriculture and Animal Sciences (ICAGAS), 7-9 Nov, 2018 Alanya, Turkey. Authors thanks to General Directorate of Agricultural Research and Policies (GDARP) and International Center for Livestock Research and Training (ICLRT) for animal materiel and laboratory support.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Aibibula Y, Okine A, Hanada M, Murata S, Okamoto M, Goto M (2007) Effect of replacing rolled corn with potato pulp silage in grass silage-based diets on nitrogen utilization by steers. Asian-Aust J Anim Sci 20(8): 1215-1221.

AOAC (1990) Association of Official Analitical Chemists. Official Methods of Analysis, 15th ed. Washington, DC.

Baytok E, Aksu T, Karsli MA, Muruz H (2005) The effects of formic acid, molasses and inoculant as silage additives on corn silage composition and ruminal fermentation characteristics in sheep. Turk J Vet Anim Sci 29(2): 469-474.

Bingöl NT, Karslı MA, Bolat D, Akça İ (2008) The effects of molasses and formic acid addition in sainfoin silage harvested at different maturities on silage quality and digestibility. Van Vet J 19(2): 61-66.

Boğa M, Çevik KK 2012. Ruminant hayvanlar için karma yem hazirlama programı. XIV. Akademik Bilişim Konferansı Bildirileri.Uşak, Turkey: pp 249-256 (in Turkish).

Cheng L, Hu X, Gu Z, Hong Y, Li Z, Li C (2019) Characterization of physicochemical properties of cellulose from potato pulp and their effects on enzymatic hydrolysis by cellulase. Int JBiol Mac 131: 564-571.

Çetinkaya N (1992) Yem Maddelerinin Değerlendirilmesinde Naylon TorbaMetodunun Kullanılması. Yem Magazin Dergisi 1(4): 28-30 (in Turkish).

Dhingra D, Michael M, Rajput H, Chopra S (2013). Utilization of potato processing waste for compound cattle feed. agricultural engineering today. 37(4): 40-45.

Ergün A, Tuncer Ş, Çolpan İ, Yalçin S, Yildiz G, Küçükersan MK, Küçükersan S, Şehu A (2002) Yemler,yem hijyeni ve teknolojisi. Ankara, Medipress. p:80

Filya İ (2003) The effect of *lactobacillus buchneri* and *lactobacillus plantarum* on the fermentation, aerobic stability, and ruminal degradability of low dry matter corn and sorghum silages. J Dairy Sci 86(11): 3575-3581.

Goering HK, Van soest PJ (1970) Forage fiber analyses (Apparatus, reagents, prcedures, and some applications). US Govt Print Off, U.S, Washington.

Jones DIH, Jones R, Moseley G (1990) Effect of in corporating rolled barley in autumn-country e grass silage on effluent production, silage fermentation and cattle performance. J AgriSci115(03): 399-408.

Kurnik K, Treder K, Skorupa-Kłaput M, Tretyn A, Tyburski J (2015) Removal of phenol from synthetic and ındustrial wastewater by potato pulp peroxidases. Water AirSoil Poll 226(8): 254.

Kutlu HR (2008) Yem değerlendirme ve analiz yöntemleri. Lecture Notes Çukurova University, Balcalı-Adana (in Turkish).

Marten GC, Barnes RF (1979) Prediction of energy digestibility of forages with *in vitro* rumen fermentation and fungal enzyme systems. workshop on standardization of analytical methodology for feeds. 12-14 Mar, CA.

Mohamadian S, Alipour D, Mahmoudi-Abyane M (2016) Effect of different moisture absorbents on silage fermentation quality of wet potato

pulp. Iranian J Anim Sci Res 8(2): 248-257.
Ncobela CN, Kanengoni AT, Hlatini VA, Thomas RS, Chimonyo M (2017) A review of the utility of potato by-products as a feed resource for smallholder pig production. Anim Feed Sci and Tech 227: 107-117.
Nelson ML (2010) Utilization and application of wet potato processing coproducts for finishing cattle. J Anim Sci88(13): 133-142.
NRC (2001) Nutrient requirements of dairy cattle: National Acad. Press.
Okine A, Hanada M, Aibibula Y, Okamato M (2005) Ensiling of potato pulp with or without bacterial inoculants and its effect on fermentationquality, nutrient composition and nutritive value. AnimFeedSciTech121(3-4):329-343.
Omer HA, Abdel-Magid SS, Salman FM, Salman A, Ahmed SM, Mohamed M, Awadalla IM, Zaki MS (2011) Using potato processing waste in sheep rations egypt. Life Sci J 8(4): 733-742.
Orskov ER, Shand WJ Shand (1997) Use of the nylon bag technique for protein and energy evaluation and for rumen environment studies in ruminants. livest. Res. Rural Dev 9: 1-10. http://www.cipav.org.co/lrrd/ lrrd9/1/orskov.htm.
Pen B, Oyabu T, Hıdaka S, Hıdarı H (2005) Effect of potato by-products based silage on growth performance, carcass characteristics and fatty acid composition of carcass fats in holstein steers. Asian-Aust JAnim Sci18(4): 490-496.
Rotz CA, Muck RE (1994) Changes in forage quality during harvest and storage.Forage quality, evaluation, and utilization (Foragequalityev) 828-868.
SAS S (1995) User's guide version 9.1: SAS Institute, Inc, Cary, NC, USA.
Steel RG, Torrie JH (1980) Principle and procedures of statistic: A biometrical approach: New York: McGraw-Hill.
Sugimoto M, Saito W, Ooi M, Sato Y, Saito T, Mori K (2006)The effects of potato pulp and feding level of supplements on digestibility, *ın situ* forage degradation and ruminal fermentation in beef steers.Anim Sci J 77(6): 587-594.
Sugimoto M, Chiba T, Kanamoto M, Hidari H, Kida K, Saito W, Ooi M, Sato Y, Saito T (2007) Effects of urea treatment of potato pulp (pp) and inclusion levels of potato pulp silage in supplements on digestibility and ruminal fermentation in beef steers. Anim Sci J 78(6): 587-595.
Sugimoto M, Kanamoto M, Chiba T, Hidari H, Kida K, Saito W, Ooi M, Sato Y, Saito T (2008) The effects of protein sources supplemented with urea-treated potato pulp (pp) and feeding levels of the pp silage-based concentrate on feed ıntake, digestibility and ruminal fermentation in beef steers. Anim Sci J 79(4): 443-452.
Sugimoto M, Saıto W, Ooi M, Sato Y, Saito T (2009)The effects of ınclusion levels of urea-treated potato pulp silage in concentratean droughage sources on finishing performance and carcass quality in cull beef cows.Anim Sci J 80(3): 280-285.
Sugimoto M, Saito W, Ooi M (2010) The effects of urea-treated potato pulp (pp) ensiled with beet pulp or wheat bran pellets to reduce moisture of pp and flake density of corn grain supplemented with the pp silage on digestibility and ruminal fermentation in beef steers. Anim Sci J 81(3): 316-324.
Tilley JM, Terry R (1963) A two-stage technique for the *in vitro* digestion of forage crops. Grass Forage Sci 18(2): 104-111.
Tjardes K, Buskirk D, Allen M, Ames N, Bourquin L, Rust S (2000) Brown midrib 3 corn silage improves digestion but not performance of growing beef steers.J Anim Sci 78(11): 2957 - 2965.
Tuncer Ş, Kocabatmaz M, Coşkun B, Şeker E (1989). Kimyasal maddelerle muamele edilen arpa samanının sindirilme derecesinin naylon kese (nylon bag) tekniği ile tespit edilmesi. Doğa TU Vet ve Hay D 13: 66-81 (in Turkish with an abstract in English).
Valadares NR, Andrade Junior VCD, Pereira RC, Fialho C, Teixeira M, Ferreira MAM (2019) Effect of different additives on the silage quality of sweet potato branches. Revista Caatinga, 32(2): 506-513.
Van Soest P, Robertson J (1979) Systems of analysis for evaluating fibrous feeds standardization of analytical methodology for feeds. Ottawa, ON, CA.IDRC.
Wang TY, Wu YH, Jiang CY, Liu Y (2010)Solid state fermented potato pulp can be used as poultry feed. British Poultry Sci51(2): 229-234.
Yang JS, Mu TH, Ma MM (2018) Extraction, structure, and emulsifying properties of pectin from potato pulp. Food Chem, 244: 197-205.
Yang JS, Mu TH, Ma MM (2019) Optimization of ultrasound-microwave assisted acid extraction of pectin from potato pulp by response surface methodology and its characterization. Food Chem 289: 351-359.
Zhang WW, Zhang YG, Liu Z (2012) effect of different absorbents on fermentation quality of wet potato pulp. J Anim Vet Adv 11(22): 4230-4235.
Zunong M, Tuerhong T, Okamoto M, Hongo A, Hanada M (2009)Effects of a potato pulp silage supplement on the composition of milk fatty acids when fed to grazing dairy cows. Anim Feed Sci Tech 152(1-2): 81-91.