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# The Substitution of Corn Silage with Potato Pulp Silage at Differing Level in Dairy Cows on Milk Yield, Composition and Rumen Volatile Fatty Acids*

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**Summary:** The aim of this study was to determine the quality of potato pulp silage (PPS) prepared with wheat bran and barley straw and the effects of the substituting corn silage with potato pulp silage at differing levels in dairy cows on milk yield, composition and rumen volatile fatty acid (VFA). The study consisted of two experiments. Nutrient contents, fermentation parameters, *in situ* organic matter (OM) and starch degradabilities, *in vitro* digestibility (IVD) and metabolic energy (ME) content of PPS were determined in the first experiment. The effects of substituting corn silage with potato pulp silage at 0%, 15%, 30% and 45% in the diet of lactating 12 dairy cows on feed intake, milk yield, milk components, rumen fermentation parameters were evaluated in the second experiment. While dry matter (DM), OM and crude protein (CP) contents, pH of silages were statistically similar, starch content, *in vitro* organic matter digestibility (IVOMD), ME, net energy lactation ($NE_L$), and lactic acid values were significantly higher in PPS compared with corn silage ($P<0.05$). Organic matter intake, milk yield, the composition of milk, post-feeding pH and total VFA levels of ruminal fluid at all sampling hours were similar among the dairy cows ($P>0.05$). It was concluded that; PPS prepared with wheat bran and straw had a very good silage quality and were even better than corn silage (control). Substitution of corn silage with PPS up to 45% did not cause any negative effects on rumen fermentation parameters and can be safely substituted with corn silage up to 45% in dairy cow diets.
**Key words:** Corn silage, dairy cattle, in situ, milk composition, potato pulp

## Süt İnekleri Rasyonlarına Mısır Silajı Yerine Farklı Düzeylerde Katılan Patates Posası Silajının Süt Verimi, Süt Bileşenleri ve Rumen Uçucu Yağ Asitleri

**Özet:** Bu çalışmanın amacı buğday kepeği ve saman ilave edilerek hazırlanan patates posası silajının (PPS) kalite özellikleri ile süt sığırlarında mısır silajı yerine değişik oranlarda patates posası silajı kullanımının süt verimi, sütün bileşimi ve rumen uçucu yağ asitleri (UYA) üzerine olan etkilerini saptamaktır. Bu çalışma iki aşamada yürütülmüştür. İlk aşamada PPS'nin besin madde içerikleri, fermentasyon parametreleri, in situ organik madde (OM) ve nişasta sindirilebilirlikleri, *in vitro* organik madde sindirilebilirlik (OMS) ile enerji düzeyleri saptanmıştır. İkinci aşamada ise PPS, mısır silajı yerine %0, 15, 30 ve 45 oranlarda ikame edilmiş ve 12 baş süt ineğinde yem tüketimi, süt verimi, süt bileşimi ile rumen fermentasyon parametreleri üzerine olan etkileri incelenmiştir. Silajların kuru madde (KM), organik madde (OM), hamprotein (HP) ve pH içerikleri istatistiki olarak benzer, nişasta, *in vitro* OM sindirilebilirlikleri, metabolik enerji (ME), net enerji laktasyon ($NE_L$), ile laktik asit düzeyleri PPS'de mısır silajına göre daha yüksek bulunmuştur ($P<0.05$). İneklerin OM tüketimi, süt verimi, süt bileşenleri, yemleme sonrası rumen pH ve UYA arasındaki farklılıklar önemsiz bulunmuştur ($P>0.05$). Sonuç olarak buğday kepeği ve saman ile hazırlanan PPS'nin silaj kalitesinin çok iyi ve hatta mısır silajından daha iyi olduğu belirlenmiştir. Süt ineği rasyonlarına mısır silajı yerine %45 oranında PPS katılması ineklerin rumen fermentasyon parametrelerinde olumsuz etkiye neden olmayacağı ve %45 oranında güvenle kullanılabileceği söylenebilir.
**Anahtar kelimeler:** İn situ, mısır silajı, patates posası, süt bileşimi, süt sığırı

## Introduction

The highest cost among the livestock expenses is feed expense in Turkey (Boğa and Çevik, 2012). One of the most serious problems for Turkish dairy farmers is lack of high-quality forage production. Actually, even getting enough amounts of roughages, not high-quality forages can sometimes be a problem. Especially, this problem has become very important in drought years and Turkish farmers had to import roughage. In order to solve the roughage problem; one has to extend to forage planting area and/or to create alternative roughage sources such as by-products.

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In 2017, a total of 388190674 tons of potato has been produced in the world. China is the number one among the most potato producing countries with 98988621 tons of potato per year. Indian is the second with 48523834 tons, Russia is the third with 29502491, Ukraine is the fourth with 22126868 tons and the USA is the fifth 20185915 tons in the world. Turkey is the 19th at potato production in the world. In 2017, a total of 4658288 tons of potato has been produced inTurkey (FAO, 2020).

While almost half of the produced potato is consumed as fresh vegetable, the rest of potato is used as processed food product, animal feed, industrial starch production or seed in the world (Bakshi et al., 2016). A significant part of the potato processed in starch industry is considered as waste. Indeed, one million tons of potato is been processed in starch industry in Japan every year and 10% of processed potato is utilized as waste (Oda et al., 2002). Thus, if this 'waste' product can be utilized as feed, it may have great feed potential for ruminant animals.

Potato starch industry residue (especially potato pulp) that is not well-known in Turkey has been utilized as animal feed in countries where potato production is in excess (Pen et al., 2005). Indeed, Wang et al. (2010) have used the solid fermented potato pulp as poultry feed. On the other hand, Aibibula et al. (2007) substituted the PPS with rolled corn in the diets of ruminant animals. These studies have shown that this product provides important benefits to the economy of countries when it is properly utilized.

The main limitations in using vegetable waste such as potato pulp as livestock feed are the high moisture content and presence of contaminants. Drying and ensiling can be a good option to enhance storage life and use of these products as animal feeds easier (Bakshi et al., 2016). Silage is probably the most economical way to conserve it. Addition of moisture absorbents into potato pulp silage reduce the spoiling and also improve the silage quality (Mohamadian et al., 2016).

Thus, the objective of this study was to evaluate the quality of PPS prepared with wheat bran and barley straw and the effects of the substituting corn silage with PPS at differing levels in dairy cows on milk yield, composition and rumen volatile fatty acids.

**Material and Methods**

This study approved by International Center for Livestock Research and Training Animal Research Ethics Committee (30.11.2015/117). In order to obtain potato silage with an approximately 30% DM, 6% (300 kg) wheat bran and 7% (350 kg) barley straw were added into 5 tons potato pulp and ensiled after complete mixing. Corn silage was also prepared at the same time. Approximately, after 60 days of the ensiling period, then, feeding trial was carried out.

A corn silage based diet was prepared (Control group), then, 3 experimental diets were created by substituting corn silage with 15%, 30% and 45% PPS (Table 1). A total of 12 dairy lactating cows, 4 Holstein, 4 Brown Swiss, 4 Simmental cows at their peak of lactation with similar milk yield obtained from IC-LRT were allocated into one of four groups. Breeds and milk yields of cows were used as a block.

An experiment was carried out as cross-over design with two periods to increase the number of replications. Allocation of animals into groups was performed with completely randomized block design. Each feed was consumed by 6 animals with this design. Potato pulp used in this experiment was obtained from Konya Seker Company Konya Seker Potato Starch product plant. Barley straw and wheat bran were bought from the market. Corn silage, alfalfa, grass hay, consantrated mixture were provided by International

**Table 1.** Mean of daily feed consumption on wet basis

| | Control | | 15% PPS | 30% PPS | 45% PPS | |
|---|---|---|---|---|---|---|
| **Corn Silage kg/d** | 18.0 | | 15.3 | 12.6 | 9.9 | |
| **Potato Pulp Silage kg/d** | - | | 2.7 | 5.4 | 8.1 | |
| **Grass Hay kg/d** | 2.2 | | 2.2 | 2.2 | 2.2 | |
| **Alfalfa Hay kg/d** | 2.2 | | 2.2 | 2.2 | 2.2 | |
| **Consantrate kg/d** | 11.0 | | 11.0 | 11.0 | 11.0 | |
| | | | | | | |
| **Consantrate** | **DM%** | | **OM%** | **CP%** | **NDF%** | **ADF%** |
| | 90.00 | | 92.89 | 16.85 | 27.60 | 9.73 |
| | | | | | | |
| **Consantrate %** | **B** | **WB** | **C SFM** | **SBM** | **DCP** | **VM** |
| | 52.4 | 10.0 | 11.010.0 | 13.0 | 1.0 | 2.6 |

B: barley, WB: wheat bran, C: corn, SFM: sun flover meal, DCP: di calcium phosphate, VM: vitamin-mineral.

Center for Livestock Research and Training (ICLRT) Department of Cattle Breeding. Nutrient components of these feedstuffs are given in Table 1.

All of the cows were treated with Dectomax® and Anaverm® to eliminate internal and external parasites just before initiation of the experiment. Animals were individually fed and had free access to clean water, vitamin and mineral block. Each period of experiement consisted of 21 days, 13 days of adaptation to diets and 8 days of sample collection periods.

Daily feed intakes of animals were determined at the first five days of the sampling period. After complete cleaning of feed bunkers, all animals were individually fed twice a day (08:00 am and 06:00 pm). Then, at the end of fifth day, remaining orts were collected, weighted and subsampled for analysis. At the end of each adaptation period, all the cows were milked twice a day (at 02:30 and 14:30) with mobile milking machine, the amount of milk produced per cow/ milking were measured and recorded to determine milk production throughout the sampling period. To determine the composition of milk, 1% of milk produced per day was composed at the last 4 days of the sampling period and then, 50 mL of milk was subsampled from the composted milk after through homogenization. Milk sample were kept at +4 C° and analyzed for fat, crude protein, lactose and dry matter using TEKA FOSS (Combi Foss$^{TM}$ FT+) at the end of each period. On the last day of sampling, rumen fluid was sampled at 0., 2., 4., 6. and 8. hours post-feeding from each animal and pH rumen fluid was immediately determined with a portable pH meter. After the pH determination, approximately 20 mL rumen fluid sample was added into sample tubes containing 2 mL 1/1 HCl (Absolute) and stored -18 °C for volatile fatty acid analysis.

To determine ruminal DM, OM, and starch degradability, 3 ruminally cannulated Holstein cattles were used. Approximately 3-4 g of dried silage samples with 2 mm particle size was introduced into Dacron bag with 45 µ pore size. Dublicate of each silage sample were placed into the ventral part of rumen of each animal for 0., 2., 4., 8., 12., 24. and 48. hours of incubation (Tuncer et al., 1989). After the removal of bags from rumen, bags were washed under running tap water until rinse water was clear, and then they were dried. DM, OM and starch content of residues were determined. Then, DM, OM, and starch degradability values of feeds were calculated with following equation: $a + b^{(1-e-ct)}$.

All the feedstuffs and part samples were analyzed to determine dry matter (DM), ash, crude protein (CP) according to AOAC (1990), NDF (Van Soest and Robertson, 1979), ADF (Goering and Van Soest, 1970) and starch (ISO, 2002) using the automatic polarimeter (WZZ-2B, China). While the pH of silage and rumen fluid were detected by a portable pH meter (Bingöl et al., 2008), organic acid contents of silage and rumen fluid were also determined using HPLC described by Tjardes et al. (2000). Silage and ruminal ammonia-N contents were determined by distillation method described by Filya (2003). *In vitro* OM digestibility of silage samples was also determined based on Tilley and Terry (1963) modified by Marten and Barnes (1979) using the Daisy$^{II}$ incubator (ANKOM®, USA).

Milk samples were analyzed at Ankara Cattle Breed Association milk analysis laboratory using TEKA FOSS analysis machine.

Data on *in situ* degradation were analyzed as a completely randomized design using variance analysis of SAS (1995).

Animal performance trial was analyzed as Cross-over design. In this trial,12 cows were randomly allotted in 4 groups within 2 periods using breed and milk yield as a block. Data were then analyzed according to the model shown below. In this model, factors A, B, C and D were group, cows, period and order, respectively. The fixed factors were A, C and D and the random factor was B. Then, the model was:

$$Y_{ijkl} = \mu + A_j + B_{i(l)} + C_k + D_l + E_{ijkl}$$

Where:

$Y_{ijkl}$ = observation on cow i in trial j, period k and order l.

( i=1,2,3,4; j=1,2,3,4; k=1,2 ve l=1,2)

$\mu$ = the overall mean.

$A_j$ = the fixed effect of trial j.

$B_{i(l)}$ = the random effect of subject (cow i) nested in order l.

$C_k$ = the fixed effect of period k.

$D_l$ = the fixed effect of order l.

$E_{ijkl}$ = random error.

Mixed procedure of (proc mixed) of SAS v8.2 was used for statistical analysis. Tukey test was used to seperate the means. The statistical significance was considered at P<0.05 level.

**Results**

Nutrient contents, *in vitro* digestibilityand energy values of silages are given at Table 2. While DM, OM and CP contents of silages were statistically similar, starch content, *in vitro* OM digestibility, ME and $NE_L$ values were significantly higher in PPS compared with corn silage (P<0.05). However, both NDF and ADF contents of corn silage were significantly higher than those of PPS (P<0.05).

**Table 2**. Means of (± SE) nutrient composition, fermentation parameters, in vitro digestibility and energy values of silages

| Items | Corn Silage | Potato Pulp Silage | P |
|---|---|---|---|
| **DM** | 28.65±0.66 | 29.26±0.07 | 0.89 |
| **CA,%DM** | 5.85±0.30 | 5.45±0.22 | 0.78 |
| **OM,%DM** | 94.15±0.30 | 94.55±0.22 | 0.78 |
| **CP,%DM** | 8.54±0.19 | 7.97±0.11 | 0.62 |
| **Starch,%DM** | 16.52±1.49 | 39.45±0.73 | 0.01 |
| **NDF,%DM** | 54.61±0.88 | 32.07±4.13 | 0.01 |
| **ADF,%DM** | 28.72±0.88 | 17.15±2.15 | 0.01 |
| **Fermentation Parmeters** | | | |
| **pH** | 4.09±0.01 | 4.08±0.01 | 0.98 |
| **LA** | 5.43±0.13$^{b}$ | 6.012±0.17$^{a}$ | 0.04 |
| **AA** | 2.62±0.07 | 0.93±0.012 | 0.01 |
| **PA** | 0.65±0.04$^{a}$ | 0.01±0.01$^{c}$ | 0.01 |
| **BA** | - | - | 1.0 |
| **Ammonia-N** | 0.54±0.02 | 0.46±0.06 | - |
| **Digestibility and Energy Values** | | | |
| **IVOMD,%OM** | 58.13±0.59 | 77.29±0.148 | 0.01 |
| **ME, Mcal/kg** | 2.56±0.026 | 3.41±0.01 | 0.01 |
| **$NE_L$, Mcal/kg** | 1.30±0.02 | 1.77±0.01 | 0.01 |

DM: Dry Matter, CA: Crude Ash, OM: Organic Matter, CP: Crude Protein, ADF: Acid Detergent Fiber, NDF: Neutral Detergent Fiber, IVOMD: In vitro Organic Matter Digestibility, ME: Metabolisable Energy, $NE_L$: Net Energy for Lactation, LA: Lactic Acid, AA: Acetic Acid, PA: Propionic Acid, BA: Butyric Acid, AMN: Ammonia Nitrogen.

Silage fermentation parameters are shown at Table 2. Silage pH and ammonia-N levels were similar between two silages (P>0.05). Whereas lactic acid content was higher acetic acid, the propionic acid level was less in PPS compared with corn silage (P<0.05).

In situ OM and starch degradibilities and fractions of silages are presented at Table 3 and 4, respectively. Potato pulp silage had sigificanly higher both OM and starch degradibilities after 48 h incubation than corn silage (P<0.05). Corn silage had significanly higher water soluable degredable organic matter (WSOM), water soluable starch (WSS), non-degredable starch (NDS) and non-degredable organic matter (NDOM) contents than potato pulp silage, but potential degredable organic matter (PDOM)and potential degredable starch (PDS)contents were significanly greater in potato pulp silage compared with corn silage (P<0.05).

Daily DM, OM, and CP intakes were statistically similar (P>0.05), but numerically decreased as the percentages of PPS increased in the diets (Table 5). Cows fed 45% PPS in their diet consumed 1.58 kg less daily DM compared to cows fed a control diet.

**Table 3.** Means of organic matter and starch degradable of silages

| Groups | 0. hours | 2. hours | 4. hours | 8. hours | 12. hours | 24. hours | 48. hours |
|---|---|---|---|---|---|---|---|
| Organic Matter Degradability, %OM | | | | | | | |
| **Corn Silage** | 34.09±1.01 | 30.99±1.41 | 28.91±1.05 | 36.02±1.31 | 43.04±1.02 | 56.10±1.85 | 68.87±1.40 |
| **Potato Pulp Silage** | 32.55±1.00 | 32.97±1.4 | 32.16±0.93 | 47.37±1.04 | 56.37±4.07 | 71.75±2.19 | 82.32±0.83 |
| **P** | 0.31 | 0.47 | 0.07 | 0.01 | 0.01 | 0.01 | 0.01 |
| Starch Degradability, %Starch | | | | | | | |
| **Corn Silage** | 59.50±0.66 | 51.87±1.00 | 64.32±0.53 | 66.07±0.70 | 82.41±0.31 | 90.80±0.40 | 90.87±0.44 |
| **Potato Pulp Silage** | 35.42±0.95 | 33.67±1.43 | 38.24±0.85 | 58.83±0.84 | 70.12±2.76 | 92.85±0.56 | 96.87±0.15 |
| **P** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 |

**Table 4.** Means of organic matter and starch fractions of silages

| Groups | Water Soluable | Potential Degradable | None Degradable |
|---|---|---|---|
| | | **Organic Matter, %OM** | |
| **Corn Silage** | 34.09±1.076 | 34.78±1.213 | 31.13±1.402 |
| **Potato Pulp Silage** | 32.55±1.001 | 49.77±0.913 | 17.68±0.829 |
| **P** | 0.53 | 0.02 | 0.01 |
| | | **Starch % Starch** | |
| **Corn Silage** | 59.50±0.66 | 30.84±0.76 | 9.65±0.44 |
| **Potato Pulp Silage** | 35.42±0.95 | 61.26±0.95 | 3.31±0.15 |
| **P** | 0.01 | 0.01 | 0.01 |

**Table 5.** Means of daily nutrient consumption of different level PPS consumpted cattles, kg/day

| | DM(kg) | OM | CP | NDF | ADF | DMBW (%) |
|---|---|---|---|---|---|---|
| **Control** | 20.02±1.38 | 18.6±1.28 | 2.74±0.17 | 7.64±0.59 $^{a}$ | 3.94±0.33 $^{a}$ | 3.03±0.25 |
| **15% PPS** | 21.28±0.59 | 19.77±0.54 | 2.87±0.08 | 8.01±0.22$^{a}$ | 4.17±0.11 $^{a}$ | 3.19±0.21 |
| **30% PPS** | 20.66±0.62 | 19.19±0.57 | 2.79±0.09 | 7.54±0.22 $^{a}$ | 3.91±0.11 $^{a}$ | 3.08±0.18 |
| **45% PPS** | 18.44±1.38 | 17.14±1.29 | 2.51±0.17 | 6.54±0.51$^{b}$ | 3.38±0.28 $^{b}$ | 2.72±0.20 |
| **SEM** | 1.0527 | 0.9791 | 0.1306 | 0.4161 | 0.2254 | 0.2173 |
| **P** | 0.26 | 0.26 | 0.23 | 0.07 | 0.08 | 0.48 |

Control: 0% PPS, Group 1: 15% PPS, Group 2: 30% PPS, Group 3: 45% PPS (PPS: Potato Pulp Silage, DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, NDF: Neutral Detergent Fiber, ADF: Asit Detergent Fiber, DMBW: Dry Matter Body Weight rate).
$^{a,\ b}$: The different letter in same colomn indicates that statistically difference (p<0.05).

Similarly, daily NDF (P=0.07) and ADF (P=0.08) intakes tended to decrease as the percentages of PPS increased in the diets.

Daily milk yields and milk compositions are shown at Table 6. Daily milk yield did not change with the addition of PPS into a control diet (P>0.05). Daily milk yield was around 22 L for all the groups. The composition of milk was also similar among treatment groups (P>0.05). While the percentages of milk fat were 3.99, 4.38, 4.33, and 3.73%, the percentages of milk DM were 13.11, 13.50, 13.52, and 12.89% for corn silage, 15, 30, and 45% PPS groups, respectively.

Post-feeding pH's of ruminal fluids were similar at all sampling hours (P>0.05) (Table 7), except 6$^{th}$ h post-feeding. pH values did not drop below 6 in any group and at any sampling hours. Ruminal ammonia-N con-

**Table 6.** Means of milk yield, L and milk components, DM% of different level potato pulp silage consumpted cattle

| | Groups | | | | | |
|---|---|---|---|---|---|---|
| | Control | 15% PPS | 30% PPS | 45% PPS | SEM | p |
| **Daily Milk Yi-eld** | 21.95±2.04 | 22.05±1.6 | 21.95±1.61 | 21.92±1.88 | 1.8075 | 0.99 |
| **Milk Fat** | 3.99±0.193 | 4.38±0.339 | 4.33±0.356 | 3.73±0.206 | 0.2891 | 0.38 |
| **Protein** | 3.32±0.229 | 3.40±0.149 | 3.46±0.134 | 3.32±0.200 | 0.1867 | 0.94 |
| **Lactose** | 5.26±0.196 | 5.34±0.189 | 5.32±0.153 | 5.34±0.315 | 0.1647 | 0.98 |
| **Dry Matter** | 13.11±0.407 | 13.50±0.500 | 13.52±0.500 | 12.89±0.51 | 0.4743 | 0.74 |
| **Urea** | 25.22±3.91 | 23.17±2.20 | 23.9±1.60 | 24.28±1.97 | 2.1807 | 0.95 |
| **Non fat Dry Matter** | 9.02±0.287 | 9.03±0.196 | 9.09±0.188 | 9.05±0.300 | 0.2519 | 0.99 |

PPS: Potato Pulp Silage.

**Table 7.** Means of (± SE) volatile fatty acid, pH and ammonia nitrogen values of received different hours ruminal fluid of different level potato pulp silage consumpted cattles, mg/dL

| | VFA | Control | 15% PPS | 30% PPS | 45% PPS | SEM | P |
|---|---|---|---|---|---|---|---|
| **0. Hours** | Total | 52.08±10.17 | 53.8±5.79 | 55.13±7.82 | 51.52±9.03 | 8.0665 | 0.17 |
| | AA | 64.99±3.81 | 64.12±4.02 | 52.74±4.41 | 59.26±1.94 | 3.7352 | 0.11 |
| | PA | 20.15±2.87 | 21.91±4.20 | 32.01±4.12 | 23.33±2.89 | 3.6179 | 0.10 |
| | BA | 14.71±1.24 | 13.62±2.07 | 13.88±1.27 | 17.00±1.81 | 1.6765 | 0.49 |
| | pH | 7.40±0.285 | 7.68±0.236 | 7.45±0.345 | 7.40±0.179 | 0.2634 | 0.85 |
| | Ammonia-N | 19.78±2.56 | 22.31±2.11 | 21.20±3.05 | 20.70±1.55 | 2.1596 | 0.46 |
| **2. Hours** | Total | 64.65±7.74[a] | 72.8±1.53[a] | 56.67±4.48[b] | 63.42±2.73[a] | 4.8163 | 0.04 |
| | AA | 63.35±3.36 | 58.8±3.47 | 59.41±3.77 | 62.07±1.19 | 2.9823 | 0.67 |
| | PA | 22.29±3.09 | 22.08±1.43 | 23.19±3.17 | 21.88±2.4 | 2.6056 | 0.99 |
| | BA | 12.68±0.72 | 14.59±0.77 | 13.27±1.94 | 15.40±1.64 | 1.3827 | 0.51 |
| | pH | 6.88±0.250 | 6.60±0.124 | 7.06±0.190 | 6.88±0.050 | 0.1713 | 0.13 |
| | Ammonia-N | 22.71±2.94 | 28.14±1.90 | 21.75±2.13 | 23.78±2.84 | 1.7588 | 0.10 |
| **4. Hours** | Total | 65.2±5.55 | 70.68±19.18 | 70.34±18.20 | 64.38±5.87 | 14.1809 | 0.98 |
| | AA | 62.75±2.90 | 58.46±8.19 | 59.09±8.76 | 61.45±2.26 | 6.4292 | 0.95 |
| | PA | 22.71±3.93 | 19.64±5.67 | 18.64±5.14 | 21.51±3.97 | 4.8165 | 0.99 |
| | BA | 14.14±1.81 | 20.72±9.18 | 20.3±8.50 | 13.70±2.10 | 6.5774 | 0.81 |
| | pH | 6.77±0.156 | 7.12±0.365 | 7.00±0.463 | 6.60±0.153 | 0.3213 | 0.68 |
| | Ammonia-N | 24.24±2.71 | 27.21±2.80 | 28.42±3.06 | 24.08±2.90 | 2.8889 | 0.19 |
| **6. Hours** | Total | 59.23±4.62 | 74.3±7.58 | 74.76±8.35 | 59.96±4.82 | 6.7411 | 0.11 |
| | AA | 60.98±2.58 | 60.6±3.40 | 60.51±3.59 | 61.52±2.18 | 3.0642 | 0.99 |
| | PA | 24.31±3.14 | 24.96±3.39 | 24.69±3.80 | 23.48±3.43 | 3.5342 | 0.99 |
| | BA | 14.17±1.87 | 11.48±2.49 | 10.70±2.11 | 13.99±1.86 | 2.1452 | 0.45 |
| | pH | 6.30±0.113[b] | 6.47±0.080[b] | 6.27±0.080[b] | 7.02±0.182[a] | 0.1155 | 0.01 |
| | Ammonia-N | 17.79±1.92 | 16.74±1.04 | 16.45±1.12 | 16.31±1.61 | 1.4922 | 0.89 |
| **8. Hours** | Total | 51.33±9.46 | 52.75±5.45 | 74.57±8.4 | 50.56±8.71 | 7.9408 | 0.15 |
| | AA | 61.86±3.28 | 63.24±4.30 | 52.78±4.02 | 58.16±2.1 | 3.5918 | 0.14 |
| | PA | 20.16±2.61[b] | 21.64±3.18[b] | 31.63±3.39[a] | 23.89±3.43[b] | 3.1678 | 0.06 |
| | BA | 15.58±0.55 | 14.47±1.87 | 13.28±1.47 | 17.54±2.06 | 1.5846 | 0.32 |
| | pH | 7.10±0.268 | 7.43±0.191 | 7.28±0.336 | 7.08±0.192 | 0.2525 | 0.73 |
| | Ammonia-N | 18.65±1.93 | 20.90±1.68 | 20.85±2.24 | 20.15±1.55 | 1.8063 | 0.13 |

PPS: Potato Pulp Silage.
VFA: Volatile Fatty Acid, AA: Acetic Acid, PA: Propionic Acid, BA: Butyric Acid,
[a, b]: The different letter in same row indicates that statistically difference (p<0.05)

centrations were also similar among groups at all sampling hours (P>0.05). Typically, ruminaly amonia-N concentrations increased 2 to 4 h post-feeding and then, dropped slowly later on (Table 7).

Post-feeding ruminal total volatile fatty acid concentrations and the percentages of volatile fatty acids in total concentrations are presented at Table 7. Total volatile fatty acid concentrations varied from 50.56 to 74.76 mg/dL. The percentages of acetic acid, propionic acid and butyric acid ranged from 52.74, 18.64, and 10.70 to 64.99, 32.01, and 20.72%, respectively, for all groups and sampling times. Amounts of total fatty acids were generally similar among groups at all sampling hours (P>0.05), except 2 h post feeding. Percentages of volatile acids were also similar in general (P>0.05), except the percentage of propionic acid 8 h post-feeding.

**Discussion and Conclusion**

The main objective of this study was to compare the silage quality of PPS with corn silage and effects of substituting it at differing levels with corn silage in dairy animal performance.

Since the DM content of potato pulp was tried to be made equal to that of corn silage, DM contents of silages were similar. Dry matter contents were at the lower edge of DM necessary for ideal silage making (Yaylak and Alçiçek, 2004). Dry matter content of PPS silage was lower than that of Pen et al. (2005) but similar to Sugimato et al. (2008) and Zhang et al. (2012). It seemed that DM content of PPSwas closely correlated to the level of other feedstuffs added into silage as moister absorbent. Organic matter content of silages was similar. Organic matter content of PPS was also similar with Sugimato et al. (2008), Sugimoto et al. (2009) and Sugimoto et al. (2010) but lower than that of Zunong et al. (2009). It was thought that these differences may have resulted from contamination with soil and ash content of other feedstuffs used in silage making. Crude protein contents did not differ between silages. CP content of PPS was close to that of Zhang et al. (2012) but higher than those of Sugimoto et al. (2007) (potato pulp silage without any material), Okine et al. (2005) and Zunong et al. (2009). The CP content of PPS depends on mainly CP content of other material added into silage. In the current study, wheat bran increased CP content of PPS. While starch content was significantly higher, both NDF and ADF contents were significantly less in PPS silage compared with corn silage (P<0.05). Both NDF and ADF values observed for PPS in the current study were lower that of Zhang et al. (2012). Nutrient contents of potato pulp silages mainly depend on two things; one is starch levels of potato pulp and the second is the nutrient content of other material added into silage. The differences in the nutrient contents of PPS in the literature might have been resulted from these two factors. In the current study, it seemed that the starch level of potato pulp was high as it can be understood from the starch level of PPS so that PPS in the current study had very desirable nutrient content as a silage.

*In vitro* OM digestion and energy values were significantly lower in corn silage than PPS (P<0.05). Whereas *in vitro* OMD was 58.13% in corn silage, it was 77.29% in PPS (Table 2). Since energy values were calculated from *in vitro* OM digestibilities, they showed a similar pattern with *in vitro* digestibility. In this study, the OMD value of PPS was similar with that of Zunong et al. (2009), but higher than that of Nicholson and Friend (1965). Mohamadian et al. (2016) has reported that the OMD value of PPS without any moisture absorbents was 75.84%, the OMD values of PPS prepared with different moisture absorbents ranged from 73.08% to 54.48%. The differences in OMD of PPS are more likely due to the starch content of potato pulp and the nature of feed stuffs used as moister absorbant in PPS. A very high ME (13,24 MJ/kg DM) and NEL (8,56 MJ/kg DM) values has been reported for potato pulp (Kara et al., 2018), which supports the energy values obtained for PPS in the current study.

Silage pH values were similar between the two silages (P>0.05). These pH values were fairly close to pH values reported for PPS by Sugimoto et al. (2007; pH: 3.5 - 4), Sugimoto et al. (2008; pH: 4) and Zhang et al. (2012; pH: 3.9 - 4). The pH values observed in the current study were 4.08 and 4.09 for potato pulp and corn silages, respectively, which were in the range of ideal pH values of 3.8 - 4.2 for good silage fermentation (Ergün et al., 2002).

Among silage fermentation parameters, the concentration of lactic acid was higher but the concentrations of acetic and propionic acids were lower in PPS compared with corn silage (P<0.05). There was no butyric acid in both silages. It seemed that while PPS had more homo fermentative fermentation with high lactic acid and very low acetic acid production, corn silage had hetero-fermentative fermentation (Muck, 2002). The lack of butyric acid in both silages indicated a good silage fermentation as well. The silage ammonia nitrogen, an indication of soluble CP content, was similar in two groups (P>0.05), which were less than the values reported by Zhang et al. (2012) for potato pulp silage and by Baytok et al. (2005) for corn silage.

Both in situ OM and starch degradability values of PPS after 48 hours ruminal incubation were higher compared with corn silage (P<0.05). In situ OM and starch degradabilities for corn and potato pulp silage were 68.87 vs. 82.32% and 90.35 vs. 96.69%, respectively. Similarly, very high DM degradability values for PPS have been reported in the literature (Sugimato et al., 2006; Sugimato et al., 2007; Sugimato et al., 2008; Zunong et al., 2009; Sugimato et al., 2010). A higher *in vitro* OM digestibility values observed in the current study also supported the results of in situ OM and starch degradability values.

The OM and starch fractions were significantly different between the two silages. While the water soluble and non-degradable OM and starch fractions were higher, the potentially degradable OM and starch fractions were significantly less in corn silage compared with PPS (P<0.05). These differences were much greater in starch, which may have resulted from differences in the type of starch and the heat applied to potato during starch producing process to starch of PPS.

Substituting corn silage with increasing percentages of PPS in diet did not statistically affect daily nutrient intake in dairy cattles (P>0.05). Only daily NDF (P=0.07) and ADF (P=0.08) consumptions tended to be less in cows fed 45% PPS compared with cows fed corn silage. While cows fed 15% PPS had the highest DM consumption (21.28 kg) and cows fed 45% PPS had the lowest DM consumption (18.44 kg). Cows fed 45% PPS consumed 1.58 kg less DM compared with cows fed corn silage. Addition of PPS as energy source to a diet of dairy cows did not affect DMI of animal (Okine et al., 2005), which supports the results of the current study. The less daily NDF and ADF consumptions in cows fed 45% PPS were due to lower DMI and NDF and ADF contents of diet cows fed 45% PPS.

Daily milk yields and milk compositions were similar among dairy cows fed on different diets (P>0.05). Substitution of corn silage with PPS did not cause any significant effect neither on daily milk yield nor milk components (P>0.05). Daily milk yields were 21.95, 22.05, 21.95 and 21.92 L/day of cows fed 0, 15, 30, 45% PPS containing diet, respectively. Addition of PPS up to 30% into control diet numerically improved milk fat, milk protein, milk lactose and total DM contents but the addition of 45% PPS to the control diet decreased the milk fat content. This decrease in milk fat might have resulted from less daily NDF consumption of cows fed 45% PPS containing diet compared with other groups. Replacing barley or corn with PPS in diet did not alter (Schneider et al., 1985; Zunong et al., 2009) daily milk yield of dairy cows. It is well known that milk yield is more ralated with the genetics of animals. If animals have a good genetic potential, which can be accomplished with appropriate feeding (Ünalan and Cebeci, 2004). In this case, cows seemed to give optimal milk yield because cows fed 45% PPS diet produced the same milk yield, but dropped fed intake compared with cows fed control diet. If they have more potential they can produce more milk and consume a little bit more DM.

Substitution of corn silage with PPS did not generally alter the pos-feeding ruminal pH values of dairy cows. Ruminal pH values never dropped below 6.27 at any sampling hours/groups, which were well-above the critical value of 5.5 for ruminal asidosis (Öztürk and Pişkin, 2009). Similar ruminal pH values have been reported for cows fed on PPS (Sugimato et al., 2006; Sugimato et al., 2008; Sugimato et al., 2010).

Post-feeding ruminal ammonia-N levels were statistically similar among groups (P>0.05). In general, while ruminal ammonia-N levels were the highest at 2-4 h post-feeding it was the lowest at 6 h post-feeding. The lowest ammonia-N was 16.31 mg/dL among all groups and sampling hour, which were well-above the critical level of 5 mg/dL for optimal microbial protein synthesis in the rumen (Satter and Slyter, 1974).

In general, post-feeding ruminal volatile fatty acid concentrations of cows fed on a different diet were similar (P>0.05), except 2-h post-feeding. Generally, 0-h post feeding total VFA concentrations were the lowest in all groups, increased with feeding and then, came close back to starting levels (0-h post-feeding level) at 8-h post-feeding. Even though these increases were statistically similar among all groups and hours (P>0.05) only total VFA level was significantly lower 2-h post-feeding in cows fed 30% PPS compared with other groups (P<0.05). The percentages of acetic acid, propionic acid and butyric acid were generally similar among groups (P>0.05), except 8-h post feeding propionic acid levels. Especially, percentages of acetic acid and propionic acid levels are very important for the synthesis of milk fat and lactose in a dairy cow (Tekce and Gül, 2014). The percentages of acetic acid and propionic acid ranged from 52.74 and 18.64 to 64.99 and 32.01%, respectively, for all groups and sampling times, which were at desirable levels for ideal milk fat and lactose synthesis. Sugimoto et al. (2006), Sugimoto et al. (2008) and Sugimoto et al. (2010) have reported the rather low total VFA, propionic and butyric acid levels, but higher acetic acid level compared with the results of the present study. The differences between these studies might have resulted from the carbohydrate contents of the total ration used in these experiments.

It can be concluded that PPS prepared with wheat bran and barley straw offers a very good silage quality, even better than corn silage. Substitution of corn silage with PPS up to 45% did not cause any negative effects but resulted in some positive effects on animal performance. Although cows fed PPS had 1.58 kg/day lower dry matter consumption than cows fed corn silage, there was no difference in milk yield. Substution of corn silage with PPS did not cause any changes at the rumen fermentation parameters in dairy cows. Therefore, corn silage can be substituted by PPS upto %45 in dairy cow diets.

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