

## Effects of Cultivars on Ensiling Characteristics, Chemical Composition, and Ruminal Degradability of Pea Silage

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### ABSTRACT

A study was conducted to determine the effects of cultivar on ensiling characteristics, chemical composition and ruminal nutrient degradability of pea (*Pisum sativum* L.) silage. The cultivars evaluated were Lenca (L), Carneval (C), and Delta (D). Peas were field-grown and forage was harvested and ensiled in mini-silos for 0, 2, 4, 8, 16, and 70 d. The ensiled forage of all cultivars went through a rapid fermentation with a sharp reduction in pH during the first 2 days of ensiling. Extensive proteolysis took place between 0 and 2 d as indicated by a reduction in true protein and neutral detergent insoluble protein (NDICP) and an increase in nonprotein nitrogen. Chemical analysis of the 70 d silage showed that cultivar L contained higher neutral detergent fiber (NDF) and acid detergent fiber and lower starch levels than C and D. Crude protein was highest for C (20.5% DM), intermediate for D (19.0% DM) and lowest for L (17.9% DM). Distribution of protein fractions showed that L contains lower soluble protein and higher NDICP levels than the other two pea cultivars. However, no difference in acid detergent insoluble protein levels was observed between the three cultivars. Results of the in situ incubation experiment indicated that L had lower ruminal DM (69.2 vs 74.0%) and CP (84.1 vs 90.6%) degradabilities than C or D. However, ruminal degradability of NDF was similar among the three cultivars (average of 32.9%). It was concluded that chemical composition and ruminal nutrient degradability of pea silage are significantly influenced by cultivars.

**(Key words:** chemical composition, ensiling characteristics, pea silage, ruminal degradability)

**Abbreviation key:** ADICP = acid detergent insoluble CP, C = Carneval, D = Delta, IVDMD = in vitro dry

matter disappearance, L = Lenca, NDICP = neutral detergent insoluble CP, SCP = soluble protein, TP = true protein.

### INTRODUCTION

Forages are a major constituent of dairy and beef cattle diets. In Canada, corn and barley silages are the most common cereal silages, while alfalfa silage is the main legume silage. Alfalfa silage contains more protein and less fermentable carbohydrates relative to cereal silages, due to its low starch content (Khorasani et al., 1993; Mustafa et al., 2000). Other legume forages such as peas can be ensiled to provide a source of both protein and starch (Mustafa et al., 2000). Annual forage species can be used as emergency crops when perennial forages stands have been winterkilled. Furthermore, they represent a viable means of providing feed on a short-term basis and can replace summer fallow in crop rotations. Field peas are annuals that fit well into short crop rotations, and may tolerate specific climatic and soil conditions better than other commonly used legume species such as alfalfa.

The nutritional value of alternative forages must be evaluated to determine whether they are viable alternatives to conventional forages. Data on the feeding value of pea silage for ruminants are limited. Pea silage has been feed to dairy (Mustafa et al., 2000) and beef cattle (Wielgosz et al., 2000). These studies showed that ruminal and total tract nutrient digestibilities of pea silage were similar to alfalfa silage but higher than barley silage. Due to the wide variation in nutrient composition of field pea cultivars (Christensen et al., 1998), it is expected that cultivars will affect ensiling characteristics and the feeding value of pea silage. Information on the chemical composition and ruminal degradability of pea silage produced from different cultivars is not available. Therefore, our objective was to determine the variation in ensiling characteristics, chemical composition, and ruminal degradability of pea silage as affected by cultivars.

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## MATERIALS AND METHODS

### Forage Material and Ensiling

Field peas cultivars Lenca (**L**), Carneval (**C**), and Delta (**D**) were sown on 20 May 2001 in Ste Anne-de-Bellevue, QC, Canada, on a Chicot fine sandy loam. Seeding was done in 20 × 30 m plots at a rate of 127 kg·ha<sup>-1</sup>. Field plots were arranged in a randomized complete block design with three replications. Forages were harvested at full-pod stage (20 July 2001) and chopped to a theoretical cut length of 25 mm using a flail forage harvester. The harvested forages were wilted to a targeted 30% DM content. Representative herbage samples (1000 g) of the three pea varieties were packed manually using a pestle (Sebastain et al., 1996), in triplicates, into mini silo made of PVC tubing (7.6 cm diameter and 25 cm height; capacity one kg). The filled silos were sealed with plastic lids equipped with gas valves, stored at ambient temperature and allowed to ensile for 2, 4, 8, 16 and 70 d. Triplicate samples of fresh forage (0 d after ensiling) from each cultivar were also stored at -20°C. Dry matter losses during the fermentation and the storage phases were estimated by weighing the mini silo before and after the 70-d ensiling period.

### Laboratory Chemical Analyses

After the designated ensiling time, silos were opened and the ensiled forage was mixed thoroughly. Twenty-five grams of the fresh and the ensiled forages were homogenized for 1 min in 250 ml of distilled water. The pH of the water extract was immediately determined using a Accumet pH meter (Denver Instrument Company, Mansfield, TX). A portion of the extract (20 ml) was filtered through a Whatman 54 filter paper, acidified with 50 µl of 50% H<sub>2</sub>SO<sub>4</sub> and frozen before further analysis. One ml of each filtered and acidified water extract was combined with 200 µl of 25% metaphosphoric acid containing isocaproic acid as an internal standard. Samples were centrifuged for 15 min at 10,000 × g and analyzed for acetic, propionic, and butyric acids by gas chromatography (Varian model 3400; Varian Canada Inc., Ville St-Laurent, QC, Canada) equipped with a 30-m capillary column (Stabilwax-DA, 0.53 mm ID; Restek Corporation, Bellefonte, PA). Initial column temperature was set at 80°C for 30 s, then temperature was increased at the rate of 15°C per minute until it reached 180°C; this temperature was maintained for 1 min. Therefore, run time was 8.16 min. Injector and detector temperatures were 250 and 300°C, respectively. Gas flows were 30, 300 and 30 ml/min for He, air and H<sub>2</sub>, respectively. Volume of sample injected was

0.4 µl. Lactic acid was determined following the procedure of Barker and Summerson (1941).

Subsamples (500 g) of the fresh (0 d) and the ensiled forages (2, 4, 8, 16, and 70 d) were also dried in a forced-air oven at 55°C for 48 h and then ground through a 1-mm screen using a Wiley Mill (A.H. Thomas, Philadelphia, PA). Ground forage samples were analyzed for moisture, CP (Kjeldahl nitrogen × 6.25), and ADF according to the procedures of the AOAC (1990). NDF was determined without the use of sodium sulfite and with the inclusion of heat stable α-amylase (Van Soest et al., 1991). Neutral (**NDICP**) and acid (**ADICP**) detergent insoluble CP were determined by analyzing NDF and ADF residues for Kjeldahl nitrogen (Licitra et al., 1996). NPN and soluble protein (**SCP**) were determined according to the procedures of Licitra et al. (1996). True protein (**TP**) content of the silages was estimated according to Sniffen et al. (1992).

Samples of the fresh forages and the 70 d silage were also analyzed for ash, ether extract, acid detergent lignin (AOAC, 1990), and starch (McCleary et al., 1997). True protein of the 70 d silage was further partitioned into rapidly (B1), intermediately (B2), and slowly (B3) degradable fractions (Sniffen et al., 1992). In vitro DM disappearance (**IVDMD**) of the 70 d silage was determined using the DAISY<sup>II</sup> (ANKOM Technology, Fairport, NY) apparatus and following the two-stage procedure as described by Holden (1999).

### In Situ Ruminant Degradability

Equal portions (200 g) of the three replicates of the dry 70 d silage were composited to obtain a single sample for each cultivar. Quadruplicate samples weighing approximately 5 g (air dry basis) of each cultivar were weighed into nylon bags (10 × 20 cm, ANKOM Technology). The nylon bags were then incubated into the rumens of two lactating Holstein cows (two bags per time period per cow) fitted with flexible rumen cannulas for 0, 6, 12, 24, 48, 72, and 96 h. The cows were fed a 50:50 forage:concentrate diet which consisted (DM basis) of 20% corn silage, 20% alfalfa silage, 10% brome hay, and 50% concentrate mixture. The composition of the TMR was of 6.9% ash, 2.5% ether extract, 17.9% CP, 16.2% ADF, and 29.6% NDF. At the end of each incubation time, bags were removed from each cow and washed under cold tap water until the rinsing water was clear. Zero-h disappearance was estimated by washing duplicate bags containing samples of the three cultivars.

Residues from the nylon bags at each incubation time were analyzed for DM, CP, and NDF as described above. Ruminant nutrient disappearance data were used to determine nutrient degradation parameters using the

equation (Ørskov and McDonald, 1979) with the addition of a discrete digestion lag time (Khorasani et al., 1994):

$$P = a + b \times (1 - e^{-c(t-\text{lag})})$$

where P is the DM, CP, or NDF disappearance (%) at time t, a is the soluble fraction (%), b is the slowly degradable fraction (%), and c is the rate of degradation of the b fraction (%/h). Effective degradability (ED) of DM, CP, and NDF was then calculated according to the equation (Ørskov and McDonald, 1979):

$$ED = a + ((b \times c)/(k + c))$$

Where k is the rumen outflow rate assumed to be 5%/h and a, b, and c are as described above.

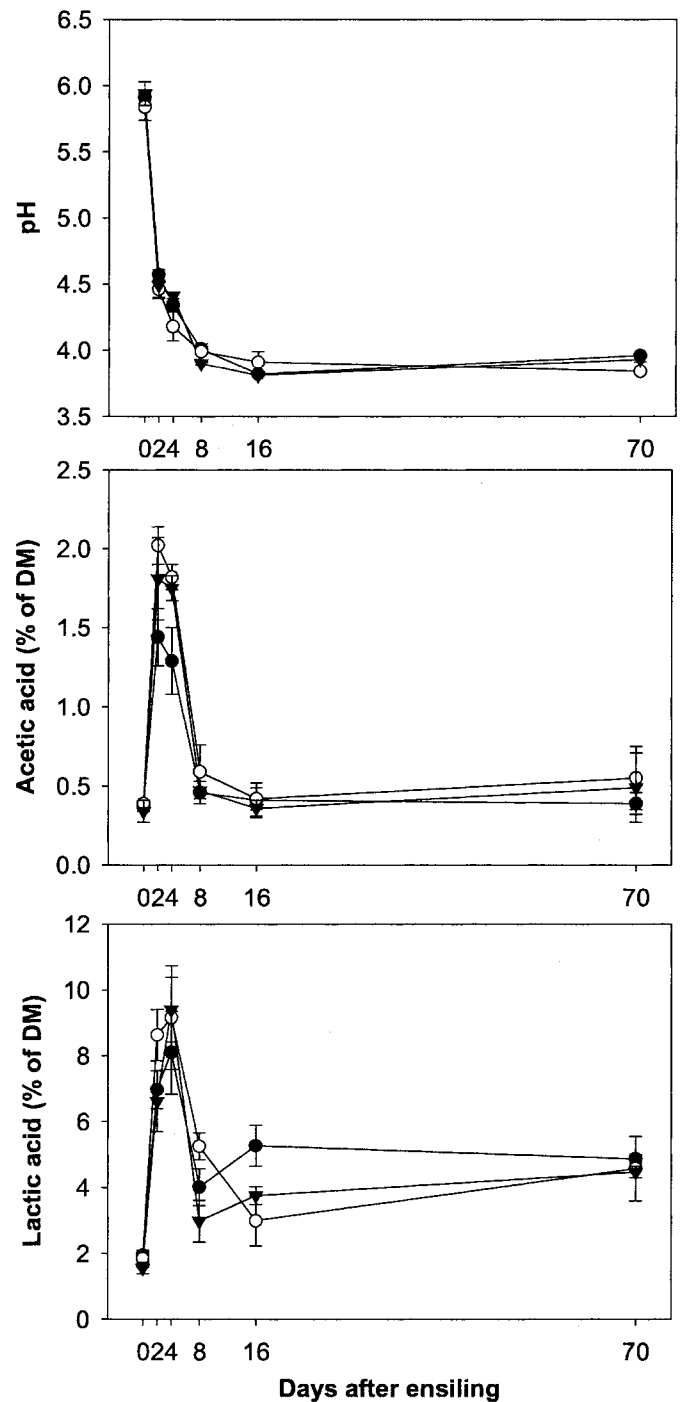
### Statistical Analyses

Statistical analyses were performed using the GLM procedure of SAS (1989). The study of chemical changes during ensiling was analyzed using a randomized complete block model with split plot restriction and 3 replications (Gomez and Gomez, 1984). Main plots were the pea cultivars, and subplots were the ensiling periods. When interactions were significant, data were also re-analyzed using a randomized complete block model for each ensiling period or pea cultivar. Chemical composition data of the 70 d silages were analyzed using a completely randomized model with 3 replications. Data from the in situ study were analyzed using a randomized complete block design with 3 replications and cows as blocks. When significant effects were detected ( $P < 0.05$ ), least significant difference was used to determine significant differences among means (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### Ensiling Characteristics of Pea Silage

Irrespective of pea cultivar, ensiled forages went through a rapid fermentation within 2 d of ensiling as indicated by the sharp drop in pH (Figure 1). There was an initial rapid decline ( $P < 0.05$ ) in pH for the three pea cultivars between d 0 and d 2 of fermentation. This was followed by a gradual decline ( $P < 0.05$ ) from d 2 to d 8 where pH fell below 4.0 by d 8 (Figure 1). The pH of the ensiled forages stabilized after d 8 and remained stable up to d 70. Differences in pH between the three ensiled forages at a given ensiling time were minimal and the 70 d silage of the three pea cultivars were all well preserved as indicated low pH values (Figure 1). The rapid decline in pH of the ensiled forage is



**Figure 1.** Changes in pH, lactic acid, and acetic acid of ensiled forage pea cultivars Lenca (●), Carneval (○), and Delta (▼). Vertical bars represent  $\pm$  SD.

likely the result of fermentation of water-soluble carbohydrates by acetic and lactic acid producing bacteria (Rooke et al., 1990; Davies et al., 1998). The general pattern in changes in pH reported this study is consis-

tent with changes observed for other ensiled forages such as perennial ryegrass (Davies et al., 1998) and Italian ryegrass (Zhu et al., 1999) silage.

Lactic and acetic acids were the main fermentation acids in all silage treatments regardless of the ensiling period (Figure 1). Propionic and butyric acids were generally undetectable across all treatments (data not shown). Lactic acid increased ( $P < 0.05$ ) up to d 4 postensiling, declined ( $P < 0.05$ ) sharply from d 4 to d 8, and then stabilized. The rapid drop in pH observed between d 0 and d 4 coincided with the peak in lactic acid. The reduction in pH that occurred between d 4 and d 8 postensiling was not paralleled by a similar reduction in lactic acid. Reasons for this discrepancy are not clear. A secondary fermentation by clostridia that ferment lactic acid to butyric acid may be one reason (Vetter and Von Glan, 1978). However, butyric acid was not detected in the silages of our study, thus clostridial fermentation cannot be implicated. Ward et al. (2001) indicated that acids other than butyric acid (i.e. isobutyric and isovaleric acid) could also result from secondary clostridial fermentation of lactic acid, however, these acids were not measured in our study. In agreement with our findings, Davies et al. (1998) found that lactic acid concentration of ensiled perennial ryegrass peaked at d 4 postensiling and then dropped between d 4 and d 14 postensiling, while pH continued to drop. Similar trends have also been reported by Kung et al. (2000). The changes in acetic acid concentration during ensiling were similar to those observed for lactic acid, but peaked at d 2 (Figure 1).

Under the conditions of the present study, it appears that there are small differences between the three pea cultivars in terms of ensiling parameters (pH, lactic acid, and acetic acid concentrations).

### Changes in Protein Fraction During Ensiling

There was significant ( $P < 0.05$ ) and rapid increase in SCP level from d 0 to d 4 postensiling for all cultivars (Figure 2). A further increase in SCP between d 8 and d 16 was observed for L and C, but not D. Changes in NPN level during ensiling were in general, similar to those reported for SCP (Figure 2). For all cultivars, there were no changes in SCP and NPN levels between d 16 and d 70. The increase in SCP levels during ensiling can be attributed mainly to increased levels of NPN. At any ensiling period, NPN constituted most of SCP (at least 85% of SCP) regardless of the cultivar (Figure 2).

Neutral detergent insoluble protein at any given ensiling time was similar for C and D but lower ( $P < 0.05$ ) than for L (Figure 2). Regardless of silage treatment, NDICP declined ( $P < 0.05$ ) sharply between 0 and 2 d postensiling. The magnitude of decline (37%) was simi-

lar for all cultivars. There were no changes in NDICP of the ensiled forages between d 2 and d 16. However, there was an increase ( $P < 0.05$ ) in NDICP between d 16 and d 70 for L but not for C and D. The reduction in the CP associated with NDF (i.e. NDICP) during ensiling is not a likely result of actual loss of carbohydrate fractions of NDF (i.e. cellulose and hemicellulose). This was supported by the fact that NDF corrected for associated CP was not affected by ensiling time averaging 37.7, 29.2, and 29.6% for L, C, and D, respectively. Our results may help to explain the small reduction in NDF content of forages as a result of ensiling (Kung et al., 1991; McAllister et al., 1995).

Changes in ADICP during the ensiling process were somewhat different from changes observed for NDICP (Figure 2). There was an increase ( $P < 0.05$ ) in ADICP for the three cultivars between d 0 and d 2 postensiling, followed by a decline ( $P < 0.05$ ) between d 2 and d 16. This decline continued until d 70 with L ( $P < 0.05$ ), but no further changes were observed for C and D. The TP fraction declined ( $P < 0.05$ ) rapidly between d 0 and d 2 for all cultivars (Figure 2). While the TP content of L was then stable, that of C and D further declined ( $P < 0.05$ ) between d 2 and d 4, and d 2 and d 16, respectively. No changes in TP fraction were observed between d 16 and d 70 for all cultivars.

The increase in SCP and NPN and the reduction in NDICP and TP between d 0 and d 2 postensiling suggest an extensive proteolysis of TP into nonprotein compounds during the early stage of ensiling. This is in good agreement with previous studies, which showed extensive proteolysis of forage protein during the first few days of ensiling due to the action of plant enzymes collectively known as proteases (Ohshima and McDonald, 1978; Papadopoulos and Mckersie, 1983; Mckersie, 1985; Heron et al., 1986). Heron et al. (1989) indicated that most proteolytic activity during ensiling occurs within a relatively short period of time followed by a longer period of much reduced activity. It appears that most of the proteolytic activity takes place within the first 2 d postensiling, suggesting that proteases in pea forage behave in a similar manner to those found in other forages such as alfalfa and red clover (Papadopoulos and Mckersie, 1983). Reasons for the short-term proteolysis during ensiling are not clear. However, Mckersie and Buchanan-Smith (1982) indicated that the cessation of proteolysis in alfalfa silage after few days of ensiling was not due to loss of enzyme activity and that pH was not inhibiting. Other factors, such as availability of substrate and end product inhibition, are thought to be responsible (Heron et al., 1989).

The condition of the forage at the time of ensiling as affected by forage species, DM content and initial pH significantly influences the extent of proteolysis that

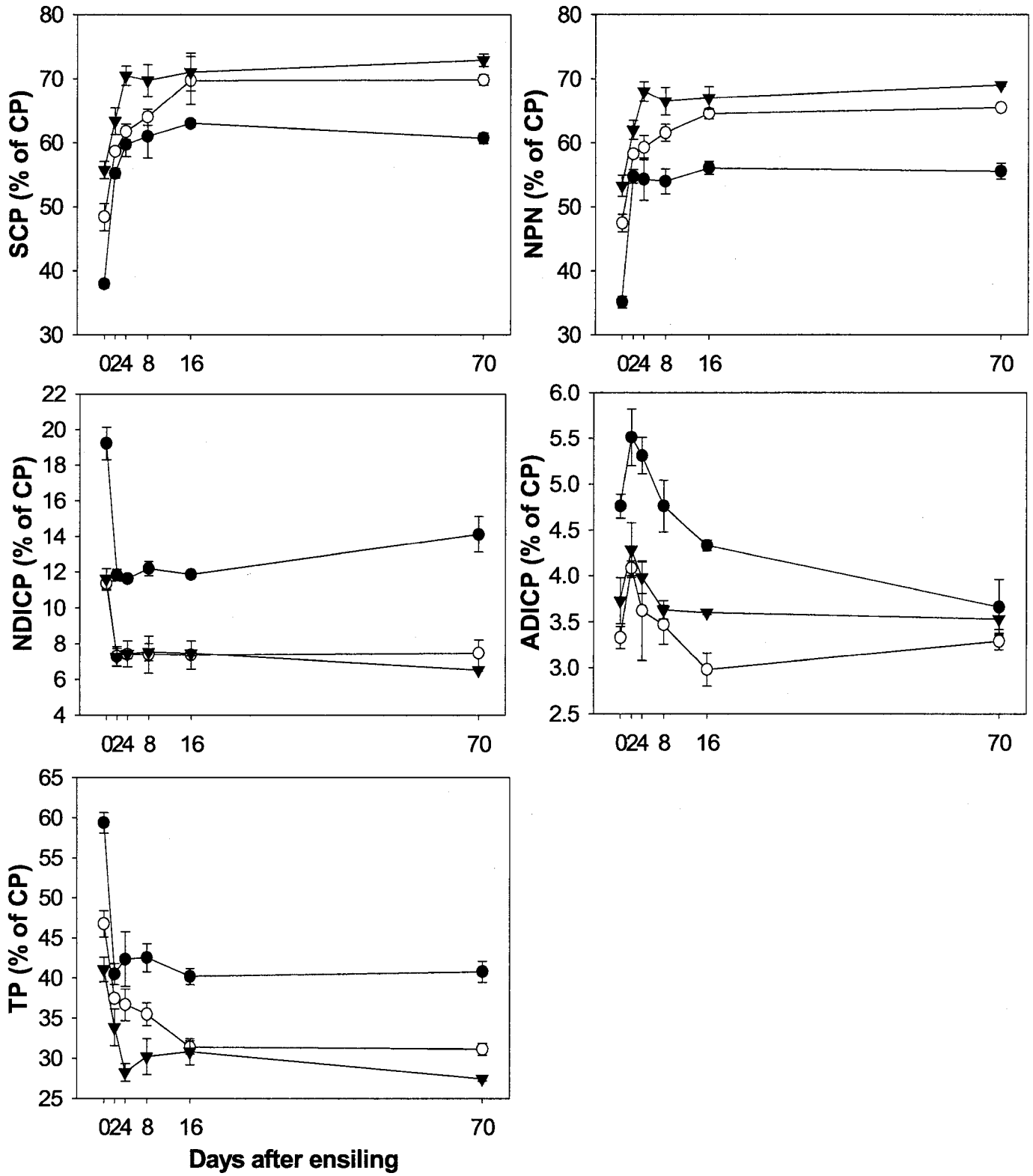


Figure 2. Changes in neutral detergent insoluble protein (NDICP), acid detergent insoluble protein (ADICP), soluble protein (SCP), NPN, and true protein (TP) of ensiled forage pea cultivars Lenca (●), Carneval (○), and Delta (▼). Vertical bars represent ±SD.

**Table 1.** Chemical composition of three forage pea cultivars before ensiling.

	Pea cultivars			SEM
	Lenca	Carneval	Delta	
DM, %	29.0	28.7	27.8	0.40
Ash, % DM	8.8 <sup>b</sup>	6.6 <sup>a</sup>	10.0 <sup>a</sup>	0.25
Ether extract, % DM	2.4 <sup>a</sup>	1.3 <sup>b</sup>	1.7 <sup>b</sup>	0.1
NDF, % DM	44.6 <sup>a</sup>	34.1 <sup>b</sup>	35.6 <sup>b</sup>	0.72
ADF, % DM	29.3 <sup>a</sup>	24.6 <sup>b</sup>	25.7 <sup>b</sup>	0.67
ADL, % of NDF	9.8	9.2	8.5	0.57
Starch, % DM	7.2 <sup>c</sup>	9.6 <sup>b</sup>	11.0 <sup>a</sup>	0.32
CP, % DM	17.1 <sup>c</sup>	20.4 <sup>a</sup>	18.8 <sup>b</sup>	0.33
Soluble protein, % of CP	38.0 <sup>c</sup>	50.6 <sup>b</sup>	55.2 <sup>a</sup>	0.63
NPN, % of CP	35.1 <sup>c</sup>	47.4 <sup>b</sup>	53.3 <sup>a</sup>	0.79
Neutral detergent insoluble protein, % of CP	19.2 <sup>a</sup>	11.4 <sup>b</sup>	11.0 <sup>b</sup>	0.38
Acid detergent insoluble protein, % of CP	5.1 <sup>a</sup>	3.3 <sup>b</sup>	3.7 <sup>b</sup>	0.20
TDN <sup>1</sup> , %	64.8 <sup>b</sup>	69.0 <sup>a</sup>	68.1 <sup>a</sup>	0.86
NE <sub>L</sub> <sup>1</sup> , Mcal/kg	1.47 <sup>b</sup>	1.57 <sup>a</sup>	1.55 <sup>a</sup>	0.021

<sup>a,b,c</sup>Means within row followed by different letters are different ( $P < 0.05$ ).

<sup>1</sup>Calculated using the equation of Weiss et al. (1992).

takes place during ensiling (Papadopoulos and Mckersie, 1983). Mckersie (1985) found a strong positive relationship between the initial pH of forage at ensiling and proteolytic activity. The optimum pH for proteolysis of pea silage appeared to be between 5.9 and 4.5, which is within the range reported for ryegrass (Heron et al., 1989) and alfalfa silages (Papadopoulos and Mcker-sie, 1983).

### Chemical Composition of the 70 d Silages

Chemical composition of forages before ensiling is shown in Table 1. For most parameters, differences in chemical composition between the forages before ensiling were similar to those observed between the 70 d silages (Table 2 and 3). Dry matter recoveries for the

70 d silages were high (>90%), suggesting minimal loss to secondary fermentation by molds and aerobic bacteria (Table 2). Neutral detergent fiber and ADF of the 70 d silages were higher ( $P < 0.05$ ) for the L than for C and D (Table 2). However, ADL content was similar for the three varieties and averaged 8.5% of NDF. The NDF and ADF values reported for L are in good agreement with values previously reported for pea silage (cultivar Grande, Mustafa et al., 2000). Delta and C have similar starch content, which was higher ( $P < 0.05$ ) than that of L. The starch concentrations observed for pea silages in this study were lower than previously reported values (Mustafa et al., 2000), indicating variations in starch content between pea cultivars. Christensen et al. (1998) reported starch values for five field pea cultivars ranging from 27.1 to 49.6%.

**Table 2.** Chemical composition of three forage pea cultivars 70 d after ensiling.

	Pea cultivars			SEM
	Lenca	Carneval	Delta	
DM, %	26.5	28.0	27.4	0.43
Ash, % DM	9.3 <sup>a</sup>	6.8 <sup>b</sup>	10.0 <sup>a</sup>	0.30
Ether extract, % DM	2.3 <sup>a</sup>	1.4 <sup>b</sup>	1.6 <sup>b</sup>	0.09
NDF, % of DM	42.7 <sup>a</sup>	31.7 <sup>b</sup>	33.3 <sup>b</sup>	0.79
ADF, % of DM	31.8 <sup>a</sup>	25.2 <sup>b</sup>	25.3 <sup>b</sup>	0.52
ADL, % of NDF	9.1	8.4	8.0	0.34
Starch, % of DM	6.8 <sup>b</sup>	9.2 <sup>a</sup>	10.3 <sup>a</sup>	0.42
Total carbohydrates <sup>1</sup> , % of DM	70.4	71.4	69.4	0.83
Nonstructural carbohydrates <sup>1</sup> , % of DM	30.2 <sup>c</sup>	41.2 <sup>a</sup>	37.4 <sup>b</sup>	0.98
TDN <sup>2</sup> , %	64.3 <sup>c</sup>	71.9 <sup>a</sup>	68.3 <sup>b</sup>	0.85
NE <sub>L</sub> <sup>2</sup> , Mcal/kg	1.46 <sup>c</sup>	1.65 <sup>a</sup>	1.55 <sup>b</sup>	0.04
IVDMD, %	67.3 <sup>b</sup>	72.7 <sup>a</sup>	73.8 <sup>a</sup>	0.96
DM recovery	94.6	95.0	95.2	1.94

<sup>a,b,c</sup>Means within row followed by different letters are different ( $P < 0.05$ ).

<sup>1</sup>Calculated according to Sniffen et al. (1992).

<sup>2</sup>Calculated using the equation of Weiss et al. (1992).

**Table 3.** Protein fractionation of three forage pea cultivars 70 d after ensiling.

	Pea cultivars			SEM
	Lenca	Carneval	Delta	
CP, % of DM	17.9 <sup>c</sup>	20.5 <sup>a</sup>	19.0 <sup>b</sup>	0.24
Soluble protein, % of CP	60.3 <sup>c</sup>	69.8 <sup>b</sup>	73.6 <sup>a</sup>	0.39
NPN, % of CP	55.6 <sup>c</sup>	65.5 <sup>b</sup>	69.0 <sup>a</sup>	0.43
Neutral detergent insoluble protein, % of CP	14.1 <sup>a</sup>	7.5 <sup>b</sup>	6.5 <sup>b</sup>	0.57
Acid detergent insoluble protein, % of CP	4.2	3.3	3.5	0.36
True protein <sup>1</sup>				
Total, % of CP	40.3 <sup>a</sup>	31.2 <sup>b</sup>	27.5 <sup>c</sup>	0.54
Rapidly degradable (B1), % of true protein	11.7	14.0	16.8	1.72
Intermediately degradable (B2), % of true protein	63.5 <sup>b</sup>	72.6 <sup>a</sup>	72.3 <sup>a</sup>	1.87
Slowly degradable (B3), % of true protein	24.8 <sup>a</sup>	13.4 <sup>b</sup>	10.9 <sup>b</sup>	2.14

<sup>a,b,c</sup>Means within row followed by different letters are different ( $P < 0.05$ ).

<sup>1</sup>Calculated using the equations of Sniffen et al. (1992).

Total digestible nutrients and  $NE_L$  were highest ( $P < 0.05$ ) for C, intermediate ( $P < 0.05$ ) for D, and lowest ( $P < 0.05$ ) for L (Table 2). The higher energy content of C can be attributed to its higher nonstructural carbohydrates and lower fiber levels relative to the other two cultivars. The energy values reported for C are in good agreement with the values reported for cultivar Grande (Mustafa et al., 2000). Carneval had IVDMD similar to D but higher ( $P < 0.05$ ) than L (Table 2).

Crude protein content was highest ( $P < 0.05$ ) for C, intermediate for D, and lowest for L (Table 3). As expected, SCP was the main CP fraction in silage of the three cultivars, and most of that protein fraction was in the form of NPN (Table 3). The cultivar ranking for the two protein fractions was  $D > C > L$  ( $P < 0.05$ ). Neutral detergent insoluble protein was higher ( $P < 0.05$ ) for L than C and D. However, ADICP was similar among the three cultivars (average 3.7% of CP). The protein fractions reported in this study for cultivars C and D were in good agreement with our previously reported values for pea silage (Mustafa et al., 2000). The TP fraction was less than 50% of CP in the silage of the three cultivars and was ( $P < 0.05$ ) highest for L, intermediate for C, and lowest for D (Table 3). Differences in TP fraction reflect the variations in NPN between the three pea silage cultivars. Most of the TP was in the form of intermediately degradable fraction followed by the slowly and the rapidly degradable fraction, respectively (Table 3). Distribution of the TP fractions reported in this study is similar to those previously reported for pea, barley and alfalfa silages (Mustafa et al., 2000).

### Ruminal Degradability of 70 d Silages

Carneval and D cultivars had a similar in situ soluble DM fraction, which was higher ( $P < 0.05$ ) than that of

L (Table 4). However, the slowly degradable DM fraction and its rate of degradation were similar among the three cultivars. Effective DM degradability was similar for C and D, and was higher ( $P < 0.05$ ) than that for L. Differences in effective DM degradability between the pea silages were consistent with those observed for IVDMD and can be attributed to the variations in the in situ soluble DM fraction between the three cultivars.

Pea silage had a high in situ soluble CP fraction, which was highest ( $P < 0.05$ ) for D, intermediate for C, and lowest for L (Table 4). Slowly degradable CP fraction was low and showed an inverse trend to that observed for in situ soluble CP fraction. Rate of degradation of the slowly degradable CP fraction was similar for the three pea cultivars (average 11.9%/h). The high in situ soluble fraction and the rapid rate of degradation of the slowly degradable fraction resulted in high ruminal degradability of CP for the three pea silages. Our values for ruminal degradability of CP for pea silages in this study were in good agreement with values previously reported (Mustafa et al., 2000).

Data on ruminal degradation characteristics of pea silage are limited. In a previous study, ruminal kinetic parameters and ruminal degradability of DM and CP reported for Mustafa et al. (2000) showed that CP of pea silage is more degradable in the rumen than CP of alfalfa and barley silage. However, the present CP degradability values were higher than those reported for silage of pea-wheat mixtures (Salawu et al., 2001).

In situ soluble NDF was low for the three pea silage cultivars (Table 4). The slowly degradable NDF fraction, its rate of degradation and effective ruminal degradability of NDF (average 32.9%) were similar for the three cultivars. Ruminal kinetic parameters of NDF reported in this study were in good agreement with values previously reported (Mustafa et al., 2000), except for rate of degradation of the slowly degradable NDF,

**Table 4.** Ruminal nutrient kinetic parameters and effective degradability of three forage pea cultivars 70 d after ensiling.

	Pea variety			SEM
	Lenca	Carneval	Delta	
DM				
Soluble fraction, % of DM	49.9 <sup>b</sup>	54.4 <sup>a</sup>	54.1 <sup>a</sup>	0.29
Slowly degradable fraction, % of DM	32.1	32.8	31.3	0.83
Degradation rate, %/h	7.7	9.6	8.5	0.71
Lag time, h	2.1 <sup>a</sup>	0.6 <sup>b</sup>	0.5 <sup>b</sup>	0.34
Effective degradability <sup>1</sup> , %	69.2 <sup>b</sup>	73.8 <sup>a</sup>	74.1 <sup>a</sup>	0.75
CP				
Soluble fraction, % of CP	69.1 <sup>c</sup>	78.9 <sup>b</sup>	82.8 <sup>a</sup>	0.62
Slowly degradable, % of CP	22.1 <sup>a</sup>	15.8 <sup>b</sup>	11.5 <sup>c</sup>	0.67
Degradation rate, %/h	11.1	13.0	11.5	1.12
Lag time, h	1.1	0.8	1.8	0.37
Effective degradability <sup>1</sup> , %	84.1 <sup>b</sup>	90.2 <sup>a</sup>	90.8 <sup>a</sup>	0.47
NDF				
Soluble fraction, % of NDF	4.1	4.1	2.0	0.62
Slowly degradable fraction, % of NDF	53.3	53.5	56.8	1.30
Degradation rate, %/h	5.4	5.8	6.6	0.32
Lag time, h	1.0	1.6	1.1	0.37
Effective degradability <sup>1</sup> , %	31.6	32.7	34.3	0.77

<sup>a,b,c</sup>Means within row followed by different letters are different ( $P < 0.05$ ).

<sup>1</sup>Calculated assuming a ruminal outflow rate of 5%/h.

which was higher in the present study. This resulted in higher effective NDF degradability for pea silages in the present study. The NDF degradation characteristics of pea silages in this study however, were in good agreement with those reported for ensiled pea-wheat mixtures (Salawu et al., 2001).

## CONCLUSIONS

Results of this study demonstrate that silage of different pea cultivars was well preserved as indicated by a rapid drop in pH and production of lactic acid. Extensive proteolysis took place in the first few days on ensiling, which resulted in a significant reduction in TP and concurrent increase in NPN. Differences in the chemical composition of the different pea cultivars were reflected in variations in ruminal degradability of DM and CP but not NDF. Further studies are needed to determine effects of pea silage variety on nutrient utilization and animal performance.

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