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Effects of Drying and Ensiling on *In situ* Cell Wall Degradation Kinetics of Tomato Pomace in Ruminant

[1]Naser Maheri-Sis, [2]Mohammad Chamani, [2]Ali Asghar Sadeghi, [1]Ali Mirzaaghazadeh, [1]Kambiz Nazeradl and [1]Abolfazl Aghajanzadeh-Golshani

[1]Department of Animal Science, Shabestar Branch, Islamic Azad University, Shabestar, East Azerbaijan, Iran

[2]Department of Animal Science, Science and Research Branch, Islamic Azad University, Tehran, Iran

Corresponding Author: Naser Maheri-Sis, Department of Animal Science, Shabestar Branch, Islamic Azad University, Shabestar, East Azerbaijan, Iran

ABSTRACT

This study was carried out to evaluate effects of drying and ensiling on ruminal cell wall (neutral detergent fibre; NDF) degradation of tomato pomace using in situ technique. Nylon bags filled with 5 g (on dry matter basis) of each wet, dried and ensiled tomato pomace were suspended in the rumen of three fistulated Ghezel rams for 0, 2, 4, 8, 12, 24, 48 and 72 h and obtained data were fitted to a non-linear degradation model to calculate ruminal degradation characteristics. Results showed that drying and ensiling, cause significant decrease in cell wall degradation of tomato pomace at all incubation times. Cell wall water soluble fraction (a) was decreased and potentially degradable fraction (b) was increased, while rate of degradation (c) and potential degradability (a+b) were not significantly affected by drying and ensiling of tomato pomace. Effective rumen degradability of cell wall was significantly reduced by the processing. In an overall conclusion, cell wall degradability of fresh tomato pomace was higher than that of dried and ensiled form. In other word, ensiling and drying can exert negative effects on cell wall degradation of tomato pomace in the rumen.

Key words: Cell wall degradation, drying, ensiling, nylon bags, tomato pomace

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.), is one of the most common vegetables in the world (El-Sayed *et al*., 2010). Annual production of tomatoes was up to 4.2×10^{6} tones in Iran (Safamehr *et al*., 2011), which most of them (about 60%) are used in tomato processing factories, producing a huge amount of wet tomato pomace as main by-product (Chakraei *et al*., 2008; Mansoori *et al*., 2008). Tomato pomace increasingly have been used as valuable but unusual feedstuff in ruminants and poultry nutrition in developing countries (AL-Betawi, 2005; Chumpawadee and Pimpa, 2008; Chumpawadee, 2009; Aghajanzadeh-Golshani *et al*., 2010; Yuangklang *et al*., 2010).

Tomato pomace is consists of peels, cores, culls, trimmings, seeds, liquor and unprocessed green tomatoes (Safamehr *et al*., 2011), which representing 5-10% of the original weight of fresh tomatoes (Ventura *et al*., 2009). El-Boushy and van der Poel (1994) predicted that production of tomato pomace are increasing and will reach up to 6×10^{6} tones at 2014 in the world.

Aghajanzadeh-Golshani *et al.* (2010) reported that tomato pomace production were up to 1.5×10^5 tonnes in Iran. Considerable production of this by-product encourages animal nutritionists to study its nutritive value. Although higher cell wall (fibre) content of this by-product limits its utilization by non ruminants (especially in poultry), it is used widely in ruminant nutrition. Tomato pomace may be considered as concentrate (due to high nutrient content) or roughage (due to high cell wall content) in ruminant nutrition. Yuangklang *et al.* (2006, 2010) proposed that it can be used as a part or even sole source of roughage in ruminant diets. Our previous studies on evaluation of nutritive value of dried tomato pomace produced in Iran, revealed that Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Ether Extract (EE), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), non Fibrous Carbohydrate (NFC) and Metabolizable Energy (ME) content of this by-product were between 92-96.30, 93-96.60, 22.17-24.08, 13.98-15.90, 47.8-50.6, 32.6-34.50, 3.70-8.41% and 8.02-11.77 MJ kg^{-1} DM, respectively (Aghajanzadeh-Golshani *et al.*, 2010; Maheri-Sis *et al.*, 2011a, b; Mirzaei-Aghsaghali *et al.*, 2011).

Fresh tomato pomace should be utilized as soon as possible after production. It is clear that it can be utilized in wet form only in the farms that are near the tomato cannery factories. In other hand its transportation in this form is difficult. However, quick spoilage (two days if exposed to the air) of fresh tomato pomace due to high water content (ca. 75%) makes the farmers to drying or ensiling this by-product for further using (Weiss *et al.*, 1997; Chedly and Lee, 1999; Caluya, 2000; Paryad and Rashidi, 2009; Abdollahzadeh *et al.*, 2010). Sometimes, because of seasonal conditions, sun drying of this by-product is limited. In such conditions, it is artificially dried which is in turn lead to increasing the price of tomato pomace substantially. Ensiling of tomato pomace is an alternative method to overcome these problems (Weiss *et al.*, 1997). Several studies indicated that effect of ensiling on nutritive value of feeds can be varied by the nature of them. Chemical composition, particularly cell wall content as well as rumen degradability, may positively or negatively affected by ensiling procedure (Kholif *et al.*, 2007; Arbabi *et al.*, 2008; Elkholy *et al.*, 2009; Abdollahzadeh *et al.*, 2010; Abarghoei *et al.*, 2011).

Published data on comparative nutritive value of fresh, dried and ensiled tomato pomace is scarce. Based on the suggestion of Chumpawadee *et al.* (2007); determining chemical compositions, as well as rate and extent of digestion in the rumen is necessary for evaluation of nutritive value of ruminant feedstuffs. Orskov *et al.* (1980) proposed that between feed evaluation methods (i.e., *in situ*, *in vivo* and *in vitro*), the nylon bags (*in situ*) technique provides a reliable tool for the initial evaluation of feedstuffs.

The aim of this study was to compare chemical composition and cell wall (NDF) degradation of fresh (wet), dried and ensiled tomato pomace in the rumen of sheep using nylon bags (*in situ*) technique.

MATERIALS AND METHODS

Sample collection and preparation: Tomato pomace samples were collected from four tomato processing factories in Shabestar, East Azerbaijan province, Iran. Drying process was done by exposure of wet tomato pomace at room temperature during 7 days. Ensiled samples were prepared by ensiling in experimental PVC tubes for 30 days with no any additives.

Chemical analysis: Dry Matter (DM) was determined by drying the samples at 105°C overnight, ash by igniting the samples in muffle furnace at 525°C for 8 h and Ether Extract (EE) by Soxhlet apparatus. Nitrogen (N) content was measured by the Kjeldahl method (AOAC, 1990). Crude protein (CP) was calculated as N*6.25. Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) were determined by procedures outlined by Goering and van Soest (1970) with modifications described by Van Soest *et al.* (1991); sulfite was omitted from NDF analysis.

***In situ* degradation procedures:** Three ruminally cannulated Ghezel rams (about 55 kg b.wt.) were used to determine *in situ* degradation characteristics. Rams were housed in individual tie stalls bedded with sawdust. Rams fed diets containing alfalfa hay (70%) and concentrate mixture (30%) at the maintenance levels. Dacron bags (18×9 cm; 40-45 micron pore size) were filled with 5 g (on dry matter basis) of each wet, dried and ensiled tomato pomace samples and then incubated in the rumen of rams for the periods of 0, 2, 4, 8,12, 24, 48 and 72 h. After the removal of bags from the rumen, bags were washed in cold water until rinse were clear and dried at 60°C for 48 h. Then rumen degradation kinetics of NDF was calculated using the nonlinear model proposed by Orskov and McDonald (1979):

$$P = a+b\ (1-e^{-ct})$$

Where:
P = Percentage of degradability for response variables at t
t = Time relative to incubation (h)
a = Highly soluble and readily degradable fraction (%)
b = Insoluble and slowly degradable fraction (%)
c = Rate constant for degradation (h^{-1})
e = 2.7182 (Natural logarithm base)

Following determination of these parameters, the effective degradability of NDF in tomato pomace was calculated using equation described by Orskov and McDonald (1979):

$$ED = \frac{a + (b \times c)}{(c+k)}$$

Where:
ED = Effective degradability for response variables (%)
a = Highly soluble and readily degradable fraction (%)
b = Insoluble and slowly degradable fraction (%)
c = Rate constant for degradation (h^{-1})
k = Rate constant of passage (h^{-1})

Statistical analysis: All of the data were analyzed based on Completely Randomized Design (CRD), by using software of SAS (1991) and means (obtained from three samples) were separated by Tukey's range test (Tukey, 1977; Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Chemical composition of tomato pomace has shown in Table 1. There is an increase in NDF and ADF as well as EE content of ensiled vs. fresh and dried tomato pomace, while CP have been decreased in ensiled samples. These variations between chemical compositions of fresh, dried and ensiled tomato pomace can be due to production of fermentation end products (organic acids) in ensiling process. As mentioned in introduction section, chemical composition of dried tomato pomace

Table 1: Chemical composition of wet, dried and ensiled tomato pomace (%)

Component	DM	CP	EE	OM	ADF	NDF
Wet	29.00	22.17	15.00	93.00	32.60	49.2
Dried	92.35	22.22	14.00	92.90	32.40	50.36
Ensiled	34.96	19.90	19.50	92.00	40.60	56.60

DM: Dry matter, CP: Crude protein, EE: Ether extract, OM: Organic matter, ADF: Acid detergent fiber, NDF: Neutral detergent fiber

Table 2: Ruminal cell wall degradation (%) of wet, dried and ensiled tomato pomace at different incubation times (h)

Incubation time (h)	Wet	Dried	Ensiled	p-value	SEM
0	19.79[a]	8.91[b]	8.77 [b]	0.0003	0.9679
2	21.28[a]	11.35[b]	10.74[b]	0.0003	0.9072
4	23.65[a]	12.37[b]	15.90[b]	0.0003	0.8821
8	28.88[a]	20.22[b]	16.83[b]	0.032	1.3802
12	32.06[a]	23.61[b]	20.19[c]	0.0001	0.8180
24	39.85[a]	34.42[b]	26.11[c]	<0.0001	0.6836
48	43.66[a]	37.80[b]	30.82[c]	0.0001	0.8331
72	45.58[a]	39.72[b]	38.76[b]	0.0024	0.8379

Means in the same row with different superscripts differ significantly at $p<0.05$

is in rang of our previous studies (Aghajanzadeh-Golshani *et al*., 2010; Maheri-Sis *et al*., 2011a, b; Mirzaei-Aghsaghali *et al*., 2011). There is some differences between chemical composition of current study comparing with some other researches (Weiss *et al*., 1997; Chumpawadee *et al*., 2007; Besharati *et al*., 2008; Mirzaei-Aghsaghali and Maheri-Sis, 2008; Chumpawadee, 2009; Abdollahzadeh *et al*., 2010). These variations in chemical composition of tomato pomace may be due to different original materials, growing conditions, extent of foreign materials, skin to seed ratio, impurities and different processing and measuring methods (Mansoori *et al*., 2008; Aghajanzadeh-Golshani *et al*., 2010).

Ruminal cell wall degradation of fresh, dried and ensiled tomato pomace at different incubation times indicated in Table 2. There are significant differences between cell wall degradation of experimental treatments in all incubation times. Ensiling and drying resulted in decrease rumen cell wall degradability. In some incubation times (12, 24 and 48 h) negative effect of ensiling on cell wall degradation was higher than that of drying process. Water solubility of NDF was up to two times (19.79%) higher in fresh tomato pomace than dried (8.91%) an ensiled (8.75%) forms. It may be caused by decrease in rumen fermentable materials due to ensiling and lag time of microbial attachment in dried tomato pomace.

Effect of ensiling and drying of tomato pomace on its cell wall degradation parameters and effective degradability were presented in Table 3. Cell wall water soluble fraction (a) was decreased and potentially degradable fraction (b) was increased, while rate of degradation (c) and potential degradability (a+b) were not significantly affected by drying and ensiling of tomato pomace. Effective rumen degradability of cell wall was significantly reduced by the processing.

Potential degradability (a+b) of NDF in current study for ensiled tomato pomace (41.13%) was in line with Weiss *et al*. (1997) which is reported that cell wall digestibility of tomato pomace was about 40% and lower than that of reported by Denek and Can (2006) and Abdollahzadeh *et al*. (2010). Different value of cell wall digestibility of tomato pomace may be due to different cell wall content and ratio of ADF to NDF as well as pectin content. Devaux *et al*. (2005) cited that cell walls are composed of three complex interpenetrated macromolecular networks: cellulose-hemicellulose,

Table 3: Ruminal cell wall degradation parameters and effective degradability of wet, dried and ensiled tomato pomace

Items	Wet	Dried	Ensiled	p-value	SEM
a (%)	18.9[a]	7.57[b]	10.10[b]	0.0004	0.9680
b (%)	27.07[b]	32.80[a]	31.03[ab]	0.0152	0.9739
a+b (%)	45.97[a]	40.37[a]	41.13[a]	0.0623	1.4225
c (h^{-1})	0.0560[a]	0.0236[a]	0.0307[a]	0.3629	0.1022
Lag time	0.60[b]	0.70[a]	0.00[c]	<0.0001	0
ED_2 (%)	38.87[a]	32.10[b]	28.53[c]	0.0003	0.7979
ED_5 (%)	33.23[a]	28.73[ab]	21.57[b]	0.2112	2.1041
ED_8 (%)	30.10[a]	31.55[b]	18.47[b]	0.0001	0.8221

Means in the same row with different superscripts differ significantly at $p<0.05$, a: Washout fraction as measured by washing loss from nylon bags, b: Potentially degradable fraction, c: Rate of degradation of fraction b (h^{-1}), ED_2, ED_5 and ED_8: Effective degradability at out flow rate of 0.02 h^{-1}, 0.05 h^{-1} and 0.08 h^{-1}, respectively

pectin and structural proteins. Pectin-rich cell wall interfaces are thought to play a key role in cell-cell adhesion and tissue cohesion while the cellulose-hemicellulose network is thought to largely contribute to rigidity. Thus, it seems that increasing in cellulose-hemicellulose content in ensiling or drying process leads to decrease cell wall degradability in the rumen. Findings of many workers (Weiss *et al*., 1997; Kholif *et al*., 2007; Arbabi *et al*., 2008; Elkholy *et al*., 2009; Abdollahzadeh *et al*., 2010; Abarghoei *et al*., 2011) showed that ensiling conditions such as ensiling time and temperature, dry matter content, additives and silage pH could have significant effect on nutritive value of ensiled feedstuffs.

However due to lack of sufficient knowledge and published articles in this issue (cell wall degradability of tomato pomace); we should waiting further findings. Off course, it is clear that many factors such as chemical composition of samples, bag pore size, sample size, washing procedures, grinding, diet of host animal, species of animal, sample preparation, incubation time and washing method as well as tomato processing methods and conditions can be cause variation of rumen degradability of nutrients (Chumpawadee, 2009; Maheri-Sis *et al*., 2011a, b).

CONCLUSION

Results of current study demonstrated that ensiling and drying decreases soluble fraction and increases potentially degradable fraction as well as effective degradability of tomato pomace cell wall. In other word, cell wall degradability of fresh tomato pomace was higher than that of ensiled and dried forms. Based on the results of current study effective degradability of cell wall in tomato pomace were in range of 18.47- 38.87%, which is indicate low cell wall degradability of this by-product in the rumen. Thus, there is need to further studies to improve cell wall degradability of tomato pomace.

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