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Effects of Microwave Irradiation on Ruminal Dry Matter Degradation of Tomato Pomace

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Abstract: This study was conducted to evaluate effects of 1000W microwave irradiation for 2.5 and 5 min on ruminal dry matter (DM) degradation parameters of tomato pomace. Nylon bags filled with 5 g of each of untreated or microwave treated tomato pomace, were suspended in the rumen of three fistulated Gezel rams for 0,4,8,12,16,24,36,48 and 72 h, and obtained data were fitted to a non-linear degradation model to calculate ruminal degradation characteristics. Microwave treatments significantly decreased DM degradability of tomato pomace only on 0 and 4h incubation times. Although microwave irradiation decreased ($p<0.0001$) the water soluble fraction (*a*) and increased ($p<0.05$) the potentially degradable fraction (*b*) of DM, but constant rate of degradation (*c*), total degradability (*a*+*b*) and effective rumen degradability of DM were not significantly affected by microwave irradiation. The effect of 5 min irradiation on decreasing water soluble fraction of DM was higher than that of 2.5 min, but irradiation time can not affect potentially degradable fraction (*b*). In conclusion, microwave irradiation reduced DM solubility in the rumen, but has not significant effect on the extent of total and effective degradability of tomato pomace.

Key words: Dry matter degradation, microwave irradiation, nylon bags, tomato pomace

INTRODUCTION

Using agro-industrial by-products in ruminant nutrition is one of the important strategies to overtop feed shortage in current century especially in developing country (Mirzaei-Aghsaghali and Maheri-Sis, 2008). Tomato pomace is one of the agro-industrial by-products which are producing in huge amount in the world. Annual production of tomato pomace exceeds 150,000 MT in Iran (Besharati *et al*., 2008). If it was loosed unused, causes serious environmental pollution as well as acting as a substrate for insect and microbial proliferation (Kaur *et al*., 2006). Tomato pomace can be used as a valuable by-product in ruminant nutrition (Besharati *et al*., 2008; Mirzaei-Aghsaghali and Maheri-Sis, 2008, Aghajanzadeh-Golshani *et al*., 2010). It is contains 21.7% protein, 13.4% fat and 57.4% neutral detergent fiber on dry matter basis and 26% DM on as-fed basis (Abdollahzadeh *et al*., 2010). Because of quick spoilage of wet tomato pomace, usually it is dried or ensiled for further using (Abdollahzadeh *et al*., 2010; Aghajanzadeh-Golshani *et al*., 2010).

Different technologies have been used in order to processing and drying feedstuffs. Microwave irradiation is one of the most effective food and feed drying and processing methods which have been used in resent years. Microwaves are a nonionising form of energy that interact with polar molecules and charged particles of penetrated medium to generate heat. Microwave heating shortens processing time because microwaves penetrate solid matter and therefore work faster than systems which transfer heat by conduction from surface to centre. This improves product quality by minimizing changes in product texture, nutritional value and lowering moisture content (Grundas, 2011). Microwave irradiation has been used recently by Al-Harahsheha *et al*. (2009) for drying tomato pomace. They were found that microwave drying could be used effectively for drying of such waste product by shortening of the drying process time. The drying rate was found to increase with increasing microwave dosage.

Preliminary research has suggested that dry matter disappearance of some poor-quality fodder materials can be improved by microwave treatment (Brodie *et al*., 2010). Although effect of microwave irradiation on ruminal degradation of certain feedstuffs for ruminants has been studied previously by some researchers (Sadeghi and Shawrang, 2006a, b; Sadeghi and Shawrang, 2008; Faramarzi Garmroodi *et al*., 2009; Ebrahimi *et al*., 2010; Salamatdoust Nobar *et al*., 2010; Maheri Sis *et al*., 2011), but it seems that, there is needs to further investigations for understanding nutritive value of individual feeds and by-products.

The nutritive value of ruminant feed is determined by the concentration of its chemical compositions, as well as

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rate and extent of digestion in the rumen (Chumpawadee *et al*., 2007). Three common methods including: *in situ*, *in vivo* and *in vitro* techniques have been used in order to evaluate the nutritive value of feedstuffs (Maheri-Sis *et al*., 2008).The nylon bag (*in situ*) technique, provides a powerful tool for the initial evaluation of feedstuffs and for improving our understanding of the processes of degradation which occur within the rumen. It is the more efficient method for measuring rate and extent of digestion in the rumen (Ørskov *et al*., 1980).

The aim of this study was to determine the effects of microwave irradiation on ruminal dry matter degradation of tomato pomace using nylon bags technique.

MATERIALS AND METHODS

Sample collection and chemical analysis: Tomato pomace samples were collected from four tomato processing factories in Shabestar, East Azerbaijan province, Iran. Dry Matter (DM) was determined by drying the samples at 105ºC overnight and ash by igniting the samples in muffle furnace at 525ºC for 8 h. 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. Non-fibrous carbohydrate (NFC) was calculated using the equation of NRC (2001); NFC% = 100 - (NDF% + CP% + EE% + Ash %). All experimental procedures (including chemical composition and *in situ* degradation) were conducted at summer 2009 in animal research farm of Islamic Azad University, Shabestar Branch, Shabestar, Iran.

***In situ* degradation procedures:** Three ruminally cannulated Gezel rams (about 55 kg BW) 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 dried and ground samples and then incubated in the rumen of rams for the periods of 0, 4, 8, 12, 16, 24, 36, 48, 72 h. After the removal of bags from the rumen, bags were washed in cold water until rinse were clear and dried at 60ºC for 48 h (Karsli and Russell, 2002). Then rumen degradation kinetics of DM was calculated using the nonlinear model proposed by Ørskov 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 DM in tomato pomace was calculated using and equation described by Ørskov and McDonald (1979):

$$ED = a + (b*c)/(c+k)$$

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})

when calculating effective degradability, rate constant of passage was assumed to be 0.02, 0.05 and 0.08 per hour (Bhargava and Ørskov, 1987) so that the results could be extrapolated to other ruminants that differ in rumen capacity.

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 Duncan's multiple range tests (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Chemical composition of tomato pomace was presented in Table 1. There are some differences and variations between chemical compositions in current study comparing with some other researches (Denek and Can, 2006; Chumpawadee *et al*., 2007; Besharati *et al*., 2008; Chumpawadee, 2009; Aghajanzadeh-Golshani *et al*., 2010). These variations in chemical composition of by-products can be due to different original materials, growing conditions (geographic, seasonal variations, climatic conditions and soil characteristics), extent of foreign materials, impurities and different processing and measuring methods. It is predictable that, different chemical composition can be leads to different nutritive value, because chemical composition is important index of nutritive value of feeds (Maheri-Sis *et al*., 2008; Aghajanzadeh-Golshani *et al*., 2010).

Ruminal DM degradation of microwave treated and untreated tomato pomace at different incubation times were shown in Table 2. Dry matter degradability only at 0 and 4h incubation times was significantly affected by

Table1: Chemical composition of microwave treated tomato pomace on dry matter basis (%).

DM	CP	EE	CA	ADF	NDF	NFC
94.46	24.08	13.98	5.73	33.6	47.8	8.41

DM: dry matter; CP: crude protein; EE: ether extract; CA: crude ash; ADF: acid detergent fiber; NDF: neutral detergent fiber; NFC: Non Fiber Carbohydrate

Table 2: Ruminal dry matter degradation (%) of microwave treated and untreated tomato pomace at different incubation times (h)

Incubation time (h)	untreated	microwave treated (2.5 min)	microwave treated (5 min)	*P* value	S.E.M
0	32.18^{a}	24.95^{b}	24.25^{b}	0.0001	0.93
4	36.58^{a}	34.84^{a}	30.32^{b}	0.0012	1.06
8	48.37	49.86	53.92	0.1605	1.77
12	66.23	60.66	63.84	0.0897	1.59
16	72.18	72.61	71.83	0.9752	2.06
24	76.64	75.79	74.89	0.6527	1.50
36	77.24	76.38	77.19	0.6346	1.09
48	78.93	78.19	77.48	0.6602	1.37
72	79.19	78.56	78.01	0.7138	1.31

Means in the same row with different letters (a and b) differ ($p<0.05$)

Table 3: Ruminal dry matter degradation parameters (%) and effective degradability of microwave treated and untreated tomato pomace

Items	untreated	microwave treated(2.5 min)	microwave treated (5 min)	p-value	S.E.M
a (%)	27.55^{a}	21.73^{b}	19.93^{c}	0.0001	0.431
b (%)	53.27^{b}	58.05^{a}	59.41^{a}	0.0133	1.010
a+b (%)	80.82	79.78	79.34	0.1240	0.793
c (h^{-1})	0.087	0.094	0.102	0.4475	0.004
ED (%) Out flow rate 0.02 h^{-1}	70.80	69.60	69.50	0.1310	0.004
ED (%) Out flow rate 0.05 h^{-1}	61.30	59.60	59.70	0.6621	0.015
ED (%) Out flow rate 0.08 h^{-1}	55.20	53.00	53.10	0.8114	0.023

Means in the same row with different letters (a, b, c) differ ($p<0.05$); *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: effective degradability

the microwave irradiation. No significant differences have been observed between microwave treated and untreated tomato pomace at other incubation times. Increasing microwave irradiation times (5 min vs. 2.5 min) also had no significant effect on solubility and subsequent degradability of dried tomato pomace. This result is in line with findings of Sadeghi and Shawrang, (2006a). They are found that increasing the microwave irradiation time from 3 to 5 min could not affect the soluble fraction of corn grain (degradation at 0h incubation), but 7 min irradiation led to decrease dry matter solubility of DM. Comparing microwave treating effect on DM solubility in current study with other related investigations (Sadeghi and Shawrang, 2006a,b; Sadeghi and Shawrang, 2007; Sadeghi and Shawrang, 2008; Faramarzi Garmroodi *et al*., 2009) indicated that effect of microwave irradiation can be affected by irradiation time and characteristics of tested materials (feeds).

Effect of microwave irradiation on ruminal dry matter degradation parameters and effective degradability of tomato pomace were presented in Table 3. Microwave irradiation significantly resulted in decreasing ($p<0.0001$) the soluble fraction (*a*) and increasing ($p<0.05$) the potentially degradable fraction (*b*) of dry matter of tomato pomace. Increasing the microwave irradiation time decreased the soluble (*a*) fraction of DM ($p<0.05$), but no significant differences have been observed between 2.5 and 5 min irradiation times. Microwave irradiation could not alter degradation rate of the *b* fraction (*c*) as well as total degradability (*a+b*) tomato pomace.

Effect of microwave treating on *a* and *b* fraction was in agreement with Sadeghi and Shawrang (2006a, b; 2008). They are reported that increasing the microwave irradiation decreased the *a* fraction and increased the *b* fraction of DM in canola meal, corn and barley grains. These workers Supposed that chemical reactions (such as Millard reaction) occurring during heat processing are responsible for the reduction in ruminal degradation. Zhao *et al*. (2007) Suggested that, although microwave treatment causes less thermal damage to the test material than general heating methods such as hot water heating, it causes biochemical reactions and changes the molecular conformation of starch and protein, texture and physicochemical properties, such as the solubility and gelatin temperature of food products. It is notable that based on findings of Doering and Hennessy (2008); microwaves can decrease cell wall strength and enhance enzyme ability to hydrolyze cellulose.

As it is shown in Table 3, there were not differences between treatments in effective degradability. It is predictable that, when (*a+b)* and *c* were not significantly difference between treatments, effective degradability was not affected significantly. Faramarzi Garmroodi *et al*. (2010) demonstrate that there is not a positive response for enhancing the cottonseed hulls fermentability on *in vitro* studies when microwave irradiation was applied. Karn (1991) also previously had been reported that microwave drying have a minimal and inconsistent effect on organic matter digestibility of forages. However Sadeghi *et al*. (2005), Sadeghi and Shawrang (2006a, b) and Sadeghi and Shawrang, (2008) observed that microwave irradiation decrease effective degradability of soya-bean meal, canola meal, corn and barley grains. The difference between results of current study and above mentioned researches can be due to different starch and protein nature of experimental feedstuffs, irradiation times and irradiation power. Ruminal dry matter degradation parameters of untreated tomato pomace in current study were higher than those reported by Chumpawadee (2009). He was reviewed that numerous factors can be led to variation of *in sacco* degradability, 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.

CONCLUSION

Results of current study indicated that microwave irradiation resulted in decreasing soluble fraction and increase in potentially degradable fraction of tomato pomace dry matter. Increasing irradiation time led to further decrease in dry matter solubility. However microwave treatment can not improved effective rumen degradability of tomato pomace. It seems that effect of microwave treatment on rumen degradability was related to irradiation time, irradiation power and nature of chemical composition in different feedstuff.

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