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RESEARCH ARTICLE

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Effect of microwave irradiation on the fermentation characteristics and nutritive value of tomato pomace for ruminants using *in vitro* gas production technique

ABSTRACT

This study was conducted to estimate the effect of microwave irradiation on fermentation pattern, metabolizable energy content and organic matter digestibility of tomato pomace using *in vitro* gas production technique. Tomato pomace samples were collected, pooled, ground and then exposed to 1000W microwave irradiation for 0, 2.5 and 5 minutes. The experimental samples were incubated *in vitro* with rumen liquor taken from three fistulated Iranian native cows at 2, 4, 6, 8, 12, 16, 24, 36, 48, 72 and 96 h. Cumulative gas production volume at early incubation times was significantly decreased by microwave treating time ($P<0.01$). Microwave irradiation could not significantly affect gas production parameters. Significant effects were not found on metabolizable energy content (7.82 - 8.02 MJ/ Kg DM) and organic matter digestibility (51.87% - 53.15%) of microwave treated tomato pomace. The results showed that microwave irradiation may be a useful method to decrease ruminal gas production (including methane), without any negative effects on nutritional value of tomato pomace.

Key words: tomato pomace, microwave, nutritive value, gas production, metabolizable energy

Introduction

Agro-industrial by-products refer to the by-products derived in the industry due to processing of main products. Many of these agro-industrial by-products have a substantial potential nutritional value as livestock feeds. Thus, feeding such by-products will help to decrease feeding cost especially in developing countries (Sindhu et al., 2002). The ruminant animals have the unique capacity to utilize fibrous by-products because of their rumen microbes. Ruminal bacteria, protozoa and fungi together contribute to microbial fermentation of plant cell walls in the rumen (Chaji et al., 2011). Using agro-industrial by-products in ruminant nutrition is one of the economic strategies to overtop feed shortage worldwide (Mirzaei-Aghsaghali & Maheri-Sis, 2008; Chaji et al., 2011; Taher-Maddah et al. 2012). Tomato pomace is an agro-industrial by-product which is producing in significant amounts in Iran. Tomato pomace produced in Iran contains 21.7-26.4% crude protein, 13.4-15.9% fat, 3.4-12.2% crude ash and 49.2-57.4% neutral detergent fiber on dry matter basis and 26% DM on as-fed basis (Abdollahzadeh et al., 2010; Aghajanzadeh-Golshani et al., 2010; Mirzaei-Aghsaghali et al., 2011). Based on our previous studies nutritive value of dried tomato pomace can be comparable with alfalfa hay in ruminant nutrition (Maheri-Sis et al., 2007; Mirzaei-Aghsaghali et al., 2008; Aghajanzadeh-Golshani et al., 2010; Mirzaei-Aghsaghali et al., 2011).

Because of quick spoilage of wet tomato pomace, usually it is dried or ensiled for further using. Microwave irradiation is one of the most effective food and feed drying and processing methods which have been used in recent years (Sadeghi & Shawrang, 2008; Pelletier et al., 2010; Maheri-Sis et al., 2011a). Microwaves are non-ionizing electromagnetic waves positioned between the X-ray and infrared rays in the electromagnetic spectrum with frequency between 300 MHz to 300 GHz (Tatke & Jaiswal, 2011). Zhao et al., (2007) reviewed that microwave technology is

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increasingly playing an important role in drying in the food industry because of its rapid heating rate and ease of use. It also shows considerable potential for preventing mildew in food. In addition, this method of processing does not cause environmental pollution or introduce foreign chemical reagents. Chavan & Chavan (2010) suggested that microwave heating techniques have many unique advantages when compared to conventional heating methods because they are; convenient to operate and control, energy-efficient and clean. Other advantages of microwave irradiation include the following: shorter drying time, improved product quality and flexibility in producing a wide variety of dried products. Microwave irradiation has been used recently by Al-Harahsheha et al. (2009) for drying tomato pomace. They were found that drying rate have been increased with increasing microwave dosage. Aflatoxin contamination is one of the serious problems on conventional drying of tomato pomace. Farag et al. (1996) illustrated that microwave heating reduced the aflatoxin content considerably in contaminated material.

Effect of microwave irradiation on ruminal degradation of certain feedstuffs for ruminants has been studied recently by some researchers (Sadeghi & Shawrang, 2007; Ebrahimi et al., 2010, Maheri-Sis et al., 2011b, 2011c), but it seems that, there is needs to further investigations for understanding fermentation pattern and nutritive value of individual feeds and by-products.

Among three common techniques (*in vivo, in situ* and *in vitro*) used for nutritional evaluation of feeds, *in vitro* gas production technique is the superior method for feed evaluation (Ajmal Khan et al., 2003), especially in developing countries because it is capable of measuring rate and extent of nutrients fermentation with less expenditure and estimation of organic matter digestibility and metabolizable energy content of several classes of feedstuffs for ruminants (Menke et al., 1979; Maheri-Sis et al., 2008; Chen et al., 2011).

The aim of this study was to estimate the effect of microwave irradiation on fermentation pattern, metabolizable energy content and organic matter digestibility of tomato pomace using *in vitro* gas production technique.

Materials and Methods

Animals and feeds

Three fistulated Iranian native (Taleshi) cows fed twice daily with a diet containing hay (60%) and concentrate (40%) following the method described by Menke & Steingass (1988), were used for rumen liquor collection in order to conduct in gas production technique. Tomato pomace samples were collected from tomato processing factories of Shabestar region, Iran. Three samples (500 g) were dried, pooled, ground (milled through a 1 mm sieve) and exposed to 1000W microwave irradiation (emitting a 2450 MHz microwave frequency) for 0, 2.5 and 5 minutes.

Chemical analysis

Tomato pomace samples milled through a 1 mm sieve for chemical analysis and gas production procedure. Dry matter (DM) was determined by drying the samples at 105ºC overnight and ash by igniting the sample in muffle furnace at 550ºC for 8 h. Nitrogen (N) content was measured by the Kjeldal method. Crude protein (CP) was calculated as N×6.25 (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by procedures outlined by Van Soest et al. (1991). Chemical analyses were carried out in animal nutrition laboratories of Islamic Azad University, Shabestar Branch and Animal Science Research Institute, Karaj, Iran.

In vitro gas production

The amount of 200 mg samples was weighed in triplicate into calibrated glass syringes of 100 ml. The syringes were prewarmed at 39ºC before the injection of 30 ml rumen fluid-buffer mixture into each syringe followed by incubation in a water bath at 39ºC. Readings of gas production were recorded before incubation (0) and 2, 4, 6, 8, 12, 16, 24, 36, 48, 72 and 96 h after incubation. Total gas values were corrected for blank incubation and gas production from syringes contain rumen fluid. Gas production procedure was done in laboratory of Animal Science Research Institute, Karaj, Iran.

Cumulative gas production data were fitted to the model of Ørskov & McDonald (1979):

$$\mathbf{Y = \mathit{a}+\mathit{b}\ (1-\mathit{e}^{-ct})}$$

where a = gas production from the immediately soluble fraction (mL), b = gas production from the insoluble fraction (mL), c = gas production rate constant for the insoluble fraction (b), $a+b$ = potential gas production (mL), t = incubation time (h) and Y = gas production at time t.

The metabolizable energy contents of tomato pomace were calculated using equations of Menke & Steingass (1988) as follows:

$$\mathbf{ME\ (MJ/kg\ DM)=2.20+0.136\ GP+0.057\ CP+0.0029\ EE^2}$$

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where ME = metabolizable energy (MJ per kg DM), GP = 24 h net gas production (ml 200 mg^{-1}), CP = crude protein (%), EE = ether extract (%).

Organic mater digestibility of tomato pomace was calculated using equations of Menke et al. (1979) as below:

$$\mathbf{OMD\ (\%) = 0.9991\ GP + 0.595\ CP + 0.181\ XA - 9}$$

where OMD = organic mater digestibility, GP = 24 h net gas production (ml 200 mg^{-1}), CP = crude protein (%), XA = ash content (%).

Statistical analysis

All 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 & 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 (Chumpawadee et al., 2007; Besharati et al., 2008; Chumpawadee, 2009; Aghajanzadeh-Golshani et al., 2010; Mirzaei-Aghsaghali et al., 2011). 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, tomato varieties, skin to seed ratio and different processing and measuring methods. It is predictable that, different chemical composition led to different nutritive value, because chemical composition is the initial and important index of nutritive value of feeds (Aghajanzadeh-Golshani et al., 2010; Maheri-Sis et al., 2011b, 2011c).

Table 1. *Chemical composition of 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

Legend: DM - dry matter, CP - crude protein, EE - ether extract, CA - crude ash, ADF - acid detergent fiber, NDF - neutral detergent fiber, NFC - non fiber carbohydrate.

Gas production volume (ml / 200 mg DM) at different incubation times and gas production parameters (*a*, *b*, *a*+*b* and *c*) and calculated amounts of organic matter digestibility and metabolizable energy of untreated and microwave treated tomato pomace are presented in Figure 1 and Tables 2 and 3.

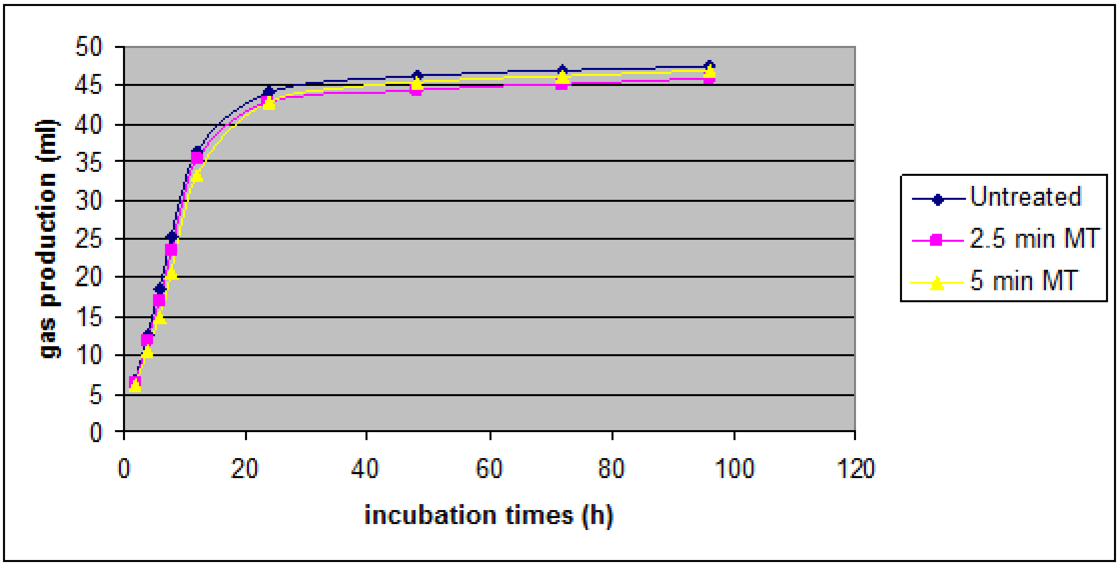

Figure 1. *In vitro gas production volume of untreated and microwave treated (MT) tomato pomace at different incubation times.*

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Table 2. *Gas production volume (ml / 200mg DM) of microwave treated and untreated tomato pomace at different incubation times (h).*

Incubation time (hours)	Untreated	Microwave treated (2.5 min)	Microwave treated (5 min)	*P*-value	S.E.M
2	6.67	6.35	6.06	0.1673	0.195
4	12.56 ^{a}	11.78 ^{a}	10.55 ^{b}	0.0040	0.253
6	18.60 ^{a}	17.03 ^{b}	15.04 ^{c}	0.0002	0.258
8	25.34 ^{a}	23.47 ^{b}	20.71 ^{c}	0.0003	0.359
12	36.34 ^{a}	35.40 ^{a}	33.30 ^{b}	0.0027	0.359
24	44.03	42.78	42.76	0.1686	0.468
48	46.23	44.35	45.43	0.1976	0.643
72	46.78	45.05	46.14	0.1899	0.585
96	47.49	45.89	46.85	0.2585	0.615

Means in the same row with different letters (a, b and c) differ (P<0.05).

Table 3. *Gas production parameters, estimated metabolizable energy (ME) contents and organic matter digestibility (OMD) of untreated and microwave treated tomato pomace.*

Items	Untreated	Microwave treated (2.5 min)	Microwave treated (5 min)	*P*-value	S.E.M
a (ml)	5.73	5.84	5.09	0.0963	0.236
b (ml)	52.89	51.39	51.83	0.1176	0.615
a+*b* (ml)	58.62	57.23	56.92	0.1284	0.325
c (ml.h^{-1})	0.114	0.113	0.096	0.0851	0.009
OMD (%)	53.15	51.89	51.87	0.4574	0.073
ME (MJ.Kg^{-1} DM)	8.02	7.82	7.82	0.2114	0.468

Legend: ***a*** - gas production from the immediately soluble fraction; ***b*** - gas production from the insoluble fraction; ***a+b*** - potential gas production; ***c*** - gas production rate constant for the insoluble fraction (*b*).

Cumulative gas production volume at early incubation times (until 12 h) was significantly decreased by microwave treating time (P<0.01). There was no significant difference between gas production parameters of untreated and microwave treated tomato pomace. The gas volume in all of incubation times and gas production parameters (*a*, *b*, *a*+*b* and *c*) for untreated tomato pomace were slightly higher than that reported by Besharati et al. (2008), Aghajanzadeh-Golshani et al. (2010) and Mirzaei-Aghsaghali et al. (2011). In our previous studies (Maheri-Sis et al., 2011b, 2011c) we found that microwave irradiation could not affect dry matter and protein degradability of tomato pomace. Karn (1991) previously had been reported that microwave drying have a minimal and inconsistent effect on organic matter digestibility of forages. Eskicioglu et al. (2007) stated that, neither the chemical mechanism of microwave interaction with materials, nor microbial destruction (sterilization) mechanism of microwave in biological systems is fully understood. Maheri-Sis et al. (2011a) observed that microwave treatment lead to increasing *in vitro* gas production parameters of sunflower meal. It seems that nature of feedstuff could have a determinative role on efficiency of microwave irradiation.

It was confirmed that gas volume at 24 h after incubation correlate with the metabolizable energy in feedstuffs (Menke et al., 1979; Menke & Steingass, 1988; Chen et al., 2011). Additionally, *in vitro* organic matter digestibility was shown to have high correlation with gas production rate and volume (Sommart et al., 2000; Kilic & Garipoglu, 2009). In this study, microwave irradiation could not significantly affect metabolizable energy content (7.82 - 8.02 MJ/kg DM) and organic matter digestibility (51.87% - 53.15%) of tomato pomace. These values were lower than those of Besharati et al. (2008), Aghajanzadeh-Golshani et al. (2010) and Mirzaei-

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Aghsaghali et al. (2011), and approximately 50-60% higher than that of Chumpawadee et al. (2007). Different nutritive values obtained from various studies may be due to different chemical compositions (especially soluble carbohydrates, crude protein, non-fibrous carbohydrates, fat, acid detergent fibre and neutral detergent fibre), processing methods, tomato varieties, skin to seed ratio, climate conditions, evaluation procedures and experimental diets and animals (Aghajanzadeh-Golshani et al., 2010; Maheri-Sis et al., 2011b, 2011c). In addition, the use of various equations by different researchers, especially in case of *in vitro* gas production technique, can be resulted in different outputs. Sadeghi & Shawrang (2007) reported that increasing the microwave irradiation time decreased solubility of DM in feedstuffs. The authors supposed that chemical reactions (such as Millard reaction) occurring during heat processing are responsible for the reduction in ruminal degradation. Zhao et al. (2007) stated that microwave irradiation 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.

Conclusion

The results showed that although microwave irradiation could not improved nutritive value of tomato pomace, but it can be a useful and cost effective method to decrease ruminal gas production (including methane) and removing aflatoxin contamination of this by-product without any negative effects on its nutritional value. It is suggested the use of different microwave power and higher treating time in further studies.

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