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Comparison of Nutritional Value of Tomato Pomace and Brewer's Grain for Ruminants Using *in vitro* Gas Production Technique

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Abstract: The aim of present study was to determine the chemical composition and estimate the nutritive value of tomato pomace and brewers' grain using *in vitro* gas production technique in sheep. Tomato pomace samples were collected from 4 tomato processing factories in East Azerbaijan, Iran and brewers' grain samples were obtained from Behnoush Food Industrial Company, Karaj, Iran. Feed samples (200 mg from each) were incubated with rumen liquor taken from 3 fistulated rams at 2, 4, 6, 8, 12, 16, 24, 36 and 48 h. The results showed that the Organic Matter (OM), Neutral Detergent Fiber (NDF) and Non Fibrous Carbohydrates (NFC) in brewers' grain were significantly higher than that of tomato pomace ($p<0.05$), while Crude Protein (CP), Ether Extract (EE) and Acid Detergent Fiber (ADF) in tomato pomace were significantly greater than that of brewers' grain ($p<0.05$). There were significant differences in Organic Matter Digestibility (OMD), Short Chain Fatty Acids (SCFA) and Metabolizable Energy (ME) contents between the two food industrial by-products ($p<0.05$). Gas productions at 24 h for tomato pomace and brewers grain were 38.99 and 31.14 mL, respectively. In an overall conclusion it seems that, the nutritive value of tomato pomace was higher than that of brewers' grain for ruminants.

Key words: Brewers' grain, tomato pomace, gas production, metabolizable energy, nutritive value

INTRODUCTION

Developing food industrial factories consequently produced large amount of wastes and by-products. Dumping or burning wastes or agro-industrial by-products causes potential air and water pollution problems. High-moisture wastes are also difficult to burn. Many by-products have a substantial potential value as animal feedstuffs. Ruminants, especially, have the unique capacity to utilize fiber, because of their rumen microbes. This means that cereals can be largely replaced by these by-products. Consequently the competition between human and animal nutrition can be decreased. Nevertheless, there is an increased cereal supply owing to genetic and management improvement. The utilization of agro-industrial by-products may be economically worthwhile, since conventional feedstuffs are often expensive. However, livestock have historically utilized large amounts of well-known and widely-available traditional by-products such as oil meals, bran, middling, brewers grains, distillers grains, beet pulp and molasses (Boucque and Fiems, 1988). But

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less conventional by-products have become available, such as vegetable-and fruit-processing residues. The extent of by-products utilization as a feed ingredient depends on the costs of the conventional feedstuffs, the safety for animal health and the attractiveness of alternative uses. As some raw materials can be used for different production processes, the available amount to the various by-products is difficult to estimate and it is even more difficult to assess the quantity used as animal feed (Boucque and Fiems, 1988). Therefore, the nutritional value of regional by-products should be the evaluated, as feed value of feedstuffs may differ greatly from one location to another.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely cultivated vegetable crops in Mediterranean Countries. Significant amounts are consumed in the form of processed products such as tomato juice, paste, puree, ketchup and sauce. During tomato processing a by-product, known as tomato pomace, is generated. This by-product represents, at most, 4% of the fruit weight (Del Valle *et al*., 2006). Dried tomato pomace contains 22.6-24.1% protein, 14.5-15.7% fat and 20.8-30.5% fiber. This by- product is a good source of vitamin B_1 and a reasonable source of vitamins A and B_2 (El-Boushy and Vander-Poel, 1994). Bordowski and Geisman (1980) reported that tomato pomace seeds protein contains approximately 13% more lysine than soy protein. In Iran, production of tomato pomace exceeds 150,000 tons year^{-1} (Besharati *et al*., 2008). The potential use of these wastes in ruminant ration should participate in reducing the shortage of feedstuffs and subsequently increase milk and meat production in Iran. However, little is known about their fermentation pattern in the rumen and a better understanding of their digestion and products of fermentation is necessary in order to properly balance their introduction into the diets and the knowledge about their potential feeding value is insufficient (Besharati *et al*., 2008).

Brewers' grains are the most important by-product of brewery industry. Every 100 L of beer accounts for an average 20 kg of brewers' grains (Mussatto *et al*., 2006). Brewers' grains are often used as a livestock feed. Because they provide protein, fiber and energy, are used in a variety of diets. Protein in Brewers' grains can meet a significant portion of supplemental protein requirements; in addition, they provide fiber and needed bulk in the diets of ruminants. On DM basis, it contains a range of 220 to 280 g kg^{-1} CP and 2.5 Mcal ME kg^{-1} DM (NRC, 2001). Brew residues can be in the form of either dried brewers' grains or wet brewers' grains, which can be marketed directly. Moisture content in wet brewers' grains ranges between 650-800 g kg^{-1} (Aguilera-Soto *et al*., 2007). The dried brewers' grains are easy to store because of its low moisture content. Brewers' grains are suitable as forage source especially at the farms located near breweries (Younker *et al*., 1998; Aguilera-Soto *et al*., 2007).

Several methods such as *in vivo*, *in situ* and *in vitro* techniques have been used in order to evaluate the nutritive value of feedstuffs (Maheri-Sis *et al*., 2008). The *in vitro* gas production technique has proved to be a potentially useful technique for feed evaluation (Menke and Steingass, 1988; Getachew *et al*., 2004) as it is capable of measuring rate and extent of nutrient degradation. In addition, *in vitro* gas production technique is less expensive, easily to determine (Getachew *et al*., 2004) and suitable for use in developing countries (Chumpawadee *et al*., 2005; Maheri-Sis *et al*., 2007, 2008). This method also predicts feed intake, digestibility, microbial nitrogen supply and amount of short chain fatty acids, carbon dioxides and metabolizable energy of ruminants feed (Babayemi, 2007; Maheri-Sis *et al*., 2008). When planning diet formulation, cost, chemical composition and digestibility of the energy of the feed source should be fully taken into account. Numerous varieties of energy feeds are available in tropical zones. However, there is insufficient information available regarding the effect of feed used on kinetics of gas production (Chumpawadee *et al*., 2007).

The aim of this study was to determine chemical composition and estimate the nutritive value of tomato pomace and brewers' grain using *in vitro* gas production technique.

MATERIALS AND METHODS

Animals and Feeds

Three fistulated Gezel rams were used for rumen liquor collection for application in gas production technique. The experimental samples were Tomato Pomace (TP) and Brewers' Grain (BG). The TP samples were collected from four tomato processing factories in East Azerbaijan, Iran and BG samples were obtained from Behnoush Food Industrial Company, Karaj, Iran. The collected samples were dried, mixed and milled through a 1 mm sieve in Animal Nutrition Laboratory of Tabriz University, Tabriz, Iran.

Chemical Analysis

Collected samples were milled through a 1 mm sieve for chemical analysis and *in vitro* gas production procedure. Dry Matter (DM) was determined by drying the samples at 105°C overnight and ash by igniting the samples in muffle furnace at 525°C for 8 h. Nitrogen (N) content was measured by the Kjeldahl method. Crude Protein (CP) was calculated as N*6.25 (AOAC, 1990). Neutral Detergent Fiber (NDF) was determined by procedures outlined by Van Soest *et al*. (1991); sulfite was omitted from NDF analysis. All of chemical analyses were performed in the Laboratory of Animal Nutrition, Islamic Azad University, Shabestar Branch, Shabestar, Iran (Mar. 2008 to Aug., 2008).

In vitro Gas Production

Rumen fluid was obtained from three fistulated Gezel rams fed twice daily at the maintenance level with a diet containing alfalfa hay (60%) and concentrate (40%). The samples were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedures of Menke *et al*. (1979). Two hundred miligram samples were weighed in triplicate into calibrated glass syringes of 100 mL. The syringes were prewarmed at 39°C before the injection of 30 mL rumen fluid-buffer mixture into each syringe followed by incubation in a water bath at 39°C. Readings of gas production were recorded before incubation 0 and 2, 4, 6, 8, 12, 16, 24, 36 and 48 h after incubation. Total gas values were corrected for blank incubation. Cumulative gas production data were fitted to the model of Orskov (1979):

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

Where:

a = The gas production from the immediately soluble fraction (mL)
b = The gas production from the insoluble fraction (mL)
c = The gas production rate constant for the insoluble fraction (b)
a + b = Potential gas production (mL)
t = Incubation time (h)
e = Neperian value (2.718282)
Y = Gas produced at time (t)

The Non Fibrous Carbohydrates (NFC), Short Chain Fatty Acids (SCFA), Digestible Organic Matter (DOM) and Metabilizable Energy (ME) values in experimental by-products were calculated using equations as below:

$$NFC = 100-(NDF + CP + EE + Ash) \text{ (NRC, 2001)}$$
$$SCFA = 0.0222 \text{ Gas} - 0.00425 \text{ (Makkar, 2005)}$$
$$DOM = 0.9991 \text{ Gas} + 0.595 \text{ CP} + 0.181 \text{ CA} + 9 \text{ (Menke and Steingass, 1988)}$$
$$ME = 0.157 \text{ Gas} + 0.084 \text{ CP} + 0.22 \text{ EE} - 0.081 \text{ CA} + 1.06 \text{ (Menke and Steingass, 1988)}$$

where, Gas is gas production at 24 h incubation (mL 200 mg^{-1} DM); a, b, c are gas production parameters described by Orskov (1979) and NDF, CP, EE, CA are neutral detergent fiber, crude protein, ether extract, crude ash (% DM) , respectively. Gas production test was carried out in the Laboratory of Animal Nutrition, Tabriz University, Tabriz, Iran (Aug, 2008).

Statistical Analysis

All of the data were analyzed by using software of SPSS (2002) and means of two sample groups were separated by independent-samples t-test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The Organic Matter (OM), Neutral Detergent Fiber (NDF) and non Fibrous Carbohydrates (NFC) in brewers' grain were significantly higher than that of tomato pomace ($p<0.05$) (Table 1) while Crude Protein (CP), Ether Extract (EE) and Acid Detergent Fiber (ADF) in tomato pomace were significantly greater than that of brewers' grain ($p<0.05$). The NDF content of brewers' grain was lower than that obtained by Pereira *et al.* (1998) but higher than that obtained by Madrid *et al.* (2002), in line with the findings of DePeters *et al.* (1997), Batajoo and Shaver (1998) and Afrozieh and Pirmohammadi (2007). The ADF content of brewers' grain was higher than the findings of DePeters *et al.* (1997), Pereira *et al.* (1998) and Madrid *et al.* (2002) and in line with Afrozieh and Pirmohammadi (2007). The OM content of brewers' grain was in agreement with several researches findings (Alawa *et al.*, 1988; DePeters *et al.*, 1997; Batajoo and Shaver, 1998; Pereira *et al.*, 1998). The CP content of brewers' grain were lower than those reported by DePeters *et al.* (1997), Batajoo and Shaver (1998), Pereira *et al.* (1998), Madrid *et al.* (2002) and Afrozieh and Pirmohammadi (2007) and in line with Alawa *et al.* (1988) and Mussatto *et al.* (2006). The NDF content of tomato pomace was lower than Weiss *et al.* (1997), Denek and Can (2006), Besharati *et al.* (2008) and Taghizadeh *et al.* (2008) and in line with Chumpawadee *et al.* (2007) and Chumpawadee and Pimpa (2008). The ADF content of tomato pomace was lower than those of Weiss *et al.* (1997), Denek and Can (2006), Chumpawadee *et al.* (2007), Besharati *et al.* (2008), Chumpawadee and Pimpa (2008) and Taghizadeh *et al.* (2008). The OM content of tomato pomace was lower than those Weiss *et al.* (1997), Ayhan and Aktan (2004), Del Valle *et al.* (2006) and Denek and Can (2006) but higher than those Besharati *et al.* (2008) and

Table 1: Chemical composition of tomato pomace and brewers grain on dry matter basis (%)

Constituents	Tomato pomace	Brewers grain	Difference
Dry matter (DM)	92.00± 1.03% DM basis	92.50±1.05% DM basis	NS
Organic matter (OM)	93.00±1.36	96.00±1.17	*
Crude protein (CP)	22.17±0.84	19.80±0.81	*
Ether extract (EE)	15.00±0.40	8.00±0.50	*
Neutral detergent fiber (NDF)	49.20±2.14	55.10±2.56	*
Acid detergent fiber (ADF)	32.60±1.95	25.20±2.11	*
Non fibrous carbohydrate (NFC)	6.63±0.56	13.10±0.40	*

NS: Non significant; *$p<0.05$, Data presented as Mean±SD

Chumpawadee and Pimpa (2008) and in agreement with several researches (Boucque and Fiems, 1988; Chumpawadee *et al.*, 2007). The CP content of tomato pomace was lower than those reported by Boucque and Fiems (1988) and Chumpawadee *et al.* (2007) but higher than those National Academy of Science (1983), Weiss *et al.* (1997), Ayhan and Aktan (2004), Del Valle *et al.* (2006), Denek and Can (2006) and Chumpawadee and Pimpa (2008) and in line with Besharati *et al.* (2008) and Taghizadeh *et al.* (2008).

The wide range of variation in chemical composition of experimental by-products between several researches 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 (Maheri-Sis *et al.*, 2008). Different chemical composition leads to different nutritive value, because chemical composition is one of the most important indices of nutritive value of feeds. Variation in chemical components of feeds such as starch, NFC, OM, CP, NDF, ADF and soluble sugars contents can be resulted in variation of *in vitro* gas production extent (Getachew *et al.*, 2004; Maheri-Sis *et al.*, 2008).

Gas production volumes (mL 200 mg^{-1} DM) in different incubation times are presented in Table 2 gas production parameters (a, b, c) and calculated amounts of SCFA, OMD and ME of tomato pomace and brewers' grain are shown in Table 3.

The gas volumes for tomato pomace in different incubation times (except of 2 h incubation) were significantly higher than that of brewers' grain ($p<0.05$). Gas volume at 24 h incubation (for 200 mg dry samples), soluble fraction (a), insoluble but fermentable fraction (b), for tomato pomace was 38.99, -5.22 and 50.25 and for brewers' grain were 31.14, 0.043 and 42.69 mL, respectively (Table 2 and 3). The negative (a) value for tomato pomace due to delay in onset of fermentation and microbial attachment was in agreement with Chumpawadee *et al.* (2007). Rate of gas production expressed in mL h^{-1} (c) in tomato pomace (0.1143) was significantly ($p<0.05$) greater than brewers' grain (0.0614). The gas volume after 24 h incubation in current study for tomato pomace was higher than what was reported by

Table 2: Comulative gas production volume (mL 200 mg^{-1} DM) at different incubation times for experimental by-products

Incubation times (h)	Tomato pomace	Brewers grain	Difference
2	2.55±0.70	2.40±0.45	NS
4	14.09±0.90	10.38±1.60	*
6	22.45±0.90	14.90±1.50	*
8	27.27±0.46	18.52±1.35	*
12	30.99±0.31	21.95±1.20	*
16	34.42±0.62	25.83±1.07	*
24	38.99±0.75	31.14±0.92	*
36	44.17±0.90	37.95±1.35	*
48	47.98±1.10	41.61±0.63	*

NS: Non significant; *$p<0.05$, Data presented as Mean±SD

Table 3: The gas production parameters, organic matter digestibility (OMD), short chain fatty acids (SCFA) and metabolizable energy (ME) contents of experimental by- products

Items	Tomato pomace	Brewers grain	Difference
a (mL)	-5.2200±1.6300	0.0430±0.0030	*
b (mL)	50.2500±2.3900	42.6900±2.4400	*
c (mL h^{-1})	0.1143±0.0031	0.0614±0.0012	*
|a|+b (mL)	55.4700±2.6400	42.7300±2.7800	*
OMD (%)	62.4100±3.5800	52.7200±2.9800	*
SCFA (mmol)	0.8613±0.1018	0.6870±0.0570	*
ME (MJ kg^{-1} DM)	11.7700±0.6900	9.0500±0.6100	*

a: The gas production from the immediately soluble fraction (mL), b: The gas production from the insoluble fraction (mL) c: The gas production rate constant for the insoluble fraction, (b) NS: Non significant, *$p<0.05$. Data presented as Mean±SD

Chumpawadee *et al.* (2007) (38.99 vs. 24.60 mL) and almost in line with Besharati *et al.* (2008) findings (38.99 vs. 34.48 mL). The gas volume after 24 h incubation for brewers' grain was lower than Getachew *et al.* (2002) findings. They are reported that gas production volume at 24 h incubation time for brewers' grain was different between laboratories (35.3-41.5 mL). Different gas production in these studies can be due to different chemical constituents of by-products, animal types and breeds and quality of inoculums source (Menke *et al.*, 1979; Getachew *et al.*, 2004). There was a positive correlation between NFC content of feeds and gas production, but feed CP, NH3-N and NDF levels were negatively correlated with gas production (Getachew *et al.*, 2004; Maheri-Sis *et al.*, 2008). As presented in our data, the volume of gas production had a negative correlation with NDF levels of experimental by products. Different gas volume and estimated values (ME, SCFA and OMD) could be due to different EE content of by products. Therefore, tomato pomace with low NDF and high EE, should have greater gas volume, ME, SCFA and OMD than brewers grain.

The ME, SCFA and OMD of tomato pomace were significantly higher than that of brewers' grain ($p<0.05$). The ME content of tomato pomace and brewers' grain in this experiment were 11.77 and 9.05 MJ kg^{-1} DM, respectively. The ME value of tomato pomace was greater than those reported by Chedly and Lee (1999), Chumpawadee *et al.* (2007) and Besharati *et al.* (2008). The ME content of brewers' grain was higher than that reported by Chedly and Lee (1999), while lower than those findings of Alawa *et al.* (1988), Board (2002) and Getachew *et al.* (2002). Difference of energetic value of feedstuffs between several researchers may be due to different chemical content and measuring method and also variation inter and intra laboratories (Getachew *et al.*, 2002). Organic matter digestibility of tomato pomace (62.41%) was higher than those reported by Chumpawadee *et al.* (2007), Besharati *et al.* (2008) and Mirzaei-Aghsaghali and Maheri-Sis (2008). Organic matter digestibility of brewers' grain (52.72%) was lower than those fined by Alawa *et al.* (1988), Boucque and Fiems (1988). The SCFA production of tomato pomace (0.8613 mmol) was higher than that reported by Besharati *et al.* (2008). The SCFA value of brewers' grain in this study was 0.6870 mmol. Vlaeminck *et al.* (2004) reported that total VFA obtained from *in vitro* rumen fermentation of brewers' grain was 1949 μmol.

The reason that, why energy content and organic matter digestibility of tomato pomace were higher than that of brewers' grain could be due to difference in chemical composition (especially soluble carbohydrates, CP, NFC, EE, ADF and NDF) and volume of gas production (Menke and Steingass, 1988; Getachew *et al.*, 2004). Blummel *et al.* (1999) reported that the gas volume in the bicarbonate buffered Hohenheim *in vitro* gas production test reflect SCFA production very closely. Gas volumes were produced quantitatively and qualitatively as a result of SCFA production (the amount of fermentative CO_2 and CH_4 could be accurately calculated from the amount and proportion of acetate, propionate and butyrate present in the incubation medium). Thus increasing amount of SCFA was lead to increase in gas production, which is resulted in high digestibility and energetic value.

CONCLUSION

In an overall conclusion the nutritive value (chemical composition, gas production characteristics, organic matter digestibility, metabolizable energy content and short chain fatty acids production) of tomato pomace were better than that of brewers grain. However, both by- products economically can be used as potential fibrous, energy and protein sources in ruminant nutrition.

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REFERENCES

Afrozieh, M. and R. Pirmohammadi, 2007. Rumen degradability of brewers grains in sheep. Proceedings of the 2nd Congress on Animal and Aquatic Science, (CAAS'2007), Karaj, Iran, pp: 185-188.

Aguilera-Soto, J.I., R.G. Ramirez, C.F. Arechiga, M.A. Lopez, R. Banuelos, M. Duran and E. Rodriguez, 2007. Influence of wet brewers grain on rumen fermentation, digestion and performance in growing lambs. J. Anim. Vet. Adv., 6: 641-645.

Alawa, J.P., G. Fishwick and R.G. Hemingway, 1988. Fresh and dried brewers grains as protein supplements to barley straw diets given to pregnant beef cows. Anim. Feed Sci. Technol., 19: 33-41.

AOAC., 1990. Official Method of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA., pp: 66-88.

Ayhan, V. and S. Aktan, 2004. Using possibilities of dried tomato pomace in broiler chicken diets. Hayvansal Üretim., 45: 19-22.

Babayemi, O.J., 2007. *In vitro* fermentation characteristics andacceptability by West African dwarf goats of some dry season forages. Afr. J. Biotechnol., 6: 1260-1265.

Batajoo, K.K. and R.D. Shaver, 1998. *In situ* dry matter, crude protein and starch degredabilities of selected grains and by-product feeds. Anim. Feed Sci. Technol., 71: 165-176.

Besharati, M., A. Taghizadeh, H. Janmohammadi and G.A. Moghadam, 2008. Evaluation of some by-Products using *in situ* and *in vitro* gas production techniques. Am. J. Anim. Vet. Sci., 3: 7-12.

Blummel, M., K.P. Aiple, H. Steingass and K. Becker, 1999. A note on the stoichiometrical relationship of short chain fatty acid productuin and gas formation *in vitro* in feedstuffs of widely different quality. J. Anim. Physiol. A. Anim. Nutr., 81: 157-167.

Board, N., 2002. The Complete Technology Book in Dairy and Poultry Industries. 1st Edn., NIIR Publication, Delhi.

Bordowski, D.L. and J.R. Geisman, 1980. Protein content and amino acid composition of protein of seeds from tomato at various stages of ripeness. J. Food. Sci., 45: 228-235.

Boucque, C.H.V. and L.O. Fiems, 1988. Vegetable by-products of agro-industrial origin. Livestock Prod. Sci., 19: 97-135.

Chedly, K. and S. Lee, 1999. Silage from by-products for smallholders. FAO Electronic Conference on Tropical Silage.

Chumpawadee, S., K. Sommart, T. Vongpralub and V. Pattarajinda, 2005. Nutritional evaluation of non forage high fibrous tropical feeds for ruminant using *in vitro* gas production technique. Pak. J. Nutr., 4: 298-303.

Chumpawadee, S., C. Anut and C. Piyanate, 2007. Chemical compositions and nutritional evaluation of energy feeds for ruminant using *in vitro* gas production technique. Pak. J. Nutr., 6: 607-612.

Chumpawadee, S. and O. Pimpa, 2008. Effect of non forage high fibrous feedstuffs as fiber sources in total mixed ration on gas production characteristics and *in vitro* fermentation. Pak. J. Nutr., 7: 459-464.

DePeters, E.J., J.G. Fadel and A. Arosemena, 1997. Digestion kinetics of neutral detergent fiber and chemical composition within some selected by-product feedstuffs. Anim. Feed Sci. Technol., 67: 127-140.

Del Valle, M., M. Camara and M.E. Torija, 2006. Chemical characterization of tomato pomace. J. Sci. Food Agric., 86: 1232-1236.

Denek, N. and A. Can, 2006. Feeding value of wet tomato pomace ensiled with wheat straw and wheat grain for Awassi sheep. Small Ruminant Res., 65: 260-265.

El-Boushy, A.R.Y. and A.F.B. Vander-Poel, 1994. Poultry Feed from Waste Processing and Use. 1st Edn., Chapman and Hall Publication, Boca Raton, pp: 192-340.

Getachew, G., G.M. Crovetto, M. Fondevila, U. Krishnamoorthy and B. Singh *et al*., 2002. Laboratory variation of 24 h *in vitro* gas production and estimated metabolizable energy values of ruminant feeds. Anim. Feed Sci. Technol., 102: 169-180.

Getachew, G., P.H. Robinson, E.J. De-Peters and S.J. Taylor, 2004. Relationships between chemical composition, dry matter degradation and *in vitro* gas production of several ruminant feeds. Anim. Feed Sci. Technol., 111: 57-71.

Madrid, J., M.M. Dolores and F. Hernandez, 2002. *In vitro* determination of ruminal dry matter and cell wall degradation and production of fermentation end-products of various by-products. Anim. Res., 51: 189-199.

Maheri-Sis, N., M. Chamani, A.A. Sadeghi, A. Mirza-Aghazadeh and A.A. Safaei, 2007. Nutritional evaluation of chickpea wastes for ruminants using *in vitro* gas production technique. J. Anim. Vet. Adv., 6: 1453-1457.

Maheri-Sis, N., M. Chamani, A.A. Sadeghi, A. Mirza-Aghazadeh and A. Aghajanzadeh-Golshani, 2008. Nutritional evaluation of kabuli and desi type chickpeas (*Cicer arietinum* L.) for ruminants using *in vitro* gas production technique. Afr. J. Biotechnol., 7: 2946-2951.

Makkar, H.P.S., 2005. *In vitro* gas methods for evaluation of feeds containing phytochemicals. Anim. Feed Sci. Technol., 123-124: 291-302.

Menke, K.H., L. Raab, A. Salewski, H. Steingass, D. Fritz and W. Schneider, 1979. The Estimation of digestibility and metabolizable energy content of ruminant feedstuffs from the gas production when they incubated with rumen liquor *in vitro*. J. Agric. Sci., 92: 217-222.

Menke, K.H. and H. Steingass, 1988. Estimation of energetic feed value obtained from chemical analysis and *in vitro* gas production using rumen fluid. Anim. Res. Dev., 28: 7-55.

Mirzaei-Aghsaghali, A. and N. Maheri-Sis, 2008. Nutritive value of some agro-industrial by-product for ruminants-a review. World J. Zool., 3: 40-46.

Mussatto, S.I., G. Dragone and I.C. Roberto, 2006. Brewers spent grain: Generation, characteristics and potential applications. J. Cereal. Sci., 43: 1-14.

National Academy of Science, 1983. Under Utilized Resources as Animal Feedstuffs. National Academic Press, Washington, DC., pp: 1-45.

NRC, (National Research Council) 2001. Nutrient Requirements of Dairy Cattle. 7th Edn., The National Academies Press, Washington, DC. USA., ISBN: 0309069971, pp: 381.

Orskov, E.R., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci., 92: 499-503.

Pereira, J.C., M.D. Carro, J. Gonzalez, M.R. Alvir and C.A. Rodriguez, 1988. Rumen degradability and intestinal digestibility of brewers' grains as affected by origin and heat treatment and of barely rootlets. Anim. Feed Sci. Technol., 74: 107-121.

SPSS, 2002. SPSS 11.0 user guide. Information Technology Services Centre. Lingnan University, Hong Kong.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill, New York, USA., ISBN-13: 978-0070609259.

Taghizadeh, A., A. Safamehr, V. Palangi and Y. Mehmannavaz, 2008. The determination of metabolizable protein of some feedstuffs used in ruminant. Res. J. Biol. Sci., 3: 804-806.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Vlaeminck, B., V. Fievez, H.V. Laar and D. Demeyer, 2004. Rumen odd and branched chain fatty acids in relation to *in vitro* rumen volatile fatty acid productions and dietary characteristics of incubated substrates. J. Anim. Physiol. Anim. Nutr., 88: 401-411.

Weiss, W.P., D.L. Frobose and M.E. Koch, 1997. Wet tomato pomace ensiled with corn plants for dairy cows. J. Dairy Sci., 80: 2896-2900.

Younker, R.S., S.D. Winland, J.L. Firkins and B.L. Hull, 1998. Effects of replacing forage fibre or non-fibre carbohydrates with dried brewers' grains. J. Dary Sci., 81: 2645-2656.