Research Journal of Biological Sciences 4 (12): 1262-1266, 2009
ISSN: 1815-8846

Variability in the Chemical Composition and *in situ* Ruminal Degradability of Sugar Beet Pulp Produced in North-East Iran

M. Mojtahedi and M. Danesh Mesgaran
Department of Animal Science, Excellence Center for Animal Science,
Ferdowsi University of Mashhad, P.O. Box 91775-1163, Mashhad, Iran

Abstract: The aim of the present study was to evaluate the chemical composition and *in situ* ruminal degradability of different Sugar Beet Pulp (SBP) sources produced in North-East Iran. Chemical composition of the samples including Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Ether Extract (EE) and total ash were determined. *In situ* ruminal degradability parameters of DM and NDF were determined using four ruminally fistulated Holstein steers. Significant differences were found among various SBP samples for DM, CP, NDF, ADF and ash contents and fiber compounds (NDF and ADF) were the most variable components. Content of NDF varied from 23.03-48.73% with a mean of 34.5% and Standard Deviation (SD) of 7.1%. ADF content ranged from 11.43-24.26% with an average of 17.3%. In addition, considerable variation was observed in degradation parameters including rapidly degradable fraction (a), slowly degradable fraction (b), fractional degradation rate (c), Potential Degradability (PD) and the Effective Degradability (ED) of DM and NDF. The a-fraction of DM varied markedly from 0.012-0.584 with a mean of 0.401 (±0.158). Moreover, c-value of NDF ranged from 0.042-0.074 h^{-1} with average of 0.054. It was concluded that the chemical composition and ruminal degradation parameters of SBP differs considerably among various SBP sources.

Key words: Sugar beet pulp, variability, chemical composition, *in situ* ruminal degradability, North-East Iran

INTRODUCTION

Iran faces a scarcity in the quantity and quality of consistent year-round supplies of conventional ruminant feeds. Therefore, better utilization of non-conventional feed resources which do not compete as human foods is imperative (Alipour and Rouzbehan, 2007).

Agro-industrial co-products, such as Sugar Beet Pulp (SBP) could play an important role in the feeding of ruminants under different management systems. In Iran, production of SBP exceeds 300,000 t $year^{-1}$ the majority is marketed as dried molassed beet pulp with smaller quantities sold as pressed pulp.

Sugar Beet Pulp is the primary by-product feedstuff remaining after extraction of sucrose from the sugar beet (Fadel, 1999). The extracted pulp that leaves the sugar extraction process contains 5-7% Dry Matter (DM). It is passed through large screw presses which increase the DM content to 15-18%. Some pulp is sold as pressed pulp at this stage but most is molassed and dried. Molasses is added to the beet pulp as it leaves the screw presses. The quantity of molasses added is somewhat dependant on the outside market price for molasses but the inclusion is always 18-22% of DM. The molassed pressed pulp can be dried by several drying methods. Typically, as the wet pulp enters the rotating drier it meets the hot gases coming from the furnace at a temperature around 1000°C and is conveyed along the drier by a series of flanges and by the draft of the fan. Gases leaving the drier are at a temperature of 120-130°C. Although, very high temperatures are used in drying the molassed pulp, the high water content of the material ensures that the actual temperature of the pulp does not rise far above 100°C. However, even this temperature for a short period could be expected to decrease the digestibility and nutritional value of SBP. The nutrient composition of all feeds varies but using feeds that are highly variable can reduce profitability of livestock operations because of increased feed costs and/or reduced production. Reduced production occurs when a diet does not contain adequate concentrations of a particular nutrient because a feed has less than anticipated concentrations of that nutrient. Increased feed costs occur when diets are over supplemented to avoid reduced production. It was shown that the chemical composition of SBP from different sources can be quite variable (Arosemena *et al*., 1995; De Peters *et al*., 1997) depending on location, year and processing methods drying method used or the amount of

Corresponding Author: Mohsen Danesh Mesgaran, Department of Animal Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Iran

molasses addedack to the pulp. The objective of the present study was to determine the chemical composition and *in situ* ruminal degradability of DM and NDF of various SBP samples produced in North-East Iran.

MATERIALS AND METHODS

Sampling and chemical composition: The SBP samples were collected from different sugar factories located in North-East of Iran. The main steps of the process used to obtain the SBP were similar for all factories. However, the most prominent difference was the quantity of molasses added to SBP; as the SBP_1 had no molasses but SBP_9 and SBP_{10} had the highest amount of molasses. Unfortunately, the amount of added molasses was not clear exactly. Samples were ground to pass a 2 mm screen and analyzed in triplicate. Dry matter, ash, Ether Extract (EE) and Crude Protein (CP) were determined by standard methods (AOAC, 2000) (methods 930.15, 942.05, 920.39 and 976.05, respectively). The Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) concentrations were determined using the methods of Van Soest *et al.* (1991). Sodium sulfite and alpha amylase were not used in the NDF assay and NDF was expressed as the ash free residue after extraction with boiling neutral solutions of sodium lauryl sulfate and EDTA.

***In situ* ruminal degradability:** For *in situ* technique, four Holstein steers (24±2 months of age and 400±25 kg of body weight) fitted with ruminal fistulae were used and housed individually in concrete floored pens. The animals were offered total mixed rations with 80:20 forage to concentrate ratio at maintenance level in two equal feedings at 08:00 and 16:00 h.

Dried samples (4 g) were weighed into 9×18 cm polyester bags (50 µm pore size), n = 4. Ruminal incubation was carried out for 2, 4, 8, 16, 24, 48 and 72 h according to Nasri *et al.* (2008). All bags were inserted at the same time, just before the morning feeding (e.g., 08:00 h). Bags representing 2 and 4 h were soaked in water (39°C for 15 min) before incubation.

At the end of each incubation period, bags were rinsed with cold tap water until the rinse water was clear. Zero time disappearance was obtained by washing unincubated bags in a similar way. All washed bags were dried in a forced-air oven at 56°C for 48 h. Disappearance of DM and NDF at each incubation time was calculated from the proportion remaining after incubation in the bags.

Calculations and statistical analysis: Degradation of DM and NDF was calculated using the equation of Orskov and McDonald (1979) as:

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

Where:

- PD = The potential degradability
- a = The rapidly degradable fraction
- b = The slowly degradable fraction
- c = The rate constant of degradation
- t = The time (h) of incubation

Effective Degradability of DM (EDDM) and NDF (EDNDF) was calculated using the equation of Orskov and McDonald (1979) as:

$$\text{EDDM or EDNDF} = \frac{a + [b \times c]}{(c + k)}$$

Where, k is the fractional outflow rate from the rumen (per hour) a, b and c are as described above. The k value used to calculate EDDM and EDNDF were 0.02, 0.04 and 0.06 h^{-1}.

Data of chemical composition and *in situ* ruminal degradability were analyzed as a completely randomized design according to the GLM procedure of SAS (2001). Duncan's multiple range test was used to compare treatment means at $p<0.05$.

RESULTS AND DISCUSSION

Variability in chemical composition: The chemical composition of various SBP samples is presented in Table 1. In addition, the averages were compared with some previous reports.

The DM, CP, NDF, ADF and ash contents were significantly differed ($p<0.05$) among the various SBP samples, although their EE content was uniform ($p>0.05$). Dry matter varied from 81.86- 92.60% with a mean of 89.5% and a Standard Deviation (SD) of 3.4%; agree closely with previous estimates (NRC, 2001; Arosemena *et al*., 1995; Woods *et al*., 2003). Crude protein content varied to some extent ranging from 8.43-10.43% with a mean of 9.50%. Average CP was slightly lower than the published results (NRC, 2001; Woods *et al*., 2003) but higher than the average value of 8.73% reported by Arosemena *et al.* (1995). In contrast to CP, the range in NDF and ADF contents among SBP sources was quite large (Fig. 1). Content of NDF varied from 23.03-48.73% with a mean of 34.5% (±7.1%) which agree with previous estimate (Arosemena *et al*., 1995) but was markedly lower than average NDF of 45.8 and 52.8% reported by NRC (2001) and Woods *et al.* (2003), respectively. Similarly, the ADF mean of 17.3% agreed closely with the 18.8% reported by Arosemena *et al.* (1995) but was much

Table 1: Chemical composition (g/100 of DM) of various sugar beet pulp samples produced in North-East Iran

Samples	DM	CP	NDF	ADF	EE	ash
SBP$_1$	90.64^{d}	9.38^{cd}	48.73^{a}	24.26^{a}	0.32	3.81^{i}
SBP$_2$	87.68^{h}	10.43^{a}	38.80^{b}	18.70^{c}	0.56	7.80^{e}
SBP$_3$	94.19^{a}	9.46^{c}	38.50^{b}	21.53^{b}	0.42	7.29^{f}
SBP$_4$	92.60^{b}	8.43^{f}	35.73^{c}	17.26^{d}	0.63	7.15^{g}
SBP$_5$	88.88^{f}	10.06^{b}	35.61^{c}	17.62^{d}	0.37	6.59^{h}
SBP$_6$	81.86^{i}	9.41^{c}	34.76^{d}	16.71^{e}	0.39	7.82^{e}
SBP$_7$	88.37^{g}	9.48^{c}	32.43^{e}	16.10^{f}	0.48	8.40^{c}
SBP$_8$	90.28^{e}	9.15^{de}	31.93^{e}	16.46^{ef}	0.40	8.05^{d}
SBP$_9$	91.71^{c}	10.34^{a}	25.94^{f}	12.86^{g}	0.52	8.85^{a}
SBP$_{10}$	88.90^{f}	8.90^{e}	23.03^{g}	11.43^{h}	0.35	8.69^{b}
Statical analysis						
AVG±SD	89.5±3.4	9.5±0.6	34.5±7.1	17.3± 3.7	0.44±0.1	7.4±1.5
S.E.M.	0.099	0.083	0.248	0.150	0.23	0.043
p-value	<0.01	<0.01	<0.01	<0.01	0.35	<0.01
Published data (average±SD)						
NRC (2001)	88.3±9.4	10.0±1.1	45.8±6.6	23.1±3.6	1.1±0.4	7.3±1.9
Arosemena *et al.* (1995)	90.8±0.8	8.7±0.8	35.8±2.8	18.8±1.5	0.5±0.2	8.4±1.7
Woods *et al.* (2003)	88.3±1.8	10.5±0.7	52.8±12.4	27.7±5.3	0.5±0.2	5.2±1.8

Mean in the same column with different (a-i) letters differ significantly (p<0.05). DM, Dry Matter; CP, Crude Protein; NDF, Neutral Detergent Fiber; ADF, Acid Detergent Fiber; EE, Ether Extract; SD, Standard Deviation

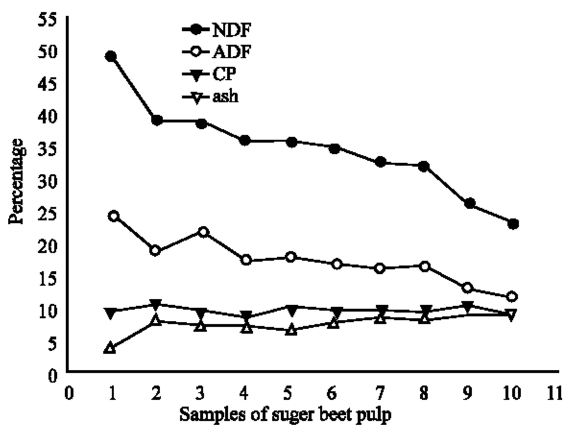

Fig. 1: The extent of Crude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and ash across different sugar beet pulp samples measured in the present study

lower than the other studies (NRC, 2001; Woods *et al.*, 2003). In the present study, the ash content was ranged from 3.81-8.85% with an average of 7.4% which is consistent with some report (NRC, 2001; Arosemena *et al.*, 1995) but slightly lower than the Woods *et al.* (2003) reported value of 5.2%.

In summary, major discrepancies among SBP sources exist for fiber compounds (NDF and ADF). These findings were expected because molasses and beet pulp without molasses had similar CP and EE content, while different values are evident for the fiber fractions (NRC, 2001); as reduction in the fiber components in SBP$_9$ and SBP$_{10}$ was due to the dilution of fiber by the addition of molasses but unmolassed SBP$_1$ had the highest NDF and ADF content (Table 1). The result confirmed the findings obtained by Fadel *et al.* (2000) who reported that drying had less effect on chemical composition than adding molasses. Variation in chemical composition of SBP samples produced in different sugar factories might be from the drying method used, the amount of molasses added back to the SBP or differences in the original plant material. Differences in nutrient composition of beet pulp from different sources have been shown (Arosemena *et al.*, 1995; De Peters *et al.*, 1997; Woods *et al.*, 2003) and the fiber fraction was shown to be the most variable component among sources. The variability in the content of NDF and ADF could pose a problem because this feedstuff is often included in the ruminant ration as source of fiber.

***In situ* ruminal degradability of DM and NDF:** *In situ* DM and NDF degradation parameters and effective degradability of the SBP samples are shown in Table 2 and 3, respectively.

As it was expected, the variation in the chemical composition of the SBP samples affected their ruminal degradation parameters. Except the rapidly degradable fraction (a) of NDF, the degradation parameters of DM and NDF including slowly degradable fraction (b), fractional degradation rate (c), the Potential Degradability (PD) and the Effective Degradability (ED) at 0.02, 0.04 and 0.06 h^{-1} outflow rates, were different among the SBP samples (p<0.05).

Results of present study indicate that a, b and c parameters of DM and c parameter of NDF are the most variable values among various SBP sources. The a- fraction of DM varied markedly from 0.012-0.58 with a mean of 0.401 and SD of 0.158. Average of a fraction was higher than the average value of 0.232 reported by Woods *et al.* (2003). In the other hand, the average b

Table 2: *In situ* DM degradation parameters and effective degradability of various sugar beet pulp samples produced in North-East Iran

	[1]Parameters				[2]ffective degradability		
Samples	a (g g^{-1})	b (g g^{-1})	c (h^{-1})	PD (g g^{-1})	EDDM2 (g g^{-1})	EDDM4 (g g^{-1})	EDDM6 (g g^{-1})
SBP_1	0.012^{g}	1.001^{a}	0.052^{d}	1.014^{a}	0.738^{e}	0.582^{h}	0.481^{h}
SBP_2	0.339^{f}	0.635^{b}	0.054^{d}	0.974^{b}	0.803^{d}	0.704^{g}	0.640^{g}
SBP_3	0.350^{f}	0.618^{b}	0.054^{d}	0.980^{b}	0.814^{d}	0.718^{fg}	0.656^{f}
SBP_4	0.405^{e}	0.573^{c}	0.068^{b}	0.978^{b}	0.846^{c}	0.767^{d}	0.710^{d}
SBP_5	0.506^{c}	0.468^{e}	0.065^{bc}	0.974^{b}	0.864^{b}	0.796^{c}	0.750^{c}
SBP_6	0.424^{d}	0.519^{d}	0.049^{d}	0.969^{b}	0.809^{d}	0.723^{f}	0.668^{f}
SBP_7	0.429^{d}	0.549^{cd}	0.055^{cd}	0.979^{b}	0.834^{c}	0.749^{e}	0.694^{e}
SBP_8	0.415^{de}	0.545^{cd}	0.072^{ab}	0.960^{b}	0.842^{c}	0.766^{d}	0.713^{d}
SBP_9	0.546^{b}	0.434^{f}	0.070^{b}	0.981^{b}	0.884^{a}	0.822^{b}	0.780^{b}
SBP_{10}	0.584^{a}	0.390^{g}	0.081^{a}	0.975^{b}	0.897^{a}	0.845^{a}	0.808^{a}
AVG	0.401	0.573	0.062	0.978	0.833	0.747	0.690
SD	0.158	0.169	0.011	0.014	0.046	0.074	0.091
S.E.M.	0.005	0.011	0.003	0.008	0.005	0.005	0.004
p-value	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01

Mean in the same column with different (a-h) letters differ significantly ($p<0.05$). [1](a), rapidly degradable DM fraction; (b), slowly degradable fraction; (c), rate constant of degradation of b fraction; PD, Potential Degradability. [2]EDDM, effective degradability of DM. M2, M4 and EDDM6 were calculated a s k = 0.02, 0.04 and 0.06 h^{-1}, respectively. (k is the ruminal outflow rate)

Table 3: *In situ* NDF degradation parameters and effective degradability of various sugar beet pulp samples produced in North-East Iran

	Parameters[1]				Effective degradability[2]		
Samples	a (g g^{-1})	b (g g^{-1})	c (h^{-1})	PD (g g^{-1})	EDNDF2 (g g^{-1})	EDNDF4 (g g^{-1})	EDNDF6 (g g^{-1})
SBP_1	0.003	0.996^{a}	0.047^{cde}	0.998^{ab}	0.701^{bc}	0.540^{def}	0.440^{de}
SBP_2	0.028	0.921^{c}	0.052^{bcd}	0.949^{cde}	0.693^{c}	0.549^{cde}	0.456^{bcd}
SBP_3	0.023	0.982^{a}	0.042^{e}	1.004^{a}	0.686^{c}	0.524^{ef}	0.426^{e}
SBP_4	0.017	0.963^{ab}	0.055^{bc}	0.979^{abc}	0.725^{a}	0.577^{b}	0.480^{b}
SBP_5	0.004	0.989^{a}	0.045^{de}	0.992^{ab}	0.684^{c}	0.523^{f}	0.424^{e}
SBP_6	0.003	0.934^{bc}	0.054^{bcd}	0.937^{de}	0.684^{c}	0.539^{def}	0.445^{cde}
SBP_7	0.005	0.941^{bc}	0.056^{b}	0.945^{de}	0.698^{bc}	0.555^{bcd}	0.460^{bcd}
SBP_8	0.001	0.933^{bc}	0.059^{b}	0.934^{de}	0.700^{bc}	0.560^{bcd}	0.466^{bc}
SBP_9	0.001	0.965^{ab}	0.050^{b}	0.966^{bcd}	0.717^{ab}	0.571^{bc}	0.474^{b}
SBP_{10}	0.005	0.920^{c}	0.074^{a}	0.925^{e}	0.728^{a}	0.600^{a}	0.512^{a}
AVG	0.009	0.954	0.054	0.962	0.701	0.553	0.458
SD	0.010	0.028	0.009	0.029	0.016	0.024	0.027
S.E.M.	0.007	0.011	0.003	0.011	0.006	0.007	0.008
p-value	0.140	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Mean in the same column with different (a-f) letters differ significantly ($p<0.05$). [1]a, rapidly degradable fraction; b, slowly degradable fraction; c, rate constant of degradation of b fraction; PD, Potential degradability. [2]EDNDF, effective degradability of NDF. F2, F4 and EDNDF6 were calculated as k = 0.02, 0.04 and 0.06 h^{-1}, respectively (k is the ruminal outflow rate)

fraction observed in this study was lower than the value reported by Woods *et al.* (2003) (0.573 vs. 0.735), which could be consequence of the processing techniques especially amount of added molasses, as four of the five sources of SBP used in the study of Woods *et al.* (2003) were unmolassed.

While in the present study, only one sample was unmolassed. In the present study, the c-value of DM averaged 0.062 h^{-1} which was considerably <0.12 and 0.084 h^{-1} reported by Woods *et al.* (2003) and De Peters *et al.* (1997), respectively that can be attributed to variation in molasses quantity among various sources.

In addition, the ED of DM varied to some extent which was very close to the previous estimates (Woods *et al.*, 2003). No difference was found among various SBP samples for a fraction of NDF and was lower than one percent of SBP NDF (0.009). The b fraction of NDF varied slightly from 0.920-0.996 with a mean of 0.954 and (±0.028). Fractional degradation rate of NDF ranged from 0.042-0.074 h^{-1} with average of 0.054. In contrast, Firkins (1995) and De Peters *et al.* (1997) reported a much larger range in NDF degradation rate (0.073-0.090 h^{-1} and 0.055-0.116 h^{-1}, respectively).

Fadel *et al.* (2000) reported that the addition of molasses rather than drying process had major effect on NDF disappearance. In this study, considerable variability was found in some *in situ* degradation parameters within SBP sources that are consistent with some other reports (De Peters *et al.*, 1997; Fadel *et al.*, 2000; Woods *et al.*, 2003). Variability in the chemical composition and ruminal degradability of SBP might influence the composition of diet, DM intake and nutrient utilization in the rumen. However, the magnitude of the impact will depend on the contribution of SBP to the total ration.

CONCLUSION

In this study, the chemical composition and *in situ* ruminal degradability parameters of SBP varied considerably among different sources and the fiber fraction including NDF and ADF were the most variable component. Therefore, it is necessary to obtain the chemical composition of SBP from different sources to use these values in precise diet formulation.

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