EVALUATING NUTRITIONAL VALUE OF SUGAR BEET PULP FOR RUMINANT ANIMALS USING IN VITRO GAS PRODUCTION TECHNIQUE

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1 INTRODUCTION

In developing countries, there is a shortage of both energy sources and feedstuffs with acceptable protein content for animal production. In view of the worldwide demand for additional feed sources, the exploitation of traditional crops, which often are grown with low inputs, and are largely adapted to the climatic conditions of the developing countries, would be a step towards better resource utilization. Dumping or burning wastes or agro-industrial by-products present potential air and water pollution problems. High-moisture wastes are also difficult to burn. Many by-products such as grape pomace, apple pomace, pomegranate pulp and sugar beet pulp (SBP) have a substantial potential value as animal feedstuffs (Kebede, et al., 2008; Mirzaei-Aghsaghali and Maheris-Sis, 2008).

Sugar beet pulp (SBP) is a common by-product from the sugar industry (Fig. 1) and in Iran, production of this by-product exceeds 300,000 t/year. Sugar beet pulp is widely used in animal nutrition as a source of energy and is characterized by an increased content of soluble fiber (pectins, glucans), which is fermented primarily to acetate. Therefore, SBP is a candidate for partially substituting cereals in ruminant diets (Fernández et al., 2009; Afshar Mirzaei-Aghsaghali et al., 2008; Kebede, et al., 2008). One study has indicated that, total diet total non-starch polysaccharide (TNSP) digestibility values for SBP as a sole feed were greater than unity, indicating an increase in the digestibility of the cell wall fraction of the lucerne (Murray et al., 2008). Previous in vitro results by the group (Murray et al., 2005) have suggested that the substitution of lucerne with SB appears to have considerable potential to enhance the nutritive value of the total diet. Also, they demonstrated that the addition of SB to lucerne at levels of up to 400 mg/g DM inclusion appears to significantly increase the rate at which Lucerne is degraded, which has important implications for the overall energy balance in the horse (Murray et al., 2006). The incorporation of sugar beet pulp into the diet has been shown to enhance the fermentation of graminaceous cell-wall carbohydrates in other species, such as pigs (Longland et al., 1994). Similar effects have been measured in horses, whereby the degradability of the fibrous fraction of mature grass hay has been enhanced by the addition of SBP to the diet (Moore-Colyer and Longland, 2001). Salman et al., (2008) showed that biological treatments could be used successfully to enrich roughages and improved the nutritive value and animal performance of goats given rations supplemented with sugar beet pulp. Fernández et al., (2009) have suggested that SBP without or with up to 13%...
Vinasse can be fed to ewes because no significant differences were observed between groups when fermentation variables, digestibility, intake, or microbial N flow to the duodenum were measured in vivo.

![Diagram of sugar beet processing](Fig. 1)

The in vivo gas production technique developed by Menke et al (1979) is a very useful tool for the rapid screening of feeds to assess their potential as energy sources for ruminant animals (Blummel and Becker 1997), assuming that the volume of gas produced reflects the end result of the fermentation of the substrate to short chain fatty acids (SCFA), microbial biomass and the neutralization of the SCFA. This technique has been used by Blummel and Orskov (1993) to determine gas production at several incubation times, and values obtained could describe the pattern of fermentation of feed by using the model of Larbi et al (1996). In addition, the application of models permits the fermentation kinetics of the soluble and readily degradable fraction of the feed and the more slowly degradable fraction to be described (Getachew et al 1998). Murray et al., 2006 demonstrated that the gas production technique appears to be a valuable tool for evaluating fibrous feedstuffs and feedstuff combinations, such as lucerne and SB, for equids in vitro, allowing the kinetics of degradation to be studied as opposed to end-point data.

Therefore, the objective of present study is to assess the nutritional composition of SBP by its chemical composition, in vitro fermentation characteristics, organic matter digestibility (OMD), metabolizable energy (ME), short chain fatty acids (SCFA) and net energy for lactation (NE).

2. METHODS AND MATERIAL

2.1. Sugar beet pulp

Randomly fresh SBP samples were collected from the sugar factory in Urmia, Iran. Samples air-dried and ground (1mm and 5mm screen) for chemical analysis and in vitro gas production, and evaluated at the laboratories of Animal Science Research Institute in Karaj.

2.2. Chemical Analysis

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 8h and 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 Georing and Van Soest (1970) with modifications described by Van Soest et al. (1991). Non-Fibrous Carbohydrate (NFC) is calculated using the equation of NRC (2001), NFC = 100 – (NDF + CP + EE + Ash).

2.3. In vitro gas production

Fermentation of SBP samples were carried out with rumen fluid obtained from three mature canulated steers (BW=550 kg) fed twice daily a diet (DMI= 12.37 kg/day) containing lucerne hay (600 g/kg) plus concentrate mixture (400 g/kg) following the method described by Menke and Steingass (1988). Both solid and liquid rumen fractions were collected before the morning feeding, placed in an insulated plastic container, sealed immediately and transported to the laboratory. Approximately 200 mg SBP samples were weighed into the glass syringes of 100 ml. The fluid-buffer mixture (30 ml) was transferred into the glass syringes of 100 ml. The glass syringes containing samples and rumen fluid-buffer mixture were incubated at 39 °C. The syringes were gently shaken 30 min after the start of incubation. The gas production was determined at 2, 4, 6, 8, 12, 24, 48, 72 and 96 h of incubation. All samples were incubated in triplicate with three syringes containing only rumen fluid-buffer mixture (blank). The net gas productions for SBP samples were determined by subtracting the volume of gas produced in the blanks. Gas production data were fitted to the model of Ørskov and McDonald (1979).
\[ P = a + b (1-e^{-ct}) \]

Where \( P \) is the gas production at time \( t \), \( a \) the gas production from soluble fraction (ml/200mg DM), \( b \) the gas production from insoluble fraction (ml/200mg DM), \( c \) the gas production rate constant (ml/h), \( a + b \) the potential gas production (ml/200mg DM) and \( t \) is the incubation time (h).

The ME and OMD contents of SBP by-product were calculated using equations of Menke and Steingass (1988) as:

- ME (MJ/kg DM) = 2.20 + 0.136 × GP + 0.057 × CP
- OMD (g/kg DM) = 14.88 + 0.889 × GP + 0.45 × CP + 0.0651 × XA

Where, \( GP \) is 24 h net gas production (ml/200mg DM), \( CP \) = Crude protein (g/kg DM), \( XA = As\text{h} content \) (g/kg DM), \( NE_l \) (MJ/kg DM) = 0.115 × GP + 0.0054 × CP + 0.014 × EE - 0.0054 × CA - 0.36 (Abas et al., 2005).

Where, \( GP \) is 24 h net gas production (ml/200 mg DM), and \( CP, EE, CA \) and DOM are crude protein, ether extract, crude ash and digestibility organic matter (g/kg DM), respectively.

**3. RESULTS**

**3.1. Chemical composition**

The chemical composition data of SBP by-product are presented in Table 1. The DM content was 954.4 g/kg DM. The CP concentration was 174 ± 0.1 g/kg DM. The NDF and ADF contents were 504 ± 20.8 and 273 ± 0.5 g/kg DM, respectively, whereas the NFC content was 259.9 ± 8 g/kg DM. The EE and ash contents were 6.1 ± 0.1 and 56 ± 0.2 g/kg DM, respectively.

<table>
<thead>
<tr>
<th></th>
<th>DM</th>
<th>CP</th>
<th>NDF</th>
<th>ADF</th>
<th>EE</th>
<th>Ash</th>
<th>NFC</th>
</tr>
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<tr>
<td>SBP</td>
<td>954.4 ± 0.2</td>
<td>174 ± 0.1</td>
<td>504 ± 20.8</td>
<td>273 ± 0.5</td>
<td>6.1 ± 0.1</td>
<td>56 ± 0.2</td>
<td>259.9 ± 8</td>
</tr>
</tbody>
</table>


**3.2. In vitro gas production**

Gas production volumes (ml/200mg DM) in different incubation times (Fig. 2), gas production parameters \((a, b, c)\) and calculated amounts of OMD, ME, SCFA and \(NE_l\) of SBP are presented in Table 2. Gas volume at 24 h incubation (for 200 mg dry samples), soluble fraction \((a)\), insoluble but fermentable fraction \((b)\), potential gas production \((a + b)\) and rate constant of gas production \((c)\) were 78.02, -4.597, 101.5, 96.90 ml/200mg DM and 0.0658 ml/h, respectively. Calculated amounts of OMD, ME, SCFA and \(NE_l\) were 924.3 g/kg DM, 13.8 MJ/kg DM, 1.728 mmol and 8.684 MJ/kg DM, respectively.

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>12</th>
<th>24</th>
<th>48</th>
<th>72</th>
<th>96</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>10.0</td>
<td>18.8</td>
<td>23.67</td>
<td>34.23</td>
<td>57.83</td>
<td>78.02</td>
<td>83.83</td>
<td>93.48</td>
<td>104.98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated parameters</th>
<th>(A)</th>
<th>(b)</th>
<th>(a + b)</th>
<th>(c)</th>
<th>OMD</th>
<th>ME</th>
<th>SCFA</th>
<th>(NE_l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>-4.597</td>
<td>101.5</td>
<td>96.90</td>
<td>0.0658</td>
<td>924.3</td>
<td>13.8</td>
<td>1.728</td>
<td>8.684</td>
</tr>
</tbody>
</table>

\(a\): the gas production from soluble fraction (ml/200mg DM), \(b\): the gas production from insoluble fraction (ml/200mg DM), \(c\): rate constant of gas production during incubation (ml/h), \((a + b)\): the potential gas production (ml/200mg DM), OMD: Organic matter digestibility (g/kg DM), ME: Metabolisable energy (MJ/kg DM), SCFA: Short chain fatty acid (mmol), \(NE_l\): net energy lactation (MJ/kg DM).
4. DISCUSSION

4.1. Chemical composition

The crude protein (174 g/kg DM) was higher than the published results (NRC, 2001; Woods et al., 2003; Murray et al., 2008; Mojtahedi and Danesh Mesgaran, 2009). Contents of NDF and ADF were higher than those reported by Murray et al., 2008 and Fernández et al., 2009. Similarly, the NDF and ADF values agreed closely (504 and 273 vs. 528 and 277 g/kg DM, respectively) with reported by Woods et al., (2003). Arosemena et al., (1995) found lower NDF (358 g/kg DM) and ADF (188 g/kg DM) in SBP. Mojtahedi and Danesh Mesgaran (2009) in a study feeding dried SBP reported lower values for average NDF (345 g/kg DM) and ADF (175 g/kg DM) than those observed in the present study (504 and 273 g/kg DM, respectively). The variability in the content of NDF and ADF could pose a problem because this by-product is often included in the ruminant ration as source of fiber (Mojtahedi and Danesh Mesgaran, 2009). In the present study, the EE content was higher than the Mojtahedi and Danesh Mesgaran (2009) average value of 4.44 g/kg DM. The ash content was higher with some report (Woods et al., 2003; Mojtahedi and Danesh Mesgaran, 2009), while lower than that reported by Arosemena et al., (1995) but agreed closely with NRC (2001). The NFC value was lower (259.9 vs. 362 g/kg DM) than that reported by NRC (2001). Alteration of dietary NFC influences ruminal fermentation patterns, total tract digestion of fiber and milk fat percentage (Sievert and Shaver, 1993; Sutton and Bines, 1987). Batajoo and Shaver (1994) concluded that for cows producing over 40 kg of milk, the diet should contain more than 30 percent NFC, but found little benefit of 42 percent over 36 percent NFC. Nocek and Russell (1988) suggested that 40 percent NFC was optimal in diets for lactating cows from an evaluation of diets based on alfalfa silage, corn silage, and 50:50 alfalfa:corn silage; dietary NFC ranged from 30 to 46 percent. In another study, the percentage and yield of milk protein increased when NFC in the dietary DM was increased from 41.7 to 46.5 percent (Minor et al., 1998). On average, dietary concentrations of NDF and NFC have a high negative correlation (Armentano and Pereira, 1997). Such difference in the chemical composition of SBP can be expected due to the morphology of the original SBP, the amount of molasses added back to the SBP, the extraction technique and probably drying method used (Mirzaei-Aghbashghali and Maheri-Sis, 2008; Mojtahedi and Danesh Mesgaran, 2009).

4.2. In vitro gas production

Gas production volumes (ml/200 mg DM) in different incubation times (Fig. 2), gas production parameters (a, b, c) and calculated amounts of SCFA, OMD, ME and NE of SBP are presented in Table 2. The cumulative gas produced at different time points increased with incubation time. Gas volume at 24 h incubation (for 200 mg dry samples) was about 1.66 times higher than that reported Kilic and Saricicek (2010). However, the variations in the nutrient compositions of feedstuffs are also known to influence in vitro gas production and related parameters (Maheri-Sis et al., 2008). The increase in ash and NFC content reduces gas production (Menk and Steingass, 1988). The negative (a) value for SBP due to delay in onset of fermentation and microbial attachment was in agreement with Kilic and Saricicek (2010), while Insoluble but fermentable fraction (b), potential gas production (a + b) and rate constant of gas production (c) contents in the current study were higher. High rate of gas production (0.0658 vs. 0.04 ml/h) possibly influenced by carbohydrate fractions readily availability to the microbial population.

The OMD content was higher than that reported by Fernández et al., (2009) and Kilic and Saricicek (2010). The different result reported by Kilic and Saricicek (2010) and Fernández et al., (2009) about OMD may be due to differences in variety, environment conditions, concentration of cell wall contents and determining method of OMD. In vitro dry matter and organic matter digestibility were shown to have high correlation with gas volume (Sommart et al., 2000).

The ME content in the present study was higher than reported by Kilic and Saricicek (2010) and NRC (2001). Menke and Steingass (1988) suggested that gas volume at 24 h after incubation has been relationship with metabolisable energy in feedstuffs. It was also illustrated by the negative correlation between ME, OMD and in vitro dry matter digestibility (IVDMD) and the ADF content (r ranging from -0.79 to -0.99) (Happi-Emaga et al., 2011).

The SCFA value of SBP was 1.728 mmol. Short chain fatty acids such as acetic, propionic, butyric, isobutyric, valeric, isoaveric, 2-methylbutyric, hexanoic and heptanoic acid, are produced in several parts of the...
gastrointestinal tract by microbial fermentation of dietary fibre. Acetate, propionate and butyrate, the predominant SCFAs, are readily absorbed and assimilated as a nutrient source by the ruminant. The SCFA account for between 50-70% of digestible energy intake. However, ruminants and monogastric herbivores depend on SCFAs for up to 80% and 30-40% of their maintenance energy requirements, respectively (Freer and Dove, 2000; Tsukahara and Ushida, 2000; Tagang et al., 2010). The NE value of SBP (8.684 MJ/kg DM) was higher than that reported by NRC (2001) (6.150 MJ/kg DM) and about 1.59 times higher than that reported by Kilic and Saricicek (2010).

5. CONCLUSION
The results of current study based on chemical composition, OMD, ME, SCFA and NE indicated that SBP could be as a valuable food industrial by-product in ruminant nutrition. Due to the high digestibility of organic matter and the high SCFA and NE contents, the SBP by-product have a potential primarily as energy supplements to diets low in energy.

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REFERENCES


