Comparing fermentation kinetics of straw from different small cereal grains by using gas production technique

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Abstract:
Chemical composition and gas production of straw from four different small grain cereals was studied. There were significant ($P < 0.01$) differences between straws from different cereals in terms of NDF, ADF and ADL contents, but CP and OM content not affected by source of cereal ($P > 0.05$). There were no significant differences between potential gas production (A), of straws from the four cereals. Results of this study shows that despite some differences in cell wall fractions of straw from these four cereal grains they had similar kinetics of gas production indicating similar fermentation pattern.

Introduction:
In temperate, semiarid, and subhumid areas winter crops and livestock production are the main agricultural activities (Arzadun et al., 2006). Use of winter cereals as a dual-purpose crop (forage and grain) is practiced at varying levels in several areas of the world. Grazing or clipping of dual-purpose cereals during winter can produce high livestock weight gains with minimal impacts on grain yield (Dove et al., 2007).

Straw produced from small grain cereals either in dual-purpose crop system or only grain system are the most important fibrous ingredients used in ruminant diets. Wheat and oat straws believed to have lower nutritive values than barley straws (Tuah et al., 1986). However, Kernan, Crowle, Spurr and Coxworth, (1979) reported similar feeding values for wheat and barley straw.

It has been estimated (Kossila, 1984) that the amount of straw produced for each unit of grain is 0.6 of wheat, 0.72 of barley, 0.78 of oats and 1.2 of rye.

Theander and Aman (1984) reported very low crude protein values for cereal straws, ranging from 24 up to 54 g kg$^{-1}$ dry matter (DM). A higher within species variability for neutral detergent fiber (NDF) and fiber fraction contents was also evident from the results reported by other researchers (Givens et al., 1995). It appears that barley straw, generally considered to have a higher digestibility value, often has a higher NDF and other fiber fractions than wheat straw (Givens et al., 1989).

Oat straw is the most palatable nutritious followed by barley and wheat. The straw of rye has little feed value and it can be used by mixing with other feed as the major roughage for beef cow (Theander and Amman, 1984). The objective of this study was to evaluate the kinetics of fermentation of straw from four different cereal crops (wheat, triticale, oat and rye).

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Materials and methods:
Experimental design and treatments
Straws from 4 different cereals were used in this study. The cereal crops were; wheat (Mordacity cultivar), oat (Dalyup cultivar), triticale (Joanilo cultivar) and rye (Danko cultivar). They were grown under the same agronomic condition in 2009 three replicates in a randomized complete block design at Research Farm of School of Agriculture, Razi University, Kermanshah, Iran.

Chemical composition:
The dried straw was ground using a lab mill to pass a 1-mm screen. Standard methods as described in AOAC (1990) were used for determination of organic matter (OM) and crude protein (CP). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest et al. (1991).

In vitro gas production:
The method used for gas production measurements was as described by Theodorou et al. (1994). All samples were ground to pass a 1mm screen. About 125 mg of each sample was weighed into tubes kept at approximately 39 °C and flushed with CO₂ before use. Each sample was incubated in three replicates. Fifteen ml of buffered rumen fluid (20% rumen fluid + 80% buffer solution) prepared (as described in in vitro digestibility section) and were anaerobically dispensed in each tube at 39 °C. All the tubes were crimped, placed in an incubator at 39 °C, and shaken at regular times. The pressure of gas produced in each tube was recorded using a pressure transducer (Manometer Digital or Testo 512) at 2, 4, 6, 8, 12, 18, 24, 48, 72 and 96 h after the start of the incubation. To estimate the kinetics of gas production, data on cumulative gas volume produced were fitted using the generalized Mitscherlich model proposed by France et al. (1993):

\[ G = A \left(1 - e^{-ct}\right) - d \left(\sqrt{t} - \sqrt{L}\right) \]

Where \( G \) (ml) denotes cumulative gas production at time \( t \), \( A \) (ml) is asymptotic gas production, \( c \) (h⁻¹) are rate constants and \( L \) (h) is lag time. The half-life (\( t_{1/2} \), h) of the fermentable fraction of each substrate was calculated as the time taken for gas accumulation to reach 50% of its asymptotic value. All gas volumes were adjusted to a common sample weight of g DM (Lopez et al., 2007).

Statistical analysis:
Data on chemical composition, gas production parameters from cereals were subjected to one way analysis of variance using the SAS (SAS, 2000) and significance between individual means was identified using Duncan multiple-range test. Data on chemical composition and gas production parameters were subjected to one way analysis of variance using the SAS and significance between individual means was identified using Duncan (Duncan, 1955).

Result and Discussion:
Chemical composition of different cereal straws
The composition of different cereal straws are given in Table 1. Crude protein and OM content were similar for all cereals (\( P > 0.05 \)), but NDF, ADF and ADL content of straws were affected by source of cereal (\( P < 0.05 \)). Straw from Wheat had significantly higher NDF and ADF (\( p < 0.05 \)). Difference between the minimum and maximum ADF content was about 50 g/kg DM. The mean value of NDF
(623.25 g/kg DM) content of straws in this study was slightly lower than the values of 669 g/kg reported by Lopez et al. (2005).

The stage of maturity at harvest also influences straw quality by affecting botanical composition, the extent of lignification, and the amount of nutrient translocation from straw to grain during maturation. Other factors known to affect the composition of straw are variety and cultivar (Kafilzadeh and Maleki, 2011), environmental and seasonal effects, (Mathison et al., 1999), and proportions of different morphological fractions of straw (Agbagla et al., 2001).

<table>
<thead>
<tr>
<th>Cereals</th>
<th>OM</th>
<th>CP</th>
<th>NDF</th>
<th>ADF</th>
<th>ADL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>991</td>
<td>24.6</td>
<td>543&lt;sup&gt;a&lt;/sup&gt;</td>
<td>280&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rye</td>
<td>991</td>
<td>17.7</td>
<td>507&lt;sup&gt;b&lt;/sup&gt;</td>
<td>263&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>17.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Triticale</td>
<td>990</td>
<td>19.3</td>
<td>510&lt;sup&gt;b&lt;/sup&gt;</td>
<td>250&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>17.5&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oat</td>
<td>990</td>
<td>25.4</td>
<td>533&lt;sup&gt;a&lt;/sup&gt;</td>
<td>227&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sig*</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin.

Values in the column with the same letters are not significantly different (P>0.05).

*Sig, Significance ;*P<0.05; **P<0.01; NS, non-significant

**In vitro gas production of different cereal straws**

Gas production parameters of different cereal straws are illustrated graphically in Fig.1. There were no significant (P>0.05) differences among cereals straw in all terms of kinetic parameters. Mean value of potential gas production (A) 281 ml gas g<sup>−1</sup> DM content of straw across all cereals. Results of this study showed that despite differences in cell wall fractions no significant difference in kinetics of fermentation among straws from 4 different cereals was observed. However, more studies on degradability are needed to confirm these results.

![Fig.1. Pattern of in vitro gas production on incubation of different cereals straw](image-url)
References:


