Evaluation of Fungal or Chemical Treatments for Barley Straw in Ruminants Feeding 1-Chemical composition, in vitro, in vivo digestibility and voluntary intake

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ABSTRACT

Sixty male lambs weighing 30.2±1.43kg and 5.5±0.5 months old were used to evaluate the effect of three forms of straw [untreated barley straw (US), a 7% urea treated barley straw (UTS), and fungi (Pleurotus ostreatus) treated barley straw (FTS)] on chemical composition, cell wall constituents, in vitro and in vivo dry and organic matter digestibility and voluntary intake. Urea and fungal treatments significantly (P<0.05) decreased the cell wall components and increased the CP content and in vitro DM and OM digestibility of barley straw as compared with the US. Average daily intake and in vivo digestibility of DM and OM were significantly (P<0.05) higher in UTS and FTS compared to the US. Likewise, the daily intake and digestibility of DM and OM of FTS was significantly (P<0.05) higher than those in UTS. In conclusion, treated straw by urea or fungi, improved CP content, nutrients digestibilities, daily feed intake and nutritive value index.

Keywords: barley straw, urea treatment, fungi, treatment, sheep.

INTRODUCTION

Interest in the effective utilization of agricultural and manufacture by-products is increasing all over the world due to economical factors and pollution. In Iraq agricultural and manufacture by-products are considered as stable source of ruminant feeds (Al-Ani et al., 1991; Hassan et al., 1998; Hassan, 2005) therefore, non traditional feed resources such as crop residues and Agro-industrial by-products must be studied in order to decrease the relay on traditional resources, to fill the gap and to decrease feeding costs. Utilization of by-product can not only be used in favor of solving feed shortage problem but also as a method to control environmental pollution (Zaza, 2004). The major limitations of using these residues as ruminant feeds are their poor in nutrients such as protein content and vitamins and they are rich in fibers with low digestibility, or low palatability and high lignin contents. The degree of lignifications is relatively more important in controlling hydrolysis rate in animal digestive tract. Therefore, chemical and biological treatments are used for many by-products to improving their nutritional value and transforming them into animal feed with high quality (Villas-Boas et al., 2002; Hassan et al., 2008). Many efforts have been employed to remove the lignin and/or to break up the linkages between lignin and carbohydrates and to increase their feed values by chemical and biological treatments (Abo-Eid et al., 2007; El-Shafie et al., 2007 and Abo-Eid, 2008). The possibility of biological methods of straw treatment has a great appeal as an alternative to the use of expensive (in terms of money and energy) chemicals. The main objective of this study was to evaluate the effect of chemical and microbial treatments of barley straws with

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urea or fungi (*Pleurotus ostreatus*, *P.O*) respectively on chemical composition, cell wall constituents, *in vitro* and *in vivo* dry and organic matter digestibility and voluntary intake.

**METRIALS AND METHODS**

**Barley straw preparation**

The barley straw was chopped (approximate 1-2 cm) and divided into three treatments [Untreated straw (US, control), Chemical treated straw with urea (UTS) and Fungal treated straw with *P.O* (FTS)].

**Chemical treatment**

The barley straw used in this experiment was chopped and treated with urea at rate of approximately 70 g / kg DM dissolved into 60% moisture on DM bases (Hassan and Muhamad, 2009). Urea was applied by spraying equal weight of urea solution on straw to provide a treatment level of 70 g urea per kg straw DM. The sprayed straw was mixed well to bring urea solution into contact with straw as completely as possible. The freshly-made material was covered with polyethylene nylon for approximately 4 weeks to absorb moisture and ammonia that formed during the heating process. At the end of the incubation period the polyethylene nylon was removed and sun dried (40 °C) for three days then stored in cotton bags for necessary tests.

**Biological treatment**

The barley straw used in this experiment was chopped and treated with urea at rate of approximately 70 g / kg DM dissolved into 60% moisture on DM bases (Hassan and Muhamad, 2009). Urea was applied by spraying equal weight of urea solution on straw to provide a treatment level of 70 g urea per kg straw DM. The sprayed straw was mixed well to bring urea solution into contact with straw as completely as possible. The freshly-made material was covered with polyethylene nylon for approximately 4 weeks to absorb moisture and ammonia that formed during the heating process. At the end of the incubation period the polyethylene nylon was removed and sun dried (40 °C) for three days then stored in nylon bags for *In vitro* and *in vivo* digestibility trial and necessary tests.

**Feeding trial**

Three treatments of barley straw were tested for digestibility and voluntary feed intake, by sixteen karadi male lambs. They were approximately 5.5±0.5 months old and had an average body weight of 30±1.43 kg. The lambs were randomly allocated to three treatments to receive either US, UTS or FTS. They all received an equal daily allowance of concentrate diet (2 % of the body weight). Formulation and chemical composition of concentrate diet are presented in table 1. The lambs were penned individually indoors on dry earth bedding and the concentrate was supplied once daily (9:00 am). Straw was given *ad libitum* level. The daily feed intake for each treatments diet was tested for a period of 5 weeks and 1 week of collection period. Daily feed intake and refused were measured and sampled during the collection period. Feces from the individual lambs were collected and weighed every morning by fitting lambs with collection bags (Saeed, 2011). The feces were mixed thoroughly by hand and 10% sub-sample was retained and stored at -15 °C. At the end of collection period, the sample of feed and refusal were dried at 65 °C for 48 h and feces were dried at 65 °C until constant weight. The dried samples were ground through 1 mm mash. Aliquots of the samples from each day were pooled and analyzed chemically. The lambs were
weighed at the beginning and the end, and once every 7
days during the experimental period. The trial was
carried out at the animal production field, Dept. of
Anim. Prod. College of Agric. Univ. of Sulaimani,
Bakrago, Sulaimani, Iraq.

Table 1. Formulation and chemical composition of concentrate diet.

<table>
<thead>
<tr>
<th>Ingredients (g/kg DM)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>490</td>
</tr>
<tr>
<td>Yellow corn</td>
<td>390</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>100</td>
</tr>
<tr>
<td>Salt</td>
<td>10</td>
</tr>
<tr>
<td>Min. &amp; vit. mix.</td>
<td>10</td>
</tr>
<tr>
<td>Chemical Composition (g/kg DM)</td>
<td></td>
</tr>
<tr>
<td>DM (g/kg fresh)</td>
<td>946</td>
</tr>
<tr>
<td>OM</td>
<td>918</td>
</tr>
<tr>
<td>TN</td>
<td>21.3</td>
</tr>
<tr>
<td>CF</td>
<td>50.8</td>
</tr>
<tr>
<td>EE</td>
<td>34</td>
</tr>
<tr>
<td>NFE</td>
<td>700</td>
</tr>
<tr>
<td>ME (MJ) *</td>
<td>12.4</td>
</tr>
</tbody>
</table>

*ME (MJ/ kg DM) = 0.012 CP +0.031 EE+0.005 CF +0.014 NFE (MAFF, 1977).

Chemical Analysis and In Vitro Digestibility
Proximate chemical analysis of raw and treated
barley straw, feces and concentrate samples in triplicate
per each determination was carried out for dry matter
(DM), crude protein (CP), ether extract (EE), crude fiber
(CF) and ash content according to the AOAC
samples were analyzed according to Goering and Van
Soest (1970) to determine neutral detergent fiber (NDF),
acid detergent fiber (ADF) and acid detergent lignin
(ADL). Hemicellulose and cellulose were determined
by difference. The In Vitro digestibilities of DM and OM
for untreated and treated barley straw were determined
using the method of Telley and Terry (1963).

Statistical Analysis
The obtained data were analyzed according to
Statistical Analysis System user's Guide (SAS, 2001) for
one way analysis of variance. Separations among means
were carried out by using Duncan's (1955) multiple
range tests.

\[ Y_{ij} = \mu + t_i + e_{ij} \]

Where:  
- \(Y_{ij}\) = Responses of animal i in treatment j, \(\mu\) = Overall
- \(t_i\) = Effect of treatments, \(e_{ij}\) = Experimental error

RESULTS AND DISCUSSION
Effect of Treatments on Chemical Composition
Table 2. Shows the proximate analysis, cell wall
components of US, UTS and FTS. Urea and fungal
treatments had significantly (P<0.05) decreased the OM
but increase the CP content of the straw. These results
are in agreement with those reported by Hassan et al.,
(2008). Similar observation were reported by some
reports (Sing et al., 1990; Fazeali et al., 2006).
However, the CP content of UST was significantly (P<0.05) higher than the CP content in the FTS. So it was expected that the treated straw with high level of urea (7.5 %) to have a higher concentration of CP as compared with straw treated with P.O. (Hassan et al., 2008) or wheat straw treated with another Pleurotus species (Sing et al., 1990). The protein content of mycelium was reported relatively high (Ragunathan et al., 1996), which make it expected that straw treated with fungal mycelium would have higher CP. Both urea and fungal treatments significantly (P<0.05) reduced NDF, ADF and ADL contents of the straw and no differences was observed among urea and fungi to degrade these components. Urea treatment can chemically break the ester bonds between lignin and hemi-cellulose and cellulose, and physically make structural fibers swollen (Chenost and Kayouli, 1997). These effects enables rumen microbes to attack the structural carbohydrates more easily, increasing digestibility, and at the same time increasing palatability of the treated straw (Bo'd'a, 1990). However, in fungi treatment the reduction in NDF, ADF and ADL contents of the straw was due to the natural habitats of P.O. fungi that largely depend on organic carbon (for their energy requirement) including carbon in the form of structural material such as lignocelluloses (Jennings and Lysek, 1996). The losses of NDF and ADF from the barley straw suggested that these fungi could solubilize and utilize the cell wall as carbon source and thus changed the ratio of soluble to un-soluble carbohydrates in the straw (Taniguch et al., 2005). The decrease in NDF and ADF contents of the treated straw has been supported by other reports (Singh et al., 1990; Okanon et al., 2005). Decrease of ADL fungal treated straw had been reported when it was treated with urea or P.O. (Hassan et al., 2008). It could be as a result of lignin degradation enzymes, produced by Pleurotus fungi during the fermentation period (Singh et al., 1990; Boyle et al., 1992).

Urea and fungal treatments also significantly (P<0.05) reduced the concentration of cellulose and hemicellulose. Among the treatments Barley straw treated with Fungal had the lowest hemicellulose content while the cellulose content was similar for both treatments. These reduction in hemicellulose was explained that the fungi depends on lignocelluloses materials, mostly release and utilized the hemicellulose and cellulose as carbohydrate sources, and able to produce laccase, cellulose, xylanase and glycosidase enzymes to degrade lignocelluloses compounds and utilize the releasing sugars(Zadrazil et al., 1996). This degradation was dependent on the substrate used (Abo-Eid et al., 2007), the species of microorganism (Mahrous et al., 2005) and incubation period (Zaza et al., 2008).

**Effect of Treatments on the in vitro Digestibility**

As it is shown in Table 2, urea and fungal treated barley straw were significantly (P<0.05) increased the digestibility of DM and OM. However, Duncan comparison test indicated that barley straw treated with fungi had significantly (P<0.05) higher DM and OM digestibility than urea treated barley straw. The lignin binds with hemicellulosic components of cell wall and through covalent linkages and physical binding, can not prevent accessibility and biodegradation of straw carbohydrate by cellulose and hemicellulytic microorganisms (Karunanandaa and Varga, 1996). Improvement the digestibility of treated straw could be as a result of solubilization of structural polymers by urea or fungi (Boyle et al., 1992), which made it more accessible to the rumen micro organisms. Similar results were reported by (Zadrazil et al., 1996). Beside the culturing conditions, the ability of various strains of fungi in cell wall degradation and digestibility improvement may be different (Tripathi and Yadav, 1992).
Table 2. Proximate analysis, cell wall components and *in vitro* digestibility in untreated, urea and fungi treated barley straw (% of DM basis).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Items %</th>
<th>T1 US</th>
<th>T2 UTS</th>
<th>T3 FTS</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>96.2</td>
<td>94.5</td>
<td>95.1</td>
<td></td>
<td>2.40</td>
</tr>
<tr>
<td>OM</td>
<td>87.8a</td>
<td>84.7b</td>
<td>82.7b</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>CP</td>
<td>4.1c</td>
<td>19.9a</td>
<td>12.4b</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>NH$_3$-N</td>
<td>0.082b</td>
<td>0.716a</td>
<td>0.079b</td>
<td></td>
<td>0.032</td>
</tr>
<tr>
<td>Ash</td>
<td>8.4b</td>
<td>9.8b</td>
<td>11.9a</td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>NDF</td>
<td>81.3a</td>
<td>75.8b</td>
<td>74.16c</td>
<td></td>
<td>0.81</td>
</tr>
<tr>
<td>ADF</td>
<td>54.3a</td>
<td>50.1b</td>
<td>50.2b</td>
<td></td>
<td>1.01</td>
</tr>
<tr>
<td>Lignin</td>
<td>11.1a</td>
<td>9.2b</td>
<td>9.13b</td>
<td></td>
<td>0.039</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>27.0a</td>
<td>25.7b</td>
<td>23.96c</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>Cellulose</td>
<td>43.2a</td>
<td>40.9b</td>
<td>41.07b</td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>IVDMD</td>
<td>45c</td>
<td>53.8b</td>
<td>57.5a</td>
<td></td>
<td>1.53</td>
</tr>
<tr>
<td>IVOMD</td>
<td>44c</td>
<td>51.3b</td>
<td>56.9a</td>
<td></td>
<td>1.51</td>
</tr>
<tr>
<td>ME MJ/ kg DM</td>
<td>6.6c</td>
<td>7.7b</td>
<td>8.54a</td>
<td></td>
<td>0.123</td>
</tr>
</tbody>
</table>

* ME=IVOMD × 0.15 (MAFF,1977) ;  abc Means with the different superscripts within row are significantly (P<0.05) different ; SEM=Standard Error of Mean

**Feeding Trail**

**In vivo Digestibility**

The effect of urea and fungi treatments on the *In vivo* digestibility's of the nutrients of straw and concentrate diets are shown in Table 3. The total tract digestibilities were significantly affected by urea and fungi treatments. Urea and fungal treated barley straw were significantly (P<0.05) increased the *in vivo* digestibility of DM. Similar findings were observed for DM and OM digestibilities. However, barley straw treated with fungi had significantly (P<0.05) higher OM digestibility than the straw treated with urea. The digestibility of CP, CF,
NDF, ADF, hemicellulose and cellulose were also significantly (P<0.05) affected by urea and fungi treatments. When the barley straw was treated with urea and fungi, the digestibility's of the most components were increased. However, lambs fed fungi treated straw showed the higher amounts of digestibility than those lambs fed urea treated straw. These results are supported by the findings of the in vitro digestibility of this study and other reports (Zadrazil et al., 1996; Fazeali et al., 2006; Hassan et al., 2008). A few reports in which digestibility of fungal treated straw were evaluated in vivo. However, Marwaha et al. (1990), and Fazeali et al. (2006), found that treatment of wheat straw by P. sajorcaule and two species of P. fungi led to an increase (P<0.05) in the digestibility of DM, CP, CF and ADF in Jersey calves and sheep respectively. Yoshida et al. (1993) found an increase (by 11%) in the DM digestibility of straw cultivated with P.O.

**Daily intake of barley straw**

The effect of treatments on daily feed intake and nutritive value index of barley straw for 6 weeks period are presented in Table 3. Urea and fungal treated barley straw significantly (P<0.05) increased the daily DM intake. At the same time differences in daily DM and OM intake between urea and fungi treatments were significantly (P<0.05) different. The Duncan comparison test indicated that barley straw treated with fungi had significantly (P<0.05) higher DM intake than the straw treated with urea. The digestible DM and OM intake were also significantly (P<0.05) increased for the urea and fungi treatments. Improvement of intake could be due to the physical (softness of the straw structure) and chemical (cell wall degradation) changes of barley straw through solubilization of structural polymers by urea (Boyle et al., 1992), which made it more accessible to the rumen microorganisms or by solid state fermentation process by fungi. In addition urea and fungal treatment significantly increased the DM and OM digestibility of straw, which increased the voluntary intake. Yamakawa et al. (1992) reported an increase in DM intake of P.O. treated rice straw from 12-13 in normal straw to about 20 g/kg W0.75 in treated straw by sheep. The nutritive value index (NVI) according to (Fazaeli et al., 2006) calculated as follows: (NVI) = Relative intake x DM digestibility (Relative intake = amount of DM intake from treated straw / amount of DM intake from initial straw). In general digestible OM intake and NVI were the highest for fungi treated straw and the lowest for untreated straw. While digestible OM intake and NVI for urea treated straw were in between. In conclusion, Treatment of barley straw by P.O. fungi or urea resulted in a reduction of cell wall and its components and increasing of CP, in vitro and in vivo digestibility’s, daily feed intake and nutritive value index by lambs.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Items %</th>
<th>T1 US</th>
<th>T2 UTS</th>
<th>T3 FTS</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td></td>
<td>59b</td>
<td>69a</td>
<td>73a</td>
<td>2.39</td>
</tr>
<tr>
<td>OM</td>
<td></td>
<td>63c</td>
<td>73b</td>
<td>77a</td>
<td>2.1</td>
</tr>
<tr>
<td>CP</td>
<td></td>
<td>39b</td>
<td>61a</td>
<td>63a</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Table 3. Effect of treatments on the In vivo digestibility of the nutrients Daily intake of barley straw.
CF & 67<sup>a</sup> & 64<sup>b</sup> & 37<sup>c</sup> & 1.36
NDF & 82<sup>a</sup> & 78<sup>a</sup> & 71<sup>b</sup> & 2.3
ADF & 65<sup>a</sup> & 61<sup>b</sup> & 55<sup>c</sup> & 1.04
Hemi-cellulose & 95<sup>a</sup> & 95<sup>a</sup> & 76<sup>b</sup> & 3.2
Cellulose & 79<sup>a</sup> & 73<sup>b</sup> & 63<sup>c</sup> & 236

abc Means with the different superscripts within row are significantly (P<0.05) different, SEM=Standard Error of Mean

### Table 4. Effect of treatments on daily nutrients intake of barley straw during the digestibility trail.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>T1 US</th>
<th>T2 US</th>
<th>T3 US</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI (g/day)</td>
<td>444&lt;sup&gt;c&lt;/sup&gt;</td>
<td>505&lt;sup&gt;b&lt;/sup&gt;</td>
<td>610&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.3</td>
</tr>
<tr>
<td>OMI (g/kg W&lt;sup&gt;0.75&lt;/sup&gt;)</td>
<td>390&lt;sup&gt;c&lt;/sup&gt;</td>
<td>428&lt;sup&gt;b&lt;/sup&gt;</td>
<td>504&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.4</td>
</tr>
<tr>
<td>Digestible DMI (g/day)</td>
<td>34.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.43</td>
</tr>
<tr>
<td>Digestible OMI (g/kg W&lt;sup&gt;0.75&lt;/sup&gt;)</td>
<td>30.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>33.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.39</td>
</tr>
<tr>
<td>Digestible DMI (g/kg W&lt;sup&gt;0.75&lt;/sup&gt;)</td>
<td>262&lt;sup&gt;c&lt;/sup&gt;</td>
<td>348.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>445.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.5</td>
</tr>
<tr>
<td>Digestible OMI (g/kg W&lt;sup&gt;0.75&lt;/sup&gt;)</td>
<td>245.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>308.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>388.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.8</td>
</tr>
<tr>
<td>Nutritive value index (NVI)</td>
<td>19.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.31</td>
</tr>
<tr>
<td>Nutritive value index (NVI)</td>
<td>100&lt;sup&gt;c&lt;/sup&gt;</td>
<td>125&lt;sup&gt;b&lt;/sup&gt;</td>
<td>157&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.2</td>
</tr>
</tbody>
</table>

abc Means with the different superscripts within row are significantly (P<0.05) different,

### REFERENCES


ﺍﻟﻔﻁﺭﻴﺔ ﻋﺒﺩ حﺴﻥﺍﻷﻤﻴﺭﺸﺎﻜﺭ ١ صﺎﺩﻕﻭ ﻣﺤﻤﺩ ﺳﺭﻭﺭ ٢ حﺴﻥﻭ ﺍﻟﺩﻴﻥ ﺧﺴﺭﻭ ٢

٢ ﺘﺒﻥ ﺍﻟﻜﻴﻤﻴﺎﺌﻴﺔ ﺛﺎﻟﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ ﺍﻟﺘﺒﻥ ﻋﻠﻰ ﺛﺎلﺜﺔ 

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