Nutrient content and nutrient availability of sorghum wet distiller’s grain in comparison with the parental grain for ruminants

Ana I Trujillo,* María Bruni and Pablo Chilibroste

Abstract

BACKGROUND: The present study aimed to compare wet sorghum distiller’s grain (WSDG) with sorghum grain (SG) in terms of: (i) chemical composition; (ii) in situ rumen degradation kinetics of organic matter (OM) and neutral detergent fiber (NDF); (iii) crude protein (CP) sub-fractions; (iv) in situ disappearance at 12 and 48 h; and (v) energy values. The WSDG intestinal digestibility (ID) of undegradable crude protein (UCP) was compared to soybean meal (SBM).

RESULTS: Compared to SG, WSDG exhibited: (i) lower (P < 0.01) dry matter and non-fiber carbohydrate content, whereas the other chemical components were higher (P < 0.01); (ii) higher (P < 0.01) degradation rates of OM and NDF and lower (P < 0.01) degradable fraction of OM and NDF; (iii) lower (P < 0.05) contents of CP sub-fractions A, B1 and B2, and higher (P < 0.05) contents of B3 and C; (iv) lower (P < 0.05) protein disappearance at 12 and 48 h and higher UCP; and (v) lower (P < 0.05) energy content. The ID of UCP for WSDG was lower (P < 0.05) compared to SBM.

CONCLUSION: The WSDG as a supplement provides a good source of energy. To enable its use as a protein supplement, further studies should be performed.

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Keywords: sorghum grain; distiller’s grain; nutritive value; degradation kinetic

INTRODUCTION

Sorghum grain is currently used as a renewable fuel source for ethanol production because it offers advantages in comparison with other cereals: its use is less competitive with human feeding and it has a lower carbon footprint. Consequently, the by-product sorghum distillers’ grain is available for livestock feeding. Furthermore, distillers’ grain comprises a relatively inexpensive supplement that provides a good source of energy and protein for cattle in pasture-based production systems.

The main concern regarding distillers’ grain is its highly variable nutritional value. The nutritional value depends on factors associated with the parental grain (i.e. crop, variety, management) and the technological process (i.e. grinding, temperature, extent of starch fermentation) used to obtain ethanol. This variability has been extensively documented in corn distiller’s grain. However, information concerning WSDG as a ruminant feed is scarce. Therefore, it is necessary to investigate further with the aim of obtaining reliable values of nutrient content and nutrient availability. These values are essential for farmers and nutritionists so that they can accurately assess the economic implications of using WSDG as supplement in pasture-based production systems. The present study aimed to compare WSDG with SG in terms of: (i) chemical composition; (ii) in situ rumen degradation kinetics of organic matter (OM) and neutral detergent fiber (NDF); (iii) crude protein (CP) sub-fractions; (iv) in situ disappearance at 12 and 48 h; and (v) total digestible nutrients (TDN), digestible energy (DE) and metabolizable energy (ME) values for ruminants. In addition, the WSDG intestinal digestibility (ID) of undegradable crude protein (UCP) is compared to soybean meal (SBM).

MATERIALS AND METHODS

Three different batches of SG and their related batches of WSDG without solubles were collected from the bioethanol plant located in Paysandú, Uruguay. Animals were handled according to the guide of good practices for the Use of Animals in Research, Testing and Teaching of the Universidad de la Republica de Uruguay.

Chemical analysis

All samples (feedstuffs and in situ residues) for chemical analysis were ground through a 1-mm screen. Dry matter (DM) (AOAC 967.03), ash (AOAC 942.05), ether extract (EE) (AOAC 920.39 A) and nitrogen (N) (AOAC 984.13) contents were determined according to the procedure of the AOAC. The OM was calculated as DM minus ash and the CP was calculated as N × 6.25. The NDF was determined without sodium sulfite and with heat stable amylase and expressed as ash free; acid detergent fiber (ADF)
also was expressed as ash free and lignin (LIG) was determined by
solubilization of cellulose with sulfuric acid. All fibers were deter-
mained according to Van Soest et al. using an ANKOM200 Fiber
Analyzer (ANKOM Technology Corp., Fairport, NY, USA). The acid
(ADICP) and neutral detergent insoluble N (NDICP) values were
determined by measuring N in theADF and NDF residue, respec-
tively. The non-protein nitrogen content and total soluble crude
protein (SCP) were determined according to Licitra et al. The
protein sub-fractions were determined according to the Cornell Net
Carbohydrate and Protein System. Non-structural carbohydrates
were calculated by difference between DM and the remaining frac-
tions as described by the NRC. The content of tannins was deter-
mained using the modified vanillin hydrochloric acid of Maxson
and Rooney. A quantitative analysis of zearalenone was performed in
WSDG and SG by a competitive direct enzyme-linked immunoas-
sorbent assay (Verato® test; Laboratorio Analitico Agro Industrial,
Paysandú, Uruguay).

**In situ ruminal degradation procedure and in vitro intestinal digestion procedure**

Two dry multiparous Holstein cows (711 ± 65 kg of body weight)
fits with rumen cannula (KEHL®, Industria e Comercio LTDA ME, São
Carlos, Brasil) were used to determine OM and NDF degra-
dation kinetics using the nylon bag technique. Fasted cows
grazed on a mixed pasture were supplemented with 2 kg of SG.
The cows were adapted to the diet for 2 weeks prior to the incu-
bation period. Briefly, 6 g DM of each feedstuff were weighed
into a bag (10 × 20 cm) made of N-free monofilament polyester
screen printing fabrics (PET 1000 120-34-W; mean pore size of
45 ± 3 μm; Sefar Inc., Heiden, Switzerland). Four bags of each batch
of feedstuff were incubated in the rumen of the two cows (two
bags per cow per incubation time) for 2, 4, 8, 12, 24 and 48 h.
For 72 h, three bags per cow were incubated because of a low
recovery of incubated residue. Bags were introduced simultane-
ously in the rumen immediately after the SG supplementation and
removed sequentially. Before rumen incubation, bags were sub-
merged (15 min) in warm water (39 °C) and, after collection from
the rumen, were soaked in cold water, and stored at −20 °C. Four
bags per batch of feedstuff were not incubated in the rumen, and
handled similarly to the incubated ones to obtain the zero-time
incubation (t0). Once thawed, bags were washed (three times)
in an automatic machine (Mueller Pop Tank; capacity of 49 L, 30
bags per wash cycle, 3 min with program wash soft without cen-
trification; Mueller Eletrodomésticos Ltda, Santa Catarina, Brazil),
dried in a forced air oven (60 °C for 48 h) and weighed. Dry mat-
ter losses were computed as the difference in weight of the pre-
and post-incubated bags, and expressed as proportion of initial
weight. Residues of replicates per time within cows were pooled
prior to chemical analysis.

Data regarding CP disappearance after 12 and 48 h ruminal
incubation were obtained using an in situ procedure as described
previously for SG and WSDG. Estimation of in vitro intestinal disappearance of UCP for WSDG
was determined using a modified three-step method. Ruminal
degradation residues after 12 h of incubation of WSDG and a
composite sample of SBM (503 CP g kg⁻¹ DM), used as a standard
protein feed, were performed using the previous in situ procedure.
After washing the bags, the ruminal residues were pooled by
animal. Approximately 0.5 g of the residue of WSDG and SBM was
weighted into filter bags (made of N-free monofilament polyester
screen printing fabrics; PET 1000 120-34-W; mean pore size of
45 ± 3 μm; Sefar Inc.). Eighteen bags were incubated in a bottle
containing 2 L of 0.1 N pre-warmed HCl solution adjusted to pH 1.9
with 1 g L⁻¹ of pepsin (P-7000; Sigma, St Louis, MO, USA) for 1 h
with constant rotation in shaker at 39 °C using a Daisy incubator
(Ankom, Fairport, NY, USA). Three empty bags were used as blanks.
After rinsing with cold tap water, bags were reintroduced into the
incubation bottle containing 2 L of pre-warmed pancreatin
solution (0.5 M KH₂PO₄ buffer adjusted to pH 7.75, containing
50 ppm of thymol and 3 g L⁻¹ of pancreatin (P-7545, Sigma), and
incubated for 24 h with constant rotation at 39 °C. After incubation,
the bags were rinsed with tap water until the run-off was clear and
dried at 60 °C for 48 h for determining DM and CP disappearance.

**Energy values**

Based on the values of heat combustion and truly digestible nutri-
ents, the energy contents as TDN, DE and ME at maintenance level
(ME: DE = 0.82) were determined using the summative equation
with in situ coefficients of digestibility of nutrients (disappearance
at 48 h of ruminal incubation) as described by Nuez-Ortin and Yu.

**Statistical analysis**

Ruminal kinetics parameters of OM and NDF were estimated using
a non-linear procedure of SAS (PROC NLIN iterative Marquardt
method).

The disappearance of OM and NDF were fitted with exponential
models described by McDonald (including Lag time, model 1) or
by Ørskov and McDonald (without Lag time, model 2), according
to the best fit:

- **Model 1:**
  \[ Y(t) = a + b \left[ 1 - e^{-ct-Lag} \right] \]
  for \( t > Lag \)
- **Model 2:**
  \[ Y(t) = a + b \left[ 1 - e^{-ct} \right] , t \geq 0 \]

where \( Y \) is ruminal disappearance at time \( t \), \( a \) is the soluble
fraction; \( b \) is the potentially degradable fraction; \( c \) is the fractional
disappearance rate constant at which \( b \) is degraded; \( Lag \) is the lag
time (h) and \( t \) is the time of incubation (h).

Effective rumen degradability (ED) of OM and NDF was estimated
using the equation of Ørskov and McDonald or McDonald, where
ED = \( a + bc/(c + k) \), ED = \( a + bc/(c + k) \) e\(^{-cLag}\), respectively, where
\( k \) is the fractional passage rate that was assumed to be 0.02/h
according to the NRC. All data were analyzed as a completely randomized design using
the Mixed procedure of SAS. The model used for the analysis was:

\[ Y_{ij} = \mu + F_i + B_j + e_{ij}, \]

where \( Y_{ij} \) is an observation of the dependent variable \( y \); \( \mu \) is the population mean for the variable; \( F_i \) is the effect
of feedstuffs (WSDG/SG), \( B_j \) is the batch effect and \( e_{ij} \) is the error
associated with the observation \( i \). The fixed effect is the feedstuff
and the random effect is the batch. When a significant difference
was found, comparisons among means were carried out using the
Tukey procedure. \( P < 0.05 \) was considered statistically significant.

**RESULTS AND DISCUSSION**

**Chemical composition**

Compared to the original grain, the DM content and non-fiber car-
bohydrate content for WSDG were lower, whereas the contents of
EE, NDF, ADI, CP, NDICP, ADICP, LIG and tannins were considerably
higher compared to SG (Table 1). Most of the fermentable car-
bohydrates present in SG were removed from the grain during fer-
mentation process, whereas the remaining nutrients in the WSDG
In addition, the OM degradation for WSDG showed a degradation pattern that was not detected for SG (Table 2). The WSDG NDF kinetic lower (Rumen degradation kinetics and sub-fractions of CP industrial byproducts. The idea that most of CP is bound to the cell wall in these agro-industrial byproducts.21 We found that WSDG is highly susceptible to spoilage as a result of microbial growth (e.g. the ear- alenone concentration was approximately two times greater for WSDG than for SG; data not shown) and this is a limitation to be addressed in the use of this product. The average nutrients content for WSDG are similar to the values reported in the literature, with the exception of NDF. The NDF in the present study showed a value greater than in WSDG plus soluble sugars.21-24 However, our NDF value was closer to values of dried sorghum distiller’s grain obtained previously from the same ethanol plant (608 g kg⁻¹ DM).25 In addition, the NDICP and ADICP in the present study were also in agreement with data obtained by Marichal et al.25 (59% and 38% of CP, respectively) and with the values of NDICP in distiller’s grain from other grains,10,26 reinforcing the idea that most of CP is bound to the cell wall in these agro-industrial byproducts.

Rumen degradation kinetics and sub-fractions of CP

Compared to SG, the a and b fractions of OM for WSDG were lower (P < 0.05), whereas the c fraction was higher (P < 0.05). In addition, the OM degradation for WSDG showed a Lag time that was not detected for SG (Table 2). The WSDG NDF kinetic degradation followed a similar pattern as that for OM degradation. The NDF degradation of SG presented neither a fraction, nor Lag time, whereas NDF degradation of WSDG presented a low value of a fraction and Lag time was fitted (Table 2). The b fraction of NDF was lower (P < 0.05) and the c fraction was higher (P < 0.05) for WSDG than for the parental grain. The reduction in ruminal degradation kinetic parameters of OM and NDF for WSDG versus the original grain is a result of the removal of the highly fermentable carbohydrates during ethanol fermentation. The degradation kinetic pattern of OM for SG corresponds to the kinetics of its main component (non-fiber carbohydrates), whereas the degradation pattern of OM for WSDG reflects the combined degradation kinetics of the cell wall and the CP.

The NDF for the WSDG has good potential for degradation despite increases in the most refractory fractions included in the cell wall. No studies for NDF degradation kinetic parameters of sorghum distillers’ grain appear to be available for comparison with our results. The ruminal kinetics parameters from the present study are in agreement with the kinetics parameters of wheat distiller’s grains reported by Mustafa et al.28 and Nuez-Oritz and Yu.29 The ED of NDF values were also comparable with their reported values. Accordingly, this byproduct is characterized as a readily degradable fiber source.

The protein chemical profile (Table 3) showed that SCP for WSDG and the A, B1 and B2 fractions was lower (P < 0.05) than for SG, whereas that for the B3 and C fractions was higher (P < 0.05). In SG, the predominant fraction of CP was the B2 fraction, whereas, in WSDG, the CP was distributed almost equally between B2, B3 and C fraction (Table 3). Nuez-Oritz and Yu28 demonstrate that chemical sub-fraction values of CP of distillers’ grains are affected by the type of cereal grain used as the fermentation substrate. Particularly, SG contains prolamins known as kafrins, which are proteins similar to zeins. Prolamins have a variable percentage of monomeric proteins and proteins highly cross-linked by disulfide bonds.29 A moderate to high content of proteins linked by disulfide bonds may explain the lowest value of soluble protein of SG in comparison with other cereals grains;28,30 therefore, the

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**Table 1.** Chemical composition of SG and WSDG

<table>
<thead>
<tr>
<th>Item</th>
<th>SG</th>
<th>WSDG</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (DM) (g kg⁻¹)</td>
<td>894 ± 4.1a</td>
<td>333 ± 2.6b</td>
<td>5.61</td>
</tr>
<tr>
<td>Organic matter (OM) (g kg⁻¹ DM)</td>
<td>896 ± 0.1a</td>
<td>987 ± 1.7a</td>
<td>0.73</td>
</tr>
<tr>
<td>Ether extract (EE) (g kg⁻¹ DM)</td>
<td>34 ± 2.7b</td>
<td>110 ± 6.8a</td>
<td>2.97</td>
</tr>
<tr>
<td>Neutral detergent fiber (NDF) (g kg⁻¹ DM)</td>
<td>130 ± 4.3b</td>
<td>702 ± 22a</td>
<td>7.69</td>
</tr>
<tr>
<td>Acid detergent fiber (ADF) (g kg⁻¹ DM)</td>
<td>42 ± 1.8b</td>
<td>283 ± 2.8a</td>
<td>1.29</td>
</tr>
<tr>
<td>Crude protein (CP) (g kg⁻¹ DM)</td>
<td>68 ± 2.3b</td>
<td>314 ± 6.9a</td>
<td>2.95</td>
</tr>
<tr>
<td>Neutral detergent insoluble CP (NDICP) (g kg⁻¹ DM)</td>
<td>24 ± 0.7b</td>
<td>193 ± 11a</td>
<td>4.51</td>
</tr>
<tr>
<td>Acid detergent insoluble CP (ADICP) (g kg⁻¹ DM)</td>
<td>15 ± 3.8b</td>
<td>106 ± 7.2a</td>
<td>3.33</td>
</tr>
<tr>
<td>Non-fiber carbohydrates (NFC) (g kg⁻¹ DM)</td>
<td>776 ± 7.9a</td>
<td>53 ± 21b</td>
<td>8.20</td>
</tr>
<tr>
<td>Lignin (LIG) (g kg⁻¹ DM)</td>
<td>14 ± 2.1b</td>
<td>109 ± 2.4a</td>
<td>1.29</td>
</tr>
<tr>
<td>Tannins (g kg⁻¹ DM)</td>
<td>2.4 ± 0.6b</td>
<td>14.2 ± 2.9a</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Data are the mean ± SD. Means in the same row with different lower case letters are significantly different (P < 0.05).

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**Table 2.** In situ ruminal kinetic parameters of OM, NDF and ED of OM and NDF for SG and WSDG

<table>
<thead>
<tr>
<th>Item</th>
<th>SG</th>
<th>WSDG</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>227a</td>
<td>79b</td>
<td>7.41</td>
</tr>
<tr>
<td>b</td>
<td>739a</td>
<td>550b</td>
<td>27.18</td>
</tr>
<tr>
<td>c (h⁻¹)</td>
<td>0.025b</td>
<td>0.048a</td>
<td>0.004</td>
</tr>
<tr>
<td>Lag (h)</td>
<td>M2</td>
<td>3.03</td>
<td>0.168</td>
</tr>
<tr>
<td>ED (k = 0.02)</td>
<td>698a</td>
<td>413b</td>
<td>5.13</td>
</tr>
<tr>
<td>NDF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>0.0</td>
<td>57a</td>
<td>2.68</td>
</tr>
<tr>
<td>b</td>
<td>793a</td>
<td>695b</td>
<td>30.23</td>
</tr>
<tr>
<td>c (h⁻¹)</td>
<td>0.035b</td>
<td>0.063a</td>
<td>0.005</td>
</tr>
<tr>
<td>Lag (h)</td>
<td>M2</td>
<td>2.78</td>
<td>0.37</td>
</tr>
<tr>
<td>ED (k = 0.02)</td>
<td>503</td>
<td>500</td>
<td>9.75</td>
</tr>
</tbody>
</table>

a Estimated by Model 1: \[Y(t) = a + b[1 - e^{-kt} – Lag(t)]\] or by Model 2: \[Y(t) = a + b(1 - e^{-kt} + e^{-kt})\], t ≥ 0.

1 a, soluble fraction; b, slowly degradable fraction; c, degradation rate constant of b; t, incubation time; Lag, lag time.

M2, model 2 (not Lag time included).

2 ED = a + (bc/(c + k)) or ED = a + (bc/(c + k))e^{-kt} for k = 0.02 h⁻¹. Means in the same row with different lower case letters are significantly different (P < 0.05).

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low SCP in WSDG is expected. Changes in the content of CP sub-fractions in distillers’ grains may be caused by the addition of nitrogen components and/or temperature during the ethanol production process. The WSDG from the ALUR (Alcoholes del Uruguay SA) ethanol plant does not contain additional nitrogen components and/or temperature during the ethanol production process. The WSDG obtained in the present study can be explained by the heat applied during the ethanol process: this causes the formation of complexes between kafirins and other components, reducing the protein digestibility. The effect of ADICP on ID of ruminal UCP of distillers’ grains has been controversial. Although several studies have suggested that ADICP is entirely indigestible and does not contribute to the animal’s metabolizable protein pool, other studies have shown that ADICP of dried distillers’ grains is partially digestible. The CP availability of the WSDG obtained in the present study shows a low to moderate utilization at the intestinal level.

### Table 3. Protein sub-fractions, disappearance of CP after 12 and 48 h of ruminal incubation for SG and WSDG and ID of UCP of WSDG

<table>
<thead>
<tr>
<th>Item</th>
<th>SG</th>
<th>WSDG</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein (CP) (g kg(^{-1}) DM)</td>
<td>68 ± 23 b</td>
<td>314 ± 6.9 a</td>
<td>1.91</td>
</tr>
<tr>
<td>Soluble CP (g kg(^{-1}) CP)</td>
<td>41 ± 2.0 a</td>
<td>23 ± 1.8 b</td>
<td>1.51</td>
</tr>
<tr>
<td>Protein sub-fractions associated with rumen degradation (g kg(^{-1}) CP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraction A (infinitely degradable)</td>
<td>13 ± 0.8 a</td>
<td>7 ± 1.7 b</td>
<td>0.77</td>
</tr>
<tr>
<td>Fraction B1 (rapidly degradable protein)</td>
<td>28 ± 2.0 a</td>
<td>16 ± 1.8 b</td>
<td>1.12</td>
</tr>
<tr>
<td>Fraction B2 (intermediately degradable protein)</td>
<td>606 ± 3.9 a</td>
<td>363 ± 28.8 b</td>
<td>11.8</td>
</tr>
<tr>
<td>Fraction B3 (slowly degradable protein)</td>
<td>131 ± 58.9 b</td>
<td>277 ± 27.9 a</td>
<td>26.6</td>
</tr>
<tr>
<td>Fraction C (undegradable protein)</td>
<td>221 ± 58.6 b</td>
<td>337 ± 15.9 a</td>
<td>24.8</td>
</tr>
<tr>
<td>Ruminal disappearance of CP (g kg(^{-1}) CP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 h of incubation</td>
<td>335 ± 16.8 a</td>
<td>124 ± 31.9 b</td>
<td>13.0</td>
</tr>
<tr>
<td>48 h of incubation</td>
<td>558 ± 48.0 a</td>
<td>208 ± 19.3 b</td>
<td>19.1</td>
</tr>
<tr>
<td>ID of UCP (g kg(^{-1}) UCP)</td>
<td>ND</td>
<td>520 ± 36</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Data are the mean ± SD.

To the best of our knowledge, no values for ID of UCP of sorghum wet distiller’s grains have been reported. Higher variability and greater values of ID of UCP were observed in corn dried distiller’s grain plus solubles (59–77%) by Kleinschmit et al. and in corn, wheat and triticale dried distiller’s grain plus solubles (79.6–95.4) by Cherevková et al. The high value of ADICP content for WSDG in the present study can be explained by the heat applied during the ethanol process: this causes the formation of complexes between kafirins and other components, reducing the protein digestibility. The effect of ADICP on ID of ruminal UCP of distillers’ grains has been controversial. Although several studies have suggested that ADICP is entirely indigestible and does not contribute to the animal’s metabolizable protein pool, other studies have shown that ADICP of dried distillers’ grains is partially digestible. The CP availability of the WSDG obtained in the present study shows a low to moderate utilization at the intestinal level.

### Table 4. Total digestible nutrients, DE and ME values of SG and WSDG

<table>
<thead>
<tr>
<th>Item</th>
<th>SG</th>
<th>WSDG</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total digestible nutrient at maintenance level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDN (g kg(^{-1}) DM)</td>
<td>886 ± 11.3 a</td>
<td>711 ± 28.3 b</td>
<td>12.4</td>
</tr>
<tr>
<td>Predicted energy values at maintenance level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE (MJ kg(^{-1}) DM)</td>
<td>15.49 ± 0.20 a</td>
<td>10.45 ± 0.52 b</td>
<td>0.23</td>
</tr>
<tr>
<td>ME (MJ kg(^{-1}) DM)</td>
<td>12.71 ± 0.16 a</td>
<td>8.57 ± 0.53 b</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Data are the mean ± SD.

### Energy content

Estimations of TDN, DE and ME energy contents for WSDG in the present study were lower (P < 0.05) than the energy values of SG (Table 4). The high-energy value of distillers’ grains can be attributed to the fat and digestible fiber contents. The comparison of the energy values for distiller’s grains with their parental grains is controversial. Some studies have reported that the energy content of distillers’ grain reaches or is higher than the energy content of the parental grain, whereas other studies show opposite results. These differences can be a result of the different industrial production processes and the method used to estimate energy. The energy value of feedstuffs can be calculated from the chemical composition. However, it is questionable whether the chemical approach can accurately estimate energy values of distillers’ grains. For this reason, biological approaches including in situ/in vitro digestibility coefficients are considered better predictors for energy content. The high-energy value for WSDG estimated by this approach is probably a result of both the high content of degradable NDF and by the high content of fat. This coincides with the data reported by Nuez-Ortin and Yu for other distillers’ grains.

### Intestinal digestibility of UCP

The ID of UCP for WSDG (Table 3) obtained in the present study was lower (P < 0.05) than the ID of UCP of SBM used as a standard protein feed (98.2%; data not shown).

### CONCLUSIONS

The results of the present study demonstrate that WSDG is characterized by a high level of degradable fiber and fat. Consequently, it has a high content of energy, although it does not reach the...
parental SG energy value. In addition, WSDG presents higher levels of CP, higher UCP and low to moderate ID UCP as a result of the CP characteristics of the parental grain and the modifications occurred during the ethanol production. Our data suggest that the WSDG can be used as a supplement providing a good source of energy; however, further studies are needed to assess its utilization as a protein supplement because inherent variations in the parental grain and in the industrial process.

ACKNOWLEDGEMENTS

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