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Original article

In situ evaluation of the protein value of soybean meal and processed full fat soybeans for ruminants

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Abstract — The rumen degradation and the intestinal digestion of dry matter (DM) and crude protein (CP) of different samples of soybean meal (SBM) and full-fat soybean (FFS) were determined using in situ techniques. Rumen effective degradability (ED) was determined in three rumen fistulated wethers on nine SBM samples, obtained by solvent extraction (SBM1 to 8) and by expelling (SBM9), and on five FFS samples, treated by extrusion (FFS1 to 4) and by toasting (FFS5). Intestinal digestibility (ID) in the original feed and in the feed residues after rumen incubation for 8 and 24 h was determined in three duodenal fistulated wethers for three samples of SBM (6, 8 and 9) and two samples of FFS (2 and 3). No differences ($P > 0.05$) were observed between the mean values of SBM and FFS for the degradation kinetic parameters and the ED of both DM and CP. On the contrary, differences were found within each feed category. The ED of CP of SBM9 (46.1%) was lower than that of all solvent extracted meals, which ranged from 55.8 to 67.0%. The ED of CP for FFS5 (toasted) was equal to the minimum value of the range of the extruded samples (57.3 to 71.3%). The ED of CP was more closely correlated with the variation of the degradation rate (k_d) ($r = 0.92$; $P < 0.001$) than with the soluble (a) or the potentially degradable (b) fractions ($r = 0.67$ and –0.68, respectively; $P < 0.01$). On the other hand, the degradation parameters of DM and CP were closely correlated ($r = 0.92$, 0.92, 0.81 and 0.79 for ED, k_d, b and a, respectively; $P < 0.001$). The effects of rumen pre-incubation time on the ID of CP, only recorded for three samples, were variable and relatively small in magnitude. The mean values of the ID of CP were similar among samples (from 95.9 to 97.6%). The protein value of soybean products is mainly determined by the ED of CP, since the increases of by-pass digestible protein, associated with its reduction, largely exceed the reductions in the microbial protein synthesis caused by the decreased feed degradability.

soybean meal / full fat soybean / rumen degradability / intestinal digestibility / protein value

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Résumé — Estimation in situ de la valeur azotée du tourteau de soja et des graines de soja chez les ruminants. La dégradabilité théorique (DT) dans le rumen et la digestibilité intestinale (DI) de la matière sèche (MS) et des matières azotées totales (MAT) de différents échantillons de tourteau de soja (TS) et de graines de soja (GS) ont été déterminées par la méthode des sachets de nylon. La DT a été mesurée sur trois béliers munis d'une canule du rumen, pour neuf TS obtenus soit par extraction à l'hexane (TS1 à 8) soit par pression (TS9), et pour cinq GS extrudées (GS1 à 4) ou chauffées (GS5). La DI des aliments et des résidus alimentaires après 8 et 24 h d'incubation dans le rumen a été établie sur trois béliers fistulés au niveau du duodénum, pour trois TS (6, 8 et 9) et deux GS (2 et 3). Pour les résultats de MS et de MAT, aucune différence significative ($P > 0,05$) n'a été trouvée entre les valeurs moyennes des TS et celles des GS, tant pour les paramètres des cinétiques de dégradation que pour la DT. En revanche, au sein d'un même groupe d'aliment, il y a eu des différences. La DT des MAT pour TS9 (46,1 %) a été inférieure à celle des TS obtenus par extraction, qui a varié de 55,8 à 67,0 %. Pour GS5 (chauffée), elle a été égale à la valeur minimale obtenue pour les échantillons extrudés (de 57,3 à 71,3 %). La variation de la DT des MAT a été plus fortement liée à la variation du taux de dégradation (k_d) ($r = 0,92$, $P < 0,001$) qu'à celle de la fraction soluble (a) et celle de la fraction insoluble mais potentiellement dégradable (b) ($r = 0,67$ et $–0,68$, respectivement, $P < 0,01$). Par ailleurs, les paramètres de dégradation de la MS et des MAT ont été étroitement corrélés ($r = 0,92$, 0,92, 0,81 et 0,79 pour la DT, k_d, b et a, respectivement, $P < 0,001$). Sur trois échantillons, le temps de séjour dans le rumen a eu des effets sur la DI des MAT, mais ces effets étaient variables et de faible amplitude. Les valeurs moyennes de DI des MAT pour tous les échantillons ont été similaires et ont varié de 95,9 à 97,6 %. La valeur azotée des produits de soja est principalement déterminée par la DT des MAT. En effet, sa diminution entraîne une augmentation des MAT non dégradées et digérées dans l'intestin qui dépasse amplement les conséquences négatives de la réduction de la synthèse protéique microbienne.

tourteau de soja / graine de soja / dégradabilité théorique / digestibilité intestinale / valeur azotée

1. INTRODUCTION

Soybean products are commonly fed concentrates in high productive ruminants because of their high content of protein and good profile in essential amino acids. Hence, ruminal degradability of protein from the main soybean products, like soybean meal (SBM) and full-fat soybeans (FFS) is extensively studied. In general, these studies indicate that, excluding heat damage cases, the protein value for ruminants of soybean products mainly varies with the degree of heat exposure during the industrial obtention process, since the protein of raw soybeans is highly degradable. However, these studies usually do not consider the possible negative effects of heat exposure on rumen fermentability of the feed and, therefore, of its contribution to microbial protein synthesis, which could counteract to some extent the advantage of more ruminally undegraded feed CP. In addition, the effects of processing soybean products on the intestinal digestibility (ID) of the by-pass protein has not been studied as widely as the protein degradation, in spite of its importance for the feed protein value.

The objectives of this experiment were: (1) for SBM and FFS samples, to study the variation in rumen degradation kinetics and to assess the net protein supply to the intestine, and (2) to study the variation in the ID of the by-pass protein.

2. MATERIALS AND METHODS

2.1. Animals and feeds

Two groups of three Manchega wethers, one fitted with rumen cannulas and the other with "T" shaped duodenal cannulas were used, respectively, to estimate the rumen effective degradability (ED) and the

ID of different soybean products. Rumen degradation was determined for eight solvent extracted meals (SBM1 to SBM8), one expeller meal (SBM9), and five full fat meals which were treated by extrusion (FFS1 to FFS4) or by toasting (dry heat, 80 ºC for 30 min) (FFS5). These samples were from different industrial origins with the aim to be representative of the market variability. The ID was measured for only five samples: SBM6, SBM8, SBM9, FFS2 and FFS3. For SBM, this selection was made based on the processing method and the ED values of CP. In FFS, the extruded samples with extreme values for this parameter were selected. The animals were fed at a DM intake level of 40 g·kg^{-1} LW$^{0.75}$ with a 2:1 grass-legume hay to concentrate diet, distributed in two equal meals (at 8.00 and 16.00 h) from 15 days before starting the experimental periods. Additional details of this diet were previously published [10].

2.2. Experimental procedures

Nylon bags (made by heat-sealing) with a pore size of 46 μm and with inner dimensions of 11 × 7 cm were filled with approximately 3 g (air-dry basis) of feed (ground at 2 mm). The bags were incubated in the rumen of each animal for periods of 2, 4, 8, 16, 24 and 48 h in two series of incubations carried out on different days. In each series, rings of 12 bags were placed simultaneously at the morning feeding in the rumen of each animal and withdrawn at the indicated times. Each ring encompassed a randomly associated pair of tested feeds. After collecting the bags from the rumen, they were rinsed under tap water and frozen (–20 ºC). After thawing, the bags were machine washed (3 times for 5 min), dried for 48 h at 80 ºC in an air-forced oven and analysed for dry matter (DM) and nitrogen (N). The disappearance of material from the bags with the incubation time was described for each animal using the model proposed by Ørskov and McDonald [14]. Effective degradability (ED) was estimated, according to the same authors, using rumen outflow rate values determined for the diet concentrate, labelled with ytterbium (Yb) as described by González et al. [9]. Rumen outflow rates (k_p) were determined by supplying, immediately before the first daily meal, a pulse dose (50 g) of labelled concentrate in the stall of each animal. A total of 18 faeces samples were obtained from the rectum of each animal, the first before supplying the marker and the others between 12 and 120 h afterwards. These samples were dried, milled and analysed for Yb. The evolution of Yb concentration in the faeces with time was described by fitting the model proposed by Grovum and Williams [12] and the rate constant derived from the decreasing phase of the concentrations was used as the k_p value.

The ID of the original feeds and their residues after 8 and 24 h of rumen incubation was studied using the mobile bag technique. To obtain the rumen-undegraded material, two additional sets of bags were incubated in the rumen of each animal and subjected to the freezing and washing treatments described above. Then, the residues were freeze-dried, pooled for each incubation time and the resulting samples were analysed for DM and N. Six sub-samples of about 200 mg of either feed samples or their rumen-undegraded residues were weighed into nylon bags with an approximately round shape (∅ ≈ 3 cm) made by heat-sealing. Two bags of each sample were introduced using a spindle through the duodenal cannula into the small intestine of each wether. No more than six bags were randomly introduced per day in each sheep at a rate of one bag every 20 min. Once recovered from the faeces, the bags were stored, washed and dried as indicated for rumen incubated bags and used intact (residue plus bag) to nitrogen analysis. Blanks containing a known weight of nylon were used to

correct for nitrogen content. The disappearance in the gut of undegraded nitrogen was calculated as the amount of nitrogen lost from the bag divided by the amount of nitrogen in the bag before the intestinal passage.

2.3. Chemical analysis

All samples were ground through a 1 mm sieve before analysis. Dry matter, ash, ether extract (EE) and crude protein (CP; N Kjeldahl × 6.25) were determined following AOAC methods [2]. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the methods of Robertson and Van Soest [15]. Insoluble N in neutral detergent (NDIN) and in acid detergent (ADIN) solutions were determined by Kjeldahl analysis of the NDF and ADF residues, respectively. Rumen incubated residues and intestinal mobile nylon bags were also analysed for nitrogen by the Kjeldahl method. The solubility of CP of the feeds was determined in McDougall buffer during 6 h according to the procedure described by Alvir et al. [1].

The faeces samples were incinerated at 550 ºC and then digested by boiling with a solution of 1.5 M HNO_3 and KCl (3.81 $g \cdot L^{-1}$). The resultant solutions were analysed for Yb by atomic absorption spectrometry (Smith-Hieftje 22, Thermo Harrell Ash, MA, USA) using predosed samples of faeces to prepare common-matrix standards.

2.4. Statistical analysis

The transit and degradation kinetics were fitted using a non-linear regression programme. The analyses of variance for rumen degradation parameters were performed with a simple model examining the effect allocated to feed and animal. For the intestinal digestibility studies, these analyses were carried out within each meal with animals and rumen pre-incubation times as factors in the model. In both studies, the means were compared by a protected LSD (least significant difference) t-test at the $P < 0.05$ level of significance. Correlation and uni- and multivariate (stepwise) regression analyses were also intended for feed evaluation. All the statistical analyses were performed using the Statistical Analysis System for Windows software v 6.12 (SAS Institute Inc., Cary, NC, USA).

3. RESULTS

3.1. Chemical composition and protein solubility of the samples

The chemical composition and the CP solubility of the soybean samples, ranked according to their content of CP within feed types, are presented in Table I. The EE content ($g \cdot kg^{-1}$ DM) in solvent SBM samples varied from 12.0 to 30.7, whereas for SBM9, obtained by expeller processing, it was 84.3. The other chemical parameters for this last sample fell in the range of variation of the solvent extracted meals, except for NDIN, whose value (8.98% of total N) surpassed this range (from 1.92 to 6.93% of total N). Within SBM samples, the most variable fraction was NDF, which ranged from 85.4 to 231 $g \cdot kg^{-1}$ DM. The variation of the CP solubility in the buffer was also wide (from 13.5 to 30.2% of total CP). The chemical composition of the FFS5 sample, processed by toasting, fell within the range of the extruded samples, except for ADIN (5.0% vs. a range from 2.3 to 4.05% of total N). The variation of CP solubility in the FFS samples was also wide (from 10.4 to 21.4% of total CP).

3.2. Rumen degradation

The degradation kinetics and ED of DM and CP are presented in Table II. Estimates of ED are based on k_p values of 5.04 ± 0.31 ($\%{\cdot}h^{-1}$) determined for the diet's concentrate. No significant ($P > 0.05$) differences

Table I. Chemical composition (g·kg^{-1} DM) of soybean samples.

Sample	Ash	CP	EE	NDF	ADF	NDIN[1]	ADIN[1]	Soluble CP[2]
SBM1	67.2	548	17.0	185	79.8	5.73	2.56	16.4
SBM2	69.7	541	12.0	209	87.2	6.92	1.90	13.5
SBM3	63.1	526	26.6	119	92.7	3.19	1.69	19.3
SBM4	65.5	521	28.4	85	65.9	1.92	2.43	30.2
SBM5	66.2	518	12.1	231	103	5.83	2.89	14.6
SBM6	66.1	507	21.6	149	94.8	6.93	2.19	17.5
SBM7	62.4	488	30.7	169	122	4.72	2.51	20.6
SBM8	65.2	484	12.5	155	112	3.18	2.33	27.6
SBM9	63.4	471	84.3	151	94.4	8.98	1.34	16.5
FFS1	50.8	425	216	196	90.7	14.9	3.19	11.2
FFS2	62.4	419	234	163	81.6	11.4	2.30	17.3
FFS3	46.9	414	239	123	70.5	6.19	2.32	21.4
FFS4	48.2	414	249	142	109	13.3	4.05	10.4
FFS5	48.2	424	236	153	96.6	8.91	5.00	11.4

CP: crude protein; EE: ether extract; NDF: neutral detergent fibre; ADF: acid detergent fibre; NDIN: neutral detergent insoluble nitrogen; ADIN: acid detergent insoluble nitrogen. SBM1 to SBM8 are solvent extracted meals; SBM9 is an expeller meal; FFS1 to FFS4 are extruded full fat meals; FFS5 is a toasted full fat meal.
[1] % of total N.
[2] % of total CP.

were observed for these parameters between the mean values of SBM and FFS for DM and CP degradation; therefore, both classes of samples are presented together, with an indication for the differences ($P < 0.05$) between samples. Rumen degradation was extensive in all samples for DM or CP.

For DM degradation of SBM, the variation of the *a* and *b* fractions between samples was relatively low, whereas there were important differences for k_d (from 3.23 to 6.63%·h^{-1}). In FFS samples, the *a* and *b* fractions of DM showed more variation, whereas k_d varied only from 4.80 to 5.76%·h^{-1}. Considering SBM and FFS samples together, the ED of DM was correlated at a similar level with the *a* ($r = 0.68$; $P < 0.01$) or *b* ($r = –0.72$; $P < 0.01$) fractions as well as with the degradation rate ($r = 0.68$; $P < 0.01$).

The degradation parameters for CP showed a higher variability than those for DM. Thus, k_d (%·h^{-1}) varied from 2.36 to 6.00 for SBM and from 4.66 to 6.20 for FFS. The variation for the ED of CP was more associated with the degradation rate ($r = 0.92$; $P < 0.001$) than with the *a* or *b* fractions, which showed similar correlations ($r = 0.67$ and –0.68, respectively; $P < 0.01$). The values of ED of CP were also more variable than those of ED of DM (mean ± CV: 59.6 ± 4.51 vs. 65.1 ± 2.37 for SBM and 62.5 ± 3.61 vs. 66.9 ± 2.93 for FFS).

A close correlation was observed between the k_d values of DM and CP ($r = 0.92$; $P < 0.001$). High correlation coefficients between DM and CP degradation were also observed for the *a* ($r = 0.79$; $P < 0.001$) and *b* ($r = 0.81$; $P < 0.001$) fractions. Therefore,

Table II. Degradation kinetics and effective degradability (ED) of dry matter and crude protein of soybean samples.

	Dry matter				Crude protein			
Sample	*a* (%)	*b* (%)	k_d (%·h^{-1})	ED (%)	*a* (%)	*b* (%)	k_d (%·h^{-1})	ED (%)
SBM1	32.9	67.1	4.82	65.8	19.6	77.6	5.34	59.5
SBM2	33.8	66.2	5.88	69.5	30.1	69.9	5.69	67.0
SBM3	30.3	68.5	5.73	66.5	22.5	76.5	5.23	61.5
SBM4	33.5	66.0	5.67	68.4	22.0	76.1	5.53	62.2
SBM5	30.0	70.0	5.34	66.1	17.8	82.2	5.46	60.7
SBM6	31.5	67.4	4.60	63.6	21.0	77.3	4.16	55.8
SBM7	28.2	70.0	5.63	65.2	22.1	76.1	5.46	61.7
SBM8	26.2	70.3	6.63	65.8	18.5	80.4	6.00	62.1
SBM9	32.2	67.8	3.23	58.7	20.8	79.2	2.36	46.0
FFS1	32.0	68.0	5.41	67.3	25.3	74.7	5.00	64.5
FFS2	34.4	65.6	4.80	66.3	18.3	81.7	4.66	57.3
FFS3	43.5	56.5	5.76	73.7	36.1	63.9	6.20	71.3
FFS4	31.0	69.0	5.26	66.3	24.0	76.0	5.13	62.3
FFS5	23.3	76.7	4.97	61.3	14.9	85.1	5.03	57.3
LSD	3.89	3.72	1.25	2.98	5.26	5.63	1.2	4.45

a and *b* represent soluble and non-soluble degradable fractions, respectively; k_d: fractional degradation rate of fraction *b*; ED: effective degradability (calculated with individual rumen transit rates averaging 5.04%·h^{-1}); LSD: least square difference at $P < 0.05$. For other abbreviations see Table I.

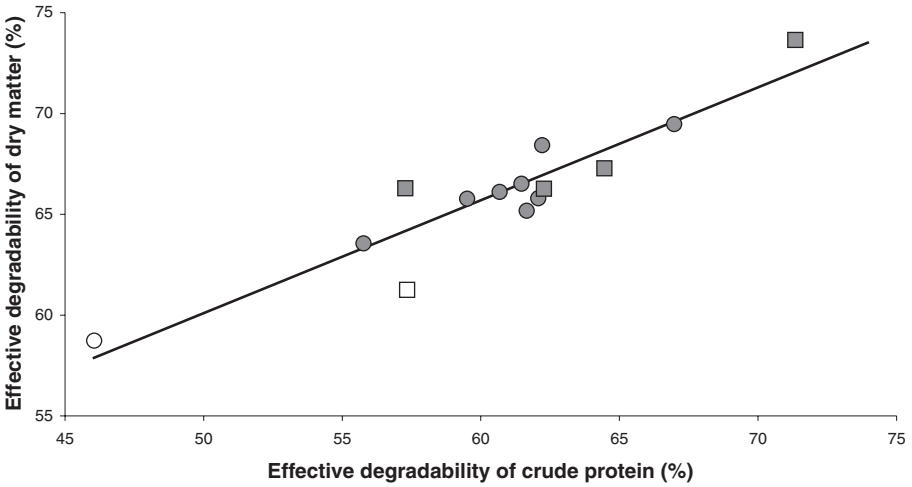

Figure 1. Relationship between the effective degradability of DM and CP in solvent (●) or expeller (○) soybean meal and in extruded (■) or toasted (□) full fat soybean. Regression equation was: Y (%) = 32.1 + 0.56 X (%) ($n = 14$; $R^2 = 0.846$; $P < 0.001$).

Table III. Intestinal digestibility (%) of dry matter and crude protein of soybean samples.

	SBM6	SBM8	SBM9	FFS2	FFS3
Dry matter					
Original feed	90.1[a]	88.6[a]	89.9[a]	93.5[a]	93.2[a]
Rumen incubated residues (8 h)	84.7[b]	79.8[b]	85.1[b]	85.0[c]	77.2[b]
Rumen incubated residues (24 h)	85.4[b]	70.5[c]	87.9[a]	88.8[b]	67.3[c]
SE	1.09	0.87	0.56	0.89	2.10
Crude protein					
Original feed	96.3[b]	96.7	96.8[b]	96.7	97.0[a]
Rumen incubated residues (8 h)	97.9[a]	97.1	97.9[a]	97.3	96.8[a]
Rumen incubated residues (24 h)	98.1[a]	96.7	98.2[a]	97.9	94.0[b]
SE	0.24	0.34	0.24	0.45	0.59

[a,b,c] Means within columns for each item that do not share a common superscript differ ($P < 0.05$); SE: mean standard error. For other abbreviations see Table I.

a close relationship was observed between the ED values of DM and CP (Fig. 1).

No regression equation could be found to predict the ED of CP of soybean products from the chemical composition or the CP solubility. This last variable did not show a correlation with the soluble CP fraction determined with nylon bags, but it was inversely related with the proportion of NDIN ($r = –0.77$; $P < 0.01$).

3.3. Intestinal digestibility

The rumen pre-incubation time had a significant effect ($P < 0.05$) on the ID of DM in all samples (Tab. III). For SBM8 and FFS3, ID decreased strongly across all pre-incubation times, whereas the reduction was relatively small for the other samples. The effects ($P < 0.05$) of rumen pre-incubation time on the ID of CP were only observed in 3 samples (Tab. III), but they were very small and opposite: an increase for SBM6 and SBM9 and a decrease for FFS3. The values of ID of CP were also very similar among samples.

4. DISCUSSION

The ED of both DM and CP differed among the samples of both SBM and FFS. These differences may be associated with the industrial production procedures and the chemical composition of the samples. So, the values found for SBM9, produced by expelling, were lower ($P < 0.05$) than those for solvent extracted SBM samples (Tab. II). This agreed with the observations of Broderick [6] and Goetsch and Owens [8] who found that the pressure extraction reduces ruminal degradability to a greater extent than the solvent extraction, because the heating effects are higher with the former process. In the same manner, the low ED of CP observed for FFS5, processed by toasting, was in the lower limit of the range observed for the extruded FFS samples. This was in line with the observation of Faldet et al. [7] who found that soybean extrusion leads to a lower content of undegraded CP than toasting. On the other hand, the variation recorded within the solvent extracted SBM samples, as well as within the extruded FFS samples, was substantial, which shows that the use of a constant value for the ED of

CP for these categories of feeds could lead to important errors. Furthermore, our results did not support differences in the mean values of ED of CP between FFS and SBM. The present results are "apparent" because the microbial contamination of bag residues was not estimated, but the underestimation of the ED of CP could be considered as very small [4, 11, 16].

The effect of rumen pre-incubation time on the ID of CP of SBM and FFS samples was limited. Previous results with the mobile nylon bag technique also indicated a low variation of ID with the rumen pre-incubation time for SBM [5, 13]. According to González et al. [10], the decrease in the ID of undegraded feed protein with the extent of rumen degradation should be associated with the progressive enrichment of feed particles in undigestible nitrogen compounds (included in NDIN or ADIN). Consequently, ID variations would depend on the concentration of these compounds in the feed as well as of the feed rumen degradation pattern. Therefore, the small effect of pre-incubation on the ID of CP is consistent with processed soybean products having low proportions of undigestible nitrogen compounds and relatively low degradation rates. In addition, part of ADIN could be degraded in the rumen [3], which may perhaps explain the small increase of ID values with longer rumen incubation times in SBM6 and SBM9 samples.

On the contrary, the reduction of ID with longer rumen incubation was net and systematic for DM as a consequence of the limited fibre digestion in the post-ruminal tract. The greatest effect coincided with the fastest DM degradation rates observed for SBM (sample 8) and FFS (sample 3), since a higher degradation rate in the rumen will enlarge the depressive effect of the fibre on the digestion in the intestines.

The low concentration of undigestible nitrogen compounds in soybean products and their high CP contents explain the small variation in ID among all samples, in spite of the important variation in ED of CP in the tested samples. Similar results were obtained for SBM [5, 13, 17, 20] or FFS [19]. Since mobile bags were recovered from the faeces instead of from the ileum, the present results may be somewhat overestimated, as a consequence of microbial contamination in the large intestine. However, different reports on SBM showed that the importance of this error is low: between 0.5 [20] and 2.0 [13, 17] percentage units.

Because the variation in the ID of CP with longer rumen residence time was very small, the effective intestinal digestibility (EID) – corresponding to the rumen outflow of feed CP – can be calculated as the average of the values obtained for the original feed and its residues after 8 and 24 h of rumen incubation. So, the values for EID were 97.4, 96.8, 97.6, 97.3 and 95.9% for SBM6, SBM8, SBM9, FFS2, and FFS3, respectively. As a result, the concentration of rumen undegraded but digestible CP were 43.1, 36.7, 52.6, 41.6, and 27.5% of total CP, respectively, showing an important variability in both feed categories.

The similar values of EID of CP among all tested soybean samples indicate that the reduction of the ED is the main factor responsible for the increase of the feed protein value, as a consequence of the change of the digestion site of proteins from the rumen to the intestine. On the other hand, this reduction of degradability is mainly associated with a deceleration of degradation, which, in turn, should improve the possibilities for the capture of degraded CP by rumen microbes. In this sense, the present results show that expelling is more effective than solvent extraction in relation to the supply of digestible bypass protein from SBM. However, the close correlation observed between the ED of both CP and DM implies that the increase of bypass protein may be associated with a lowered microbial protein synthesis, because the rumen energy supply from the feed would also be reduced. Nevertheless, the net result of both

opposite effects should be largely positive in feeds rich in digestible proteins like soybean products. A comparison of the values for the expelling sample (SBM9) with the mean values of the solvent extracted samples shows an increase of the by-pass protein by 39.4% and a decrease by 11.5% of the fermentable energy, assuming that the ED of OM should be similar to that of DM. This difference is enlarged by the higher ID of protein in soybean than in microbial CP and the high proportion of non-protein nitrogen in microbial CP. An estimation of the net increase of intestinal digestible protein by reducing rumen degradation can be derived from the equation of Figure 1. Thus, based on the specifications of the PDI system [18] and on the mean value of EID observed in the present work (97%), it can be estimated that an increase of ten percentage points of the by-pass CP leads to an increase of the intestinal digested true protein of only 8.75 and 8.53 points for SBM and FFS, respectively. So, in the above comparison between the expeller SBM sample and the mean of solvent extracted samples, the proportion of digestible protein in the intestines will represent 63.5 and 48.7% of total feed CP, respectively. However, larger studies on expeller SBM are necessary to establish the variation in the protein value in this category of meals.

5. CONCLUSIONS

The protein value for ruminants of soybean products is mainly increased by the reduction of the ED of CP, provided that heat damage is avoided. The resultant increases of by-pass protein largely exceed the reductions in the microbial protein synthesis caused by the decreased feed degradability.

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