In Situ Ruminal Degradability of Soybean Meal and Alternative Protein Feeds in Brazil – A Meta-analysis

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ABSTRACT—*Soybean meal is a co-product of widely produced soybean crop. Along with other protein meals, soybean meal contributes to ruminant nutrition. In this study, we performed a meta-analysis to compare the meal degradability parameters of soybean with alternative meals from other plant species. We analyzed ruminal degradability parameters of protein concentrated feeds. The database comprised 50 treatments from 17 studies, which compared soybean meal with cotton seed meal, rapeseed meal and sunflower meal. The potentially degradable fraction and the effective degradability of the dry matter with 5%.h^{-1} passage rate were lower (P = 0.0011 and P = 0.0268, respectively) for the alternative meals. The contents of crude protein (CP) of the alternative meals were lower (P = 0.0012) than those in soybean meal. The readily soluble fraction of CP in water was higher (P = 0.0017) for alternative meals. The potentially degradable fraction of CP was higher (P < 0.0001) for soybean meal. The effective degradability to 8%.h^{-1} passage rate of CP was higher for alternative meals (P = 0.0357) than that for the soybean meal. Partial or total replacement of soybean meal by cottonseed meal, rapeseed, and sunflower might alter the ruminal degradability parameters of the dry matter and crude protein. Soybean meal protein was more readily available to rumen microorganisms and less available to the animal compared to the protein of the alternative meals (cotton, rapeseed, and sunflower).*

Keywords— Concentrated, Metabolism, Microbial Protein, Passage Rate, Ruminants.

1. INTRODUCTION

Brazil is one of the major producers of raw materials in the world; however, there is a considerable need for industrialization in order to add value to the raw materials and generate more employment and income for the country. Among the various raw materials produced in Brazil, soybean is predominant in practically all the regions of Brazil. In practice, owing to high magnitude of soybean production, the soybean meal is a major protein-rich co-product generated, which is used in rations for animal feed. This is because of the ease of obtaining soybean meal, in addition to its ruminal degradability characteristics and intestinal digestibility [1], [2]. Brazil, as well as other countries that stand out in animal production, utilize soybean and soybean meal as the main protein sources used in animal feed [3].

The size of a country, as well as its climatic conditions, enables the production of diverse crops. These crops generate various co-products that can be used in animal feed. These co-products can be used to partially or totally replace soybean meal, depending on their price and/or ease of access [4]. Several protein-rich ingredients have been studied for formulating diets of ruminants. It is, therefore, important to understand the fermentative pattern and nutrient availability of the alternative feeds [5], [6].

The performance of the ruminants is partially dependent on microbial protein production [7]. Numerous strains of bacteria in the rumen are known; these bacteria have been grouped into those fermenting fiber and non-fiber, to facilitate their study [8]. In addition to differences in the degradation of carbohydrates, the different strains also differ in the requirements of nitrogenous constituents [9]. Therefore, it is essential that the feed should release amino acids and/or ammonia in the rumen to allow optimization of the use of nitrogen, thus, maximizing the ruminal metabolism [10].

However, feed with high biological value (with balanced percentage of amino acids contained in the proteins), is more nutritious to the animal than the proteins of microbial origin that should pass through the rumen-reticulum without being attacked and transformed by rumen microorganisms. This is because its digestion in the downstream of the digestive tract (abomasum and small intestine) would favor better performance in the animal [11]. For this purpose, methods like treatment with formaldehyde that would cause high biological value feed, such as soybean meal, to pass intact through the rumen-reticulum are sought [12], [13]. Increasing non-degradable proteins in the rumen, which are digestible in the abomasum and small intestine, by including ingredients, such as soybean meal, might result in increased productivity of the animals that will consume them [14].

In this context, it is essential to understand the digestibility characteristics of the alternative feeds; they may alter metabolism and consequently the animal's performance. Several experiments have been conducted to study the ruminal degradability characteristics of these feeds. Therefore, it is possible to conduct a meta-analysis, considering the different situations of production of alternative feeds, as well as the experimental conditions to derive a statistically relevant inference. The objective of the present study was to perform a meta-analysis to compare the *in situ* degradability parameters of soybean meal and alternative meals from other plant species.

2. MATERIAL AND METHODS

For the construction of the overall database (ODB), scientific works in journals published in Brazil, available in the public domain, were searched. The data was included from experiments published between January 1998 and December 2013. After the collection of data, a thorough reading of all the work was performed for subsequent tabulation of the data, presented in the methodology and results sections, in Microsoft Excel® spreadsheet, following the method of Lovatto et al. [15].

Experiments that involved the parameters for potential degradability of dry matter (DM) and crude protein (CP) were used [16] for estimations using the equation, $p = a + b\ (1 - e^{-ct})$, wherein "p" = potential degradability in time "t"; "a" = water soluble fraction; "b" = insoluble, but potentially degradable fraction; "c" = rate of degradation of the fraction "b"; "e" = natural logarithm. The effective ruminal degradability of dry matter (EDDM) and crude protein (EDCP) were calculated by the formula EDDM and EDCP = a + ((b * c)/(c + k)), where "k" = passage rate of particles in the rumen.

In general, passage rates used in experiments in a country have been recommended by the Agricultural and Food Research Council, AFRC, as follows [17]: $2\%.h^{-1}$ for animals with low levels of nutrition intake at a given maintenance time; $5\%.h^{-1}$ for calves and cows producing less than 15 kg milk per day, beef cattle, and ovine animals with intake less than twice the maintenance; and $8\%.h^{-1}$ for cows producing more than 15 kg milk per day, with intake more than twice the maintenance.

The feeds were classified as protein concentrates, according to the chemical composition concepts effective in Brazil, according to the Ministério da Agricultura, Pecuária e Abastecimento (MAPA). With the processed data, we obtained partial database to compare soybean meal with alternative protein feeds (PDBSM). The PDBSM was composed of 50 treatments from 17 studies: [18-35] comparing soybean meal (*Glycine max*), which is a major protein feed for ruminants, with cotton seed meal (*Gossypium hirsutum*), rapeseed (*Brassica napus*), and sunflower (*Helianthus annuus*). Analyses of variance were performed with the SAS® statistical software [36], using the mixed procedure, considering the scientific paper as a random variable.

3. RESULTS AND DISCUSSION

Statistical difference (P = 0.0011) was observed for the potentially degradable fraction of DM (Table 1). This value was higher for soybean meal, indicating that it was more degradable than the alternative meals [37]. Alternative meals contained higher fiber content in neutral detergent fiber (NDF) and acid detergent fiber (ADF) in its composition that result in reducing the degradability of feed. Future adoption of procedures for removal of seed coat (husk) from seeds, such as rapeseed and sunflower, which are submitted for oil extraction process, should enable obtaining co-products with more favorable characteristics for its use in animal nutrition. This stage of processing is called decortication (removal of the husk) [38] and is common in soybean processing; it allows obtaining soybean meals with 48 to 50% crude protein (CP) in dry matter (DM) instead of the meals with 42-45% CP in DM, ultimately resulting in greater efficiency of oil extraction.

In addition to the seed husk, cotton linter fiber may also be present in the cottonseed meal. Despite being a high degradability fiber, the ingredient residence time in the rumen that depends on the particle size and the rate of passage

can be a factor that makes the cottonseed meal less degradable compared to soybean meal. Similar to cottonseed meal, sunflower meal has high NDF and ADF, and large amount of lignin, which reduces the NDF degradability, can be subjected to decortication [39]. Therefore, besides stimulating the growth of ruminal microflora, alternative meals obtained by the currently used forms of processing might serve as important source of non-degradable protein in the rumen, thereby reducing the loss of nitrogen in the form of ammonia [40]. Moreover, they might complement amino acid supply in the intestine [41], [42]. However, considering that the crude protein is included in the dry matter, the quantity and quality of these alternative protein meals are typically less than those of soybean meal; the opposite would be an ideal condition, such that soybean meal is less degraded at the rumen level to provide more protein of better quality for use at the level of abomasum and small intestine [43], [44].

The effective degradability of DM with 5% h-1 passage rate was less (P = 0.0268) for the alternative meals; however, with the other passage rates (2%.h-1 e 8%.h-1) there was only statistical tendencies, possibly due to the lower number of data. The passage rate in the gastrointestinal tract changes the utilization of feed, due to the variation in the exposure to ruminal fermentation, as well as enzymatic digestion posterior to the rumen [45].

Pereira and Lima [46] studied a modification of *in situ* degradability model proposed by Ørskov and McDonald [16] where the estimate of degradability parameters is given by the method of ordinary minimum squares, which could be replaced by the method of weighted least squares. Using this method might reduce errors arising from the use of the same animals in the experiments and give standard error values of the smaller estimates. With this adjustment, jobs that are statistical trends can present statistical difference. However, this argument is not valid for this study because the data used are the result of several independent works, thus being of different animals. Therefore, statistic tendency of the degradability values of DM at 2%.h-1 and 8%.h-1 remains (Table 1).

Table 1 - Average adjusted dry matter (DM), water-soluble fraction of DM (a), potentially degradable fraction of DM (b), degradation rate of DM (c), and effective degradability to 2, 5, and 8%.h^{-1} of the DM of soybean meal and the alternative protein ingredients.

Parameters	N	Meal		E	P
		Soybean	Alternative		
Dry Matter (% of Natural Matter)	25	88.49	89.45	0.96	=0.2946
Water-soluble fraction (a)*	28	34.12	39.10	4.10	=0.2346
Potentially degradable fraction (b)*	29	66.93	47.65	5.30	=0.0011
Degradation rate (c)*	23	8.86	9.63	2.22	=0.7321
Effective degradability 2%.h^{-1}*†	10	81.97	70.76	5.54	=0.0706
Effective degradability 5%.h^{-1}*†	24	69.49	60.93	3.63	=0.0268
Effective degradability 8%.h^{-1}*†	20	64.86	56.84	3.86	=0.0507

* Values determined using the model of Ørskov and McDonald [16]; † Values determined considering passage rates indicated by the AFRC [17].

The CP levels of alternative meals are lower (P = 0.0012) than those of soybean meal (Table 2), whereas cotton, rapeseed, and sunflower have higher amounts of husk, and is a difficult to eliminate it. The water-soluble fraction of the CP (Table 2) was higher for alternative meals (P = 0.0017) indicating that they first contribute as substrates for microorganisms when they are solubilized. Therefore, when making use of these ingredients the availability of nitrogen should also be considered and synchronized with a rapidly degrading energy source such as soluble sugars to maximize the use of nitrogen at that time [47].

Table 2 - Average adjusted crude protein (CP), water-soluble fraction of the CP (a), potentially degradable fraction (b) of the CP (a), degradation rate of CP (c), and effective degradability to 2, 5, and 8%.h^{-1} of the CP of soybean meal and the alternative protein ingredients.

Parameters	N	Meal		E	P
		Soybean	Alternative		
Crude Protein (% of DM)	28	40.35	28.01	3.41	=0.0012
Water-soluble fraction (a)*	28	24.21	48.52	7.02	=0.0017
Potentially degradable fraction (b)*	29	73.41	40.85	6.21	<0.0001
Degradation rate (c)*	23	7.43	10.32	3.69	=0.4423
Effective degradability 2%.h^{-1}*†	10	70.91	69.53	6.63	=0.8399
Effective degradability 5%.h^{-1}*†	24	48.86	56.40	4.86	=0.1344
Effective degradability 8%.h^{-1}*†	20	42.31	54.91	5.59	=0.0357

* Values determined using the model of Ørskov and McDonald [16]; † Values determined considering passage rates indicated by the AFRC [17];

The potentially degradable fraction of CP (Table 2) showed differences ($P < 0.0001$); it was higher for soybean meal than for the alternative meals. This can be explained by the presence of husk in case of the alternative meals, and a low content of this component in soybean meal. The husk decreases the feed degradability in rumen to increase NDF and more prominently ADF. According to Zhang et al. [48], the lignin present in the ADF, is the main factor that makes the cell wall practically undegradable. This result supports proposing that the soybean meal is more degradable in the rumen, but only when considering the potential degradability of the feed.

When the passage rate was considered, a statistical difference for the effective degradability at $8\%.h^{-1}$ of CP was observed (Table 2), which was higher in the alternative meals ($P = 0.0357$). Thus, it can be said that the CP soybean meal takes longer to be degraded than the alternative meals. In this case, soybean meal provides amino-acids to the animals because the passage rate limits the ruminal degradability of CP of that feed; however, it is important to consider the characteristics of feed intake (percentage of fiber and particle size) [49]. It is noteworthy that animals into production with passing rate of $8\%.h^{-1}$ or more (cows producing than 15 kg milk per day) require thoroughly mixed diet, particularly with diverse ingredients, to ensure all the necessary nutrients, because only this will result in production to be carried out according to the physiological patterns.

Another important observation in this regard, in considering the recommendations of the AFRC [17] with respect to passage rates previously discussed, it is that we must prioritize the supply of soybean meal to high production animals and the alternative meals studied here for low production animals and/or for maintenance. This prioritization is regarded important because of high content and greater protein quality of soybean meal in comparison with the others.

4. CONCLUSIONS

Partial or total replacement of soybean meal by cottonseed meal, rapeseed, and sunflower alter the ruminal degradability parameters of the dry matter and crude protein. The protein from soybean meal is more available to rumen microorganisms and less available to the animal compared to the proteins from the alternative meals (cotton, rapeseed, and sunflower). Therefore, the alternative feeds can be used as a way of increasing the availability of amino acids derived from the diet in the intestine. However, soybean meal provides more amino acids in the intestine than the alternative meals, when considering the effective degradability $8\%.h^{-1}$. Hence, we recommend the partial replacement of soybean meal by alternative meals to dairy cows that produce more than 15 kg/d of milk. For cows producing less than 15 kg/d of milk, we recommend the use of soybean meal as the main source of amino acids in concentrate.

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