*Short communication*

# *In situ* ruminal degradability of protein feeds with distinct physical forms: a meta-analysis

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## Abstract

In ruminant livestock, rumen undegradable protein (RUP) derived from the diet and microbial protein synthesized in the rumen are essential for animal survival, maintenance, growth, production, and reproduction. RUP is influenced by diet composition, physical form, and ruminal metabolism. Here, we aimed to evaluate the ruminal degradability of protein feeds with different physical forms (meal versus grain) through a meta-analysis study. A database, composed of 45 treatments from 12 studies carried out in Brazil, was evaluated to compare the degradability of soybean, sunflower, canola, and flaxseed grains with the meal forms of soybean, peanut, sunflower, cottonseed, and corn gluten. The degradation parameters of dry matter did not differ significantly between meals and grains. However, the effective degradability of crude protein at a passage rate of 2% per hour was higher in meals than in grains. Overall, it was concluded that meal protein might be more degradable in the rumen of animals on an energy intake lower than the maintenance.

**Keywords:** Concentrated feed, metabolism, passage rate, processing, ruminants
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In ruminant livestock, the diet needs to provide all the essential nutrients for a healthy metabolism and also to maximize the production of microbial protein in the rumen (Lean *et al*., 2014). Besides microbial protein, rumen undegradable protein (RUP), primarily found in grains and industrial oil sub-products, is a good source of amino acids, necessary for animal survival, maintenance, growth, production, and reproduction (Van Duinkerken *et al*., 2011; Zhe *et al*., 2014). An effective method for increasing RUP is the processing of protein ingredients in order to change their chemical composition and structure. Structural changes are caused by grinding processes (such as browning and extrusion) using heat and steam (Nasri *et al*., 2008), whereas chemical composition changes are caused by oil extraction processes and/or peeling (Mjoun *et al*., 2010). For instance, seed decortication that involves controlled breaking, pneumatic vacuuming, banging, and gravimetric separation increases the efficiency of soybean oil extraction, leading to high-protein and less fibrous meal (Baker & Stein, 2009). The use of protein concentrates by microorganisms and ruminants depends on diet components, administration methods, and the ruminal metabolism (Broderick & Reynal, 2009). In Brazil, many studies have evaluated the availability of feed protein in grains (unprocessed products) or meals (processed co-products), since there is a wide range of protein feeds available. In this study, we aimed to evaluate various *in situ* rumen degradation parameters of protein feeds with distinct physical forms (grain versus meal) through a meta-analysis study.

A database composed of 45 treatments from 12 scientific studies conducted in Brazil and published between January 1998 and December 2013 was evaluated. All these studies, including Beran *et al*. (2005),

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Fortaleza *et al*. (2009), Garcia *et al*. (2003), Goes *et al*. (2004), Goes *et al*. (2010), Goes *et al*. (2011), Marcondes *et al*. (2009), Martins *et al*. (1999), Oliveira *et al*. (2003), Pereira *et al*. (1999), Silva *et al*. (1999), and Zeoula *et al*. (1999), compared the *in situ* ruminal degradability of protein in grains, such as soybean (*Glycine max*), sunflower (*Helianthus annuus*), canola (*Brassica napus*), and linseed (*Linum usitatissimum*), with that in processed meals such as cotton (*Gossypium hirsutum*) meal, peanut (*Arachis hypogaea*) meal, sunflower meal, soybean meal, and corn (*Zea mays*) gluten. Data were organized in tables on Excel® (Microsoft Corp., Redmond, WA, USA) and the assumptions were set as described by Lovatto *et al*. (2007), namely: definition of objectives, systematization of information, data encoding, data filtering, and data analysis.

All studies used the same parameters for estimating the potential degradation of dry matter (DM) and crude protein (CP) *in situ* as described by Ørskov and McDonald (1979):

$$p = a + b\,(1 - e^{-ct}),$$

where p is the potential degradation at time t;
a is the readily water-soluble fraction;
b is the potentially degradable fraction; and
c is the degradation rate.

Additionally, the effective degradability of DM (EDDM) or CP (EDCP) was estimated as follows:

$$\text{EDDM or EDCP} = a + [(b * c) / (c + k)],$$

where k is the rate of particle passage in the rumen.

In general, the recommended particle passage rates by the Agricultural and Food Research Council (AFRC, 1993) are 2% per hour for animals with energy consumption lower than the maintenance; 5% per hour for calves, cows, producing less than 15 kg of milk per day, and beef cattle and sheep with energy consumption less than twice the maintenance; and 8% per hour for dairy cows, producing over 15 kg of milk per day or with energy consumption more than twice the maintenance.

The feeds were classified based on protein concentration as suggested by the Ministério da Agricultura, Pecuária e Abastecimento, Brazil in 2013. Analysis of variance was performed on SAS version 9.0 (SAS Institute, Cary, NS, USA, 2002) using the mixed model and considering each article as a random variable. Differences were considered significant at $P$ <0.05.

The processing of protein feeds did not have a significant effect on DM degradation, suggesting that protein degradation parameters were similar in meals and grains (Table 1). This lack of differences could be attributed to the fact that grains were used after grinding, which probably destroyed the protein matrix and facilitated oil separation.

**Table 1** Adjusted mean of dry matter (DM), water-soluble fraction (a) of DM, potentially degradable fraction (b) of DM, degradation rate (c) of DM, and effective degradability at 2%, 5%, and 8% DM per hour in grain and meal

| Parameter | Nº Obs. | Physical form | | Standard error |
|---|---|---|---|---|
| | | Grain | Meal | |
| Dry matter (% of natural matter) | 29 | 91.94[a] | 90.41[a] | 0.98 |
| Water-soluble fraction (a)* | 36 | 2.50[a] | 8.06[a] | 4.14 |
| Potentially degradable fraction (b)* | 36 | 75.34[a] | 68.01[a] | 5.59 |
| Degradation rate (c)* | 26 | 6.78[a] | 7.14[a] | 2.13 |
| Effective degradability at 2% per hour*† | 19 | 61.09[a] | 73.22[a] | 6.97 |
| Effective degradability at 5% per hour *† | 29 | 49.17[a] | 56.69[a] | 6.01 |
| Effective degradability at 8% per hour*† | 29 | 40.21[a] | 48.48[a] | 5.89 |

*Values determined as described by Ørskov & McDonald (1979);
† Values determined at different passage rates as suggested by the Agricultural and Food Research Council (1993);
Values in each line with different superscripts differ significantly at $P$ <0.05.

Pereira & Lima (2014) modified the *in situ* degradability model of Ørskov & McDonald (1979), replacing ordinary least squares by weighted least squares and thus, reducing the effect of animals and of measurements at different times. Therefore, the modified model allows the identification of statistical differences in studies evaluating protein degradability, even when the differences are marginal. In the present study, we identified a statistically significant trend ($P$ <0.10) in the effective degradability at a passage rate of 2% DM per hour (Table 1) and the potentially degradable fraction of CP (Table 2). However, the modifications proposed by Pereira & Lima (2014) for the model of Ørskov & McDonald (1979) were not used in our analysis, because the data were derived from previous studies, but it can be used in new studies with ruminal degradability.

**Table 2** Adjusted mean of crude protein (CP), water-soluble fraction (a) of CP, potentially degradable fraction (b) of CP, degradation rate (c) of CP, and effective degradability at 2%, 5%, and 8% of CP per hour in grain and meal

| Parameter | Nº Obs. | Physical form | | Standard error |
|---|---|---|---|---|
| | | Grain | Meal | |
| Crude protein (% of dry matter) | 35 | 32.03[a] | 38.21[a] | 4.33 |
| Water-soluble fraction (a)* | 25 | 1.02[a] | 2.30[a] | 3.20 |
| Potentially degradable fraction (b)* | 36 | 42.08[a] | 56.05[a] | 8.18 |
| Degradation rate (c)* | 26 | 7.22[a] | 12.87[a] | 4.21 |
| Effective degradability at 2% per hour*† | 19 | 31.22[b] | 57.85[a] | 11.14 |
| Effective degradability at 5% per hour *† | 29 | 23.99[a] | 30.84[a] | 7.54 |
| Effective degradability at 8% per hour*† | 29 | 18.54[a] | 26.13[a] | 6.92 |

*Values determined as described by Ørskov & McDonald (1979);
† Values determined at different passage rates as suggested by the Agricultural and Food Research Council (1993); Values in each line with different superscripts differ significantly at $P$ <0.05

The potentially degradable fraction of CP in meal (P =0.0965) tended to be higher than that in grain, a difference that could be attributed to processing. It is known that oilseed processing usually increases the proportion of digestible components in meals and yields sub-products that are used as protein supplements for animals (Can *et al*., 2011).

The effective degradability of CP at a passage rate of 2% per hour was significantly higher (P =0.0274) in meal than in grain, showing that meal protein might be more degradable than grain protein in the rumen of animals with energy consumption lower than the maintenance. These results could be explained by the relatively lower DM intake of animals at maintenance and the relatively higher feed residence time in the rumen, which improves the degradability of feed (Maggioni *et al*., 2009). Other factors that might affect the degradability of protein could be the presence of lipids and hull in the feed. The hull is the fibrous portion of grain that reduces the degradability of feed, whereas lipids facilitate bacterial degradation (Doreau *et al*., 2009) by slowing down the rate of passage of digesta. Additionally, Maia *et al*. (2010) reported that biohydrogenation, a process in which some bacteria break the double bonds of unsaturated fatty acids and convert them into saturated fatty acids, prevents the negative effects of polyunsaturated fatty acids. Thus, except for nitrogen and energy, it also increases the production of RUP, which is an important source of amino acids in the intestine (Maxin *et al*., 2013).

Soybean meal is a typical processed feed product widely used as a protein source in ruminants. The oil extraction process improves protein degradability and favors amino acid intake in the intestine without impairing the availability of nitrogen in the rumen or microbial growth (Castro *et al*., 2007). Furthermore, microbial protein usually has a better amino acid balance than protein in oilseeds; however, the protein that is derived from diet is an important source of amino acids suitable for post-rumen digestion and intestinal recovery (Wang *et al*., 2016).

Highly balanced proteins are often found in meals produced under high temperature conditions (Doiron *et al*., 2009), such as in toasted soybean meal, or by the use of tannins (Oliveira & Berchielli, 2007; Andrade-Montemayor *et al*., 2009). Mezzomo *et al*. (2015) reported that the use of soybean meal treated with tannin in beef cattle reduced the consumption rate, but improved the feed conversion rate, increasing the amount of muscle and decreasing the amount of fat without any change in carcass weight. These results were attributed to the increased amount of RUP and the consequent increase in the amount of metabolizable protein. However, the use of tannins increases the production cost and requires a detailed cost-benefit analysis.

In summary, our meta-analysis revealed that the degradability of DM was not affected by the processing of protein-rich ingredients. However, the effective degradability of CP at a passage rate of 2% per hour was influenced by processing, suggesting that meal protein is more degradable than grain protein in the rumen of animals with energy intake lower than the maintenance.

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**Authors' contributions**
MB, JPV and AACT idealized the study and wrote the manuscript. DRMA performed the statistical analysis. DRMA, IMPH and ATN did the scientific review of the manuscript.

**Conflict of interest**
All the authors of this study declare that they do not have any type of conflict of interest.
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