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Comparison of Rumen Undegradable Protein Content of Conventional and Organic Feeds

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Summary with Implications

Knowledge of a feed ingredient's protein content and degradability is important in formulating diets for growing cattle. However, there are limited data on protein composition and digestibility of feeds produced in an organic production system. Two studies were conducted using an in situ mobile bag procedure to compare feeds raised in organic and conventional production systems for rumen undegradable protein (RUP) content and digestibility. No differences were observed for RUP content between organic or conventional sources for dehydrated alfalfa, field peas, or expeller pressed soybean meals. Solvent extracted soybean meals were lower in RUP content than expeller pressed soybean meals. Digestibility of RUP was lower for conventional dehydrated alfalfa compared to organic dehydrated alfalfa in Experiment 1 but not in Experiment 2; no other differences in RUP digestibility were observed between conventional and organic feeds. Expeller pressed soybean meals were consistently highest in digestible RUP as a percent of DM with the exception of SoyPass, a soybean meal treated to increase RUP content. These data suggest that feeds produced in organic or conventional systems are not different in RUP content or digestibility and that processing method appears to have greater effect on protein degradability than the production system.

Introduction

Balancing protein in cattle diets is typically done using the metabolizable

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protein (MP) system. Metabolizable protein is the summation of the protein available to cattle from different sources, including the protein from feed that escapes microbial degradation in the rumen, called rumen undegradable protein (RUP), and the protein from microbes that pass out of the rumen with the ingested feed, called microbial crude protein. The portion of crude protein (CP) from feed that is degraded by microbes is rumen degradable protein (RDP) and contributes to the microbial crude protein supply. Protein requirements are affected by age and growth; for example, animals that are younger or growing more rapidly have greater MP requirements than mature or slower growing cattle. High forage diets typically do not meet the metabolizable protein requirement of lightweight growing calves, particularly when grazing or fed ensiled forages. While the crude protein content of grazed forages may be high, the majority of that CP is highly degradable in the rumen. Therefore, RUP content is low, and the digestibility of that RUP is low relative to concentrates such as soybean meal. Lightweight calves are small enough that the microbial crude protein supply that washes out the rumen with ingesta may be insufficient to supply protein to support adequate gains. Additional RUP supplied in order to meet MP requirements will improve performance of lightweight growing cattle in most situations.

Due to the requirements of organic beef production, cattle must have access to pasture at a minimum of 30% of their intake throughout the growing season. Because of the grazing requirement, calves raised in an organic production system would likely benefit from supplemental RUP. However, there are limited data examining organic feeds for CP content, and no data available examining RUP content or digestibility. The objective of these two experiments was to evaluate and compare feeds grown in conventional and organic production systems for RUP content and digestibility. Knowing RUP content and digestibility will allow for fine-tuning of supplementation programs.

These organic protein sources are quite expensive relative to conventional feeds, so supplementing to meet yet not exceed requirements is beneficial.

Procedure

Two ruminally cannulated steers paired with two ruminally and duodenally cannulated heifers were utilized for Experiment 1, and two ruminally and duodenally cannulated heifers were used for Experiment 2. Animals were fed twice per day at 7:30 AM and 3:30 PM a diet consisting of 30% alfalfa haylage, 65% dry rolled corn, and 5% supplement at 1.8% of BW on a DM basis. Experiment 1 compared organic and conventional sources of dehydrated alfalfa pellets, field peas, fish meal, and soybean meal (SBM). Additionally, conventional dry rolled corn, alfalfa haylage, heat damaged dehydrated alfalfa pellets, dried distillers grains plus solubles (DDGS), high protein DDGS, roasted field peas, raw and roasted whole soybeans, and SoyPass, a treated soybean meal high in RUP, were also evaluated. The field peas and soybeans were roasted at 80% DM in a forced air oven set to 150 °C for 30 minutes. The conventional SBM in Experiment 1 was processed using a solvent extraction method while organic SBM was expeller pressed, a process that results in heating to higher temperatures than a solvent extraction process. Experiment 2 compared organic and conventional dehydrated alfalfa pellets, fish meal, and SBM. Conventional dry rolled corn, field peas, and alfalfa haylage as well as an organic flax meal were also evaluated. Both solvent extracted and expeller pressed conventional SBM was examined in Experiment 2. The number and type of samples of each feed examined in both experiments are shown in Table 1.

Dehydrated alfalfa pellets, soybeans, dry rolled corn, and field peas were ground through a Wiley Mill using a 6 mm screen, while the fish meals, soybean meals, and flax meal were not ground. The alfalfa haylage was freeze dried and ground

Table 1. Feed ingredients analyzed for RUP content and digestibility using *in situ* procedures

Item	Number of Samples ¹			
	Experiment 1		Experiment 2	
	CON	ORG	CON	ORG
Dry Rolled Corn	1	-	1	-
DDGS ²	1	-	-	-
High Protein DDGS	1	-	-	-
Field Peas	1	1	1	-
Roasted Field Peas	1	-	-	-
Solvent Extracted Soybean Meal	1	-	2	-
Expeller Pressed Soybean Meal	-	1	2	3
SoyPass	1	-	-	-
Raw Whole Soybeans	1	-	-	-
Roasted Whole Soybeans	1	-	-	-
Fish Meal	1	1	4	3
Alfalfa Haylage	1	-	1	-
Dehydrated Alfalfa ³	1	1	3	3
Heat Damaged Dehydrated Alfalfa ³	1	-	-	-
Flax Meal	-	-	-	1

¹ CON = Conventional, ORG = Organic; any feed with multiple samples had samples procured from different sources and/or from different production runs from the same facility

² DDGS = Dried Distillers Grains Plus Solubles

³All dehydrated alfalfas were pelleted

through a Wiley Mill using a 2 mm screen. All samples were analyzed for CP content via combustion using a Flash Smart™ Elemental Analyzer. After grinding, all feeds were weighed into 5 × 10 cm and 10 × 20 cm dacron bags with a pore size of 50 µm in the amounts of 1.25 g and 5.00 g of as-is sample, respectively. Each sample had 16 of each size of bag for use in the mobile bag procedure, with an additional 4 bags of each size withheld from incubations for use in washout testing. Bags of both sizes were divided equally between animals and incubated in the rumen for 16 hours, replicated over two days.

After rumen incubation, all bags were removed and washed in a washing machine for five cycles of one minute of agitation and two minutes spin. Washout bags were divided equally between the two days. After washing, the 10 × 20 cm bags and both sizes of washout bags were dried in a forced-air oven at 100°C for 24 hours, weighed immediately upon removal, and after at least 24 hours of air-equilibration to obtain DM content. Residues were composited by animal within day and ground through a Cyclotec Sample Mill using a 1 mm screen

and analyzed for CP to measure RUP content. Percent CP washout was determined by calculating the amount of CP that left the washout bags during the wash procedure and dividing by the amount of CP that was weighed into the bags.

Immediately after washing, the 5 × 10 cm bags were placed in a pepsin/HCl solution warmed to 37°C and gently stirred every 15 minutes for 3 hours. These bags were then removed, sorted into groups by animal and day, and frozen. When ready for duodenal insertion, the 5 × 10 cm bags were thawed and inserted in the duodenum of the corresponding heifer and retrieved from the feces approximately 18 hours after insertion, rinsed with distilled water, and frozen again. Once all bags were collected they were thawed, dried, and weighed using the same procedure for the 10 × 20 cm bags described above to obtain dry matter content. These bags were then composited by animal (Experiment 1) or by animal within day if enough residue was present (Experiment 2). The composited residues were ground in the same manner as residues from the rumen incubation process and analyzed for CP to calculate RUP digestibil-

ity. Digestible RUP content was calculated using the following equation: Digestible RUP Content = CP% × RUP Content% × RUP Digestibility%. This expresses the proportion of DM that is digestible RUP and is useful in comparing samples of differing CP and RUP content. In both experiments, the fish meals were so degraded after passing through the entire animal that insufficient residue was left for CP analysis, so no data are available for RUP digestibility or digestible RUP content of the fish meals, but all protein digested or washed out of the bag if no residue is left following intestinal insertion.

All data were analyzed using the Glimmix procedure of SAS (9.3, SAS Institute Inc., Cary, NC) with the Tukey adjustment applied. Sample was the experimental unit. Animal was considered a random effect, and day was considered a fixed effect. For washout analysis, day was considered a fixed effect and bag size was a random effect. Means of proportions were determined using the ILINK option. Differences were significant at an α value less than or equal to 0.05.

Results

For both experiments, there were no interactions ($P \geq 0.28$) of sample and day for any variable. Significant differences in RUP content, RUP digestibility, digestible RUP content, and CP washout were observed between samples ($P < 0.01$; Table 2, Table 3). In examining the direct comparisons of organic and conventional feeds, in Experiment 1 organic expeller pressed SBM had greater ($P \leq 0.05$) RUP content compared to conventional solvent extracted SBM but both were lower ($P \leq 0.05$) in RUP content than SoyPass (Table 2). No differences in RUP digestibility were observed between SBM ($P > 0.05$) but SoyPass had the highest digestible RUP content, followed by the organic SBM, and the conventional SBM was lowest ($P \leq 0.05$). Organic and conventional dehydrated alfalfa pellets did not differ ($P > 0.05$) in RUP content, but RUP digestibility was significantly greater for organic dehydrated alfalfa pellets than conventional dehydrated alfalfa pellets ($P \leq 0.05$); digestible RUP content was not different between organic and conventional dehydrated alfalfas ($P > 0.05$). No differenc-

Table 2. Experiment 1. Comparison of in situ RUP content and digestibility of organic and conventional feeds

Sample ²	Item ¹				
	Initial CP, % of DM	RUP Content, % of CP	RUP Digestibility, % of RUP	Digestible RUP Content, % of DM	Washout, % of CP
Alfalfa					
<i>Haylage</i>	18.1	10.5 ⁱ	9.5 ^h	0.2 ^j	58.3 ^b
<i>DEHY CON</i>	18.1	15.0 ⁱ	44.2 ^f	1.2 ^{ij}	31.0 ^{de}
<i>DEHY ORG</i>	23.0	16.6 ⁱ	70.5 ^c	2.4 ^{hi}	36.8 ^d
<i>HD CON</i>	21.2	53.4 ^{bc}	17.7 ^g	1.9 ⁱ	25.2 ^{ef}
Corn and Corn Byproducts					
<i>DRC</i>	9.2	38.1 ^{gh}	67.0 ^c	2.1 ⁱ	10.8 ^{gh}
<i>DDGS</i>	35.2	28.5 ⁱ	84.2 ^d	7.5 ^{fg}	27.3 ^e
<i>HP DDGS</i>	37.1	59.9 ^b	93.5 ^{bc}	18.7 ^c	5.3 ^{ij}
Field Peas					
<i>CON</i>	22.4	33.6 ^{gh}	91.5 ^{cd}	6.1 ^{fg}	18.6 ^f
<i>ORG</i>	25.0	41.0 ^{def}	93.4 ^{bc}	8.6 ^{ef}	7.3 ^{hi}
<i>RST CON</i>	22.3	25.9 ^h	91.6 ^{cd}	4.5 ^{gh}	11.2 ^{gh}
Fish Meal ³					
<i>CON</i>	69.7	16.5 ^{efg}	-	-	79.2 ^a
<i>ORG</i>	68.1	46.8 ^{cde}	-	-	49.6 ^c
CON Soybeans					
<i>Raw</i>	37.5	44.9 ^{cde}	96.7 ^{abc}	14.9 ^{cd}	5.7 ^{ij}
<i>Roasted</i>	37.0	50.5 ^{bcd}	97.3 ^{ab}	16.3 ^{cd}	3.1 ^j
Soybean Meal					
<i>SoyPass</i>	48.9	78.5 ^a	98.9 ^a	33.9 ^a	9.5 ^{ghi}
<i>SOLV CON</i>	51.2	27.3 ^h	98.5 ^a	12.5 ^{de}	11.6 ^{gh}
<i>EXP ORG</i>	47.0	60.0 ^b	98.7 ^a	26.7 ^b	12.3 ^g
SEM	-	2.08	2.00	1.05	1.58
P-Value					
<i>Sample</i>	-	< 0.01	< 0.01	< 0.01	< 0.01
<i>Day</i>	-	0.08	-	-	0.54
<i>Sample*Day</i>	-	0.54	-	-	0.96

¹ CP = Crude Protein, RUP = Rumen Undegradable Protein

² CON = Conventional, ORG = Organic, DDGS = Dried Distillers Grains plus Solubles, DEHY = Dehydrated, DRC = Dry Rolled Corn, HD = Heat Damaged, HP = High Protein, SOLV = Solvent Extracted, EXP = Expeller Pressed; all feeds are conventional unless otherwise specified

³ Fish meal had no residue remaining after retrieval from feces for crude protein analysis

^{a-j} Means within a column with different superscripts are different ($P < 0.05$)

es between conventional and organic field peas were observed for any variable ($P > 0.05$). Organic fish meal was significantly ($P \leq 0.05$) greater in RUP content compared to conventional fish meal. However, conventional fish meal had significantly greater CP washout than organic fish meal ($P \leq 0.05$), which may have affected the RUP content values. Organic SBM was similar in RUP content to high protein DDGS ($P > 0.05$)

and had the second highest digestible RUP content value in the experiment.

In Experiment 2 (Table 3), organic fish meals were consistently greater in RUP content compared to conventional fish meals ($P \leq 0.05$). No differences were observed between conventional and organic dehydrated alfalfas in RUP content, RUP digestibility, digestible RUP content, and CP washout ($P > 0.05$). Conventional solvent extract-

ed SBM were lower in RUP content and digestible RUP content compared to any of the expeller pressed SBM ($P \leq 0.05$), but conventional and organic expeller pressed SBM were similar in RUP content and digestible RUP content ($P > 0.05$). All SBM samples were similar in RUP digestibility ($P > 0.05$).

In both experiments, the fish meal bags did not have enough residue for CP analysis

Table 3. Experiment 2. Comparison of *in situ* RUP content and digestibility of organic and conventional feeds

Sample ²	Item ¹				
	Initial CP, % of DM	RUP Content, % of CP	RUP Digestibility, % of RUP	Digestible RUP Content, % of DM	Washout, % of CP
Dry Rolled Corn	8.9	42.8 ^{cde}	73.3 ^d	2.8 ^g	19.8 ^j
Field Peas	24.7	47.3 ^{cd}	88.2 ^b	10.2 ^d	34.0 ^{gh}
Flax Meal ORG	39.8	19.7 ^h	76.0 ^d	6.00 ^{ef}	26.1 ^{hi}
Fish Meal ³					
CON 1	66.7	24.8 ^{gh}	-	-	66.4 ^b
CON 2	71.9	19.5 ^h	-	-	77.9 ^a
CON 3	64.5	29.8 ^g	-	-	53.1 ^c
CON 4	67.4	31.5 ^{fg}	-	-	49.5 ^{cd}
ORG 1	69.0	49.8 ^{bc}	-	-	47.3 ^{cde}
ORG 2	72.4	57.2 ^{ab}	-	-	38.6 ^{ef}
ORG 3	68.0	47.6 ^{cd}	-	-	51.3 ^{cd}
Alfalfa					
Haylage	20.3	18.5 ^h	43.7 ^e	1.6 ^g	70.6 ^{ab}
DEHY CON 1	19.1	46.0 ^{cde}	77.2 ^{cd}	6.7 ^{ef}	35.5 ^{fg}
DEHY CON 2	19.6	40.5 ^{de}	78.6 ^{cd}	6.2 ^{ef}	39.4 ^{ef}
DEHY CON 3	17.3	40.7 ^{de}	74.5 ^d	5.2 ^f	34.7 ^{fg}
DEHY ORG 1	22.8	44.7 ^{cde}	83.4 ^{bc}	8.4 ^{de}	42.1 ^{def}
DEHY ORG 2	16.9	43.7 ^{cde}	75.2 ^d	5.5 ^f	38.0 ^f
DEHY ORG 3	18.9	37.9 ^{ef}	76.2 ^{cd}	5.5 ^f	35.2 ^{fg}
Soybean Meal					
SOLV CON 1	53.5	41.9 ^{cde}	97.3 ^a	21.8 ^c	25.4 ⁱ
SOLV CON 2	53.1	42.8 ^{cde}	96.3 ^a	21.8 ^c	26.9 ^{ghi}
EXP ORG 1	48.0	59.1 ^a	97.6 ^a	27.6 ^{ab}	15.4 ^j
EXP ORG 2	46.6	59.3 ^a	98.2 ^a	27.1 ^{ab}	15.3 ^j
EXP ORG 3	43.7	56.1 ^{ab}	96.2 ^a	23.5 ^{bc}	16.8 ^j
EXP CON 1	47.7	61.5 ^a	97.5 ^a	28.5 ^a	20.8 ^{ij}
EXP CON 2	48.5	59.7 ^a	97.2 ^a	28.0 ^a	22.4 ^{ij}
SEM	-	2.62	4.20	1.53	1.74
P-Value					
Sample	-	< 0.01	< 0.01	< 0.01	< 0.01
Day	-	0.09	< 0.01	0.15	0.92
Sample*Day	-	0.33	0.59	0.87	0.98

¹ CP = Crude Protein, RUP = Rumen Undegradable Protein

² CON = Conventional, ORG = Organic, DRC = Dry Rolled Corn, DEHY = Dehydrated, SOLV = Solvent Extracted, EXP = Expeller Pressed

³ Fish meal had no residue remaining after retrieval from feces for crude protein analysis

^{a-j} Means within a column with different superscripts are different (P < 0.05)

after undergoing ruminal and post-ruminal digestion. Therefore, we speculate that post-ruminal DM and CP digestibility, and therefore RUP digestibility, are extremely high for fish meal, and variable between samples. The high and variable CP washout values indicate that *in situ* mobile bag procedures are not an appropriate method

for evaluating fish meal using bags with 50 µm pore size.

The high digestible RUP content value for expeller pressed organic and conventional SBM in both studies indicates that expeller pressed SBM may be an excellent source of supplemental RUP when supplementing protein in organic cattle produc-

tion systems if the soybeans are produced under organic standards.

Conclusion

Feed ingredients produced in organic production systems were not significantly different in rumen undegradable protein

content or digestibility when compared to feeds produced in conventional systems. Expeller pressed SBM regardless of production system had a rumen undegradable protein content of 59% of CP with high digestibility, making it a valuable source of supplemental protein for both conventional and organic beef production systems. These data were inconclusive about the comparison of fish meals, and further research using a method other than the *in situ* mobile bag procedure is needed. Overall, processing method appeared to have more influence on rumen undegradable protein

content and digestibility than whether the feed was raised organically.

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