Protein supplement source and processing for cattle fed forage-based diets: Effects on nutrient intake and digestibility

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Protein supplements improve total-tract digestibility without increasing total intake. Both dried distillers grains with solubles (DDGS) and soybean-based options are effective. Pelleting protein supplements improves nutrient digestibility.

Summary

This study evaluated the effects of protein supplementation and pelleting on nutrient intake and digestibility in cattle fed medium-quality hay. Supplementation at 0.5% of body weight increased crude protein intake and improved apparent total-tract digestibility of dry matter, organic matter and crude protein. Total-tract NDF digestibility was greater for DDGS-based than soybean-based supplements and was also improved by pelleting. Ruminal fermentation profiles differed between supplements, but total VFA concentrations remained similar. These findings support the benefits of protein supplementation and suggest that pelleting of supplements can enhance nutrient utilization in forage-based diets.

Introduction

Protein is often a limiting nutrient in beef cattle diets, especially during winter or drought, when forage crude protein (CP) drops below 9-10%. Inadequate CP supply impairs fiber digestion, reduces intake and increases tissue mobilization and nitrogen excretion (NASEM, 2016). Protein supplementation is known to improve forage utilization, but its effectiveness depends not only on the nutrient composition of the supplement but also on its physical form and how it interacts with digestion dynamics.

Pelleted protein supplements, commonly known as "range cubes," are widely preferred by producers in extensive systems due to their ease of handling and distribution. However, little is known about how pelleting affects nutrient intake and digestibility.

Dried distillers grains with solubles (DDGS) and soybean-based products are two common protein sources in beef systems. Most supplementation studies have used DDGS as the benchmark, reflecting regional practices — in the northern Great Plains, high-protein range cubes (≥30% CP) are typically formulated with DDGS (Mueller, 2024). Importantly, soybean processing capacity in North Dakota has expanded significantly since 2023, creating new opportunities for the local use of soybean meal and hulls as livestock feed. This shift highlights the need for updated information on the efficacy of soybean-based supplements in beef cattle diets. Therefore, the objective of this study was to evaluate the effects of protein source (DDGS vs. soybean-based) and physical form (meal vs. pellet) on intake, ruminal, intestinal and total-tract digestibility in cattle fed a forage-based diet.

Experimental Procedures

Five Jersey steers (initial body weight [BW] = 994 ± 20 lb), fitted with ruminal, duodenal and ileal cannulas, were used in a 5 × 5 Latin square design with a 2 × 2 + 1 factorial arrangement of treatments. Factors included two protein sources: DDGS or a soybean-based supplement (52.5% soybean meal, 47.5% soyhulls), each in meal or pelleted form, and a negative control with no supplementation. Supplements were offered daily at 0.5% of BW. All animals received free-choice access to grass hay, mineral supplement and water. Animals were fed supplements at 7:30 a.m. and hay at 8:00 a.m., adjusted daily to maintain ~5% refusals.

Each period lasted 14 days, with seven days of adaptation and seven days of data collection. Samples of feed and refusals were collected daily and composited by steer and period. Chromic oxide (16 g/d) was dosed intraruminally from days 5 to 12 as a marker for digesta flow. Total feces were collected from days 8 to 12. Ruminal fluid was collected at multiple time points on day 9 for measurement of pH, ammonia, VFA and ruminal fluid kinetics using Co-EDTA. Duodenal and ileal digesta

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Table 1. Nutrient composition (% of DM) of the feed ingredients used in experimental diets

		Protein Supplements[1]			
Items	Hay	DDGS	DDGSP	SB	SBP
Organic matter	90.5	92.9	92.6	94.3	94.5
Crude protein	8.66	32.5	32.4	27.5	27.9
Neutral detergent fiber	68.2	47.5	43.8	31.6	33.0
Acid detergent fiber	36.9	16.2	15.0	21.3	21.9

[1]DDGS = dried distillers grains with solubles in meal form; DDGSP = dried distillers grains with solubles in pellet form; SB = soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = soybean-based supplement in pellet form.

were collected across three days, at nine-hour intervals, composited and analyzed to estimate nutrient flow and microbial protein synthesis. On day 14, ruminal contents were collected and processed to isolate bacteria for estimating microbial protein synthesis.

Data were analyzed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The model included treatment as a fixed effect, with steer and period as random effects. Preplanned contrasts evaluated supplementation (control vs. supplemented), protein source (soybean vs. DDGS), physical form (meal vs. pellet) and source × form interaction. Statistical significance was declared at $P < 0.05$ and tendencies at $P < 0.10$.

Results and Discussion

Supplementation did not affect total DM or OM intake ($P > 0.05$; Figure 1), but reduced hay DM intake ($P < 0.001$), suggesting a substitution effect. This effect is commonly observed with nutrient-dense supplements and may result from physical or metabolic intake limits. However, in forage-based systems, such substitution may be undesirable, as it can reduce the utilization of available roughage. Therefore, lower inclusion rates should be explored to maintain supplementation benefits without compromising forage intake.

Crude protein intake was higher in supplemented animals ($P < 0.001$), particularly with DDGS-based supplements compared to soybean-based ones ($P = 0.001$), reflecting their greater crude protein content. Intake of NDF tended to be lower with soybean-based supplementation ($P = 0.069$), consistent with their higher soyhull content, which is more digestible but less fibrous than DDGS.

Duodenal DM flow tended to be greater with DDGS ($P = 0.088$), and the feed-derived portion was significantly greater ($P = 0.045$). Supplementation reduced fecal DM flow ($P = 0.046$). Similar trends were observed for OM, with duodenal OM flow tending to increase with DDGS ($P = 0.072$) and the feed portion significantly greater ($P = 0.031$). Fecal OM tended to be lower in supplemented animals ($P = 0.070$). Duodenal CP flow increased with supplementation ($P = 0.003$) and with DDGS ($P = 0.005$). Fecal CP flow was also greater with supplementation ($P = 0.050$) and with DDGS ($P < 0.001$) but tended to be reduced with pelleting ($P = 0.089$), suggesting improved nitrogen digestion with the pelleted form. Duodenal NDF flow was greater with DDGS ($P = 0.020$), while fecal NDF flow tended to be reduced by supplementation ($P = 0.054$).

True ruminal digestibility of DM, OM and NDF was unaffected ($P > 0.10$), but CP digestibility was greater for soybean-based supplements ($P = 0.023$). Apparent small intestinal digestibility of

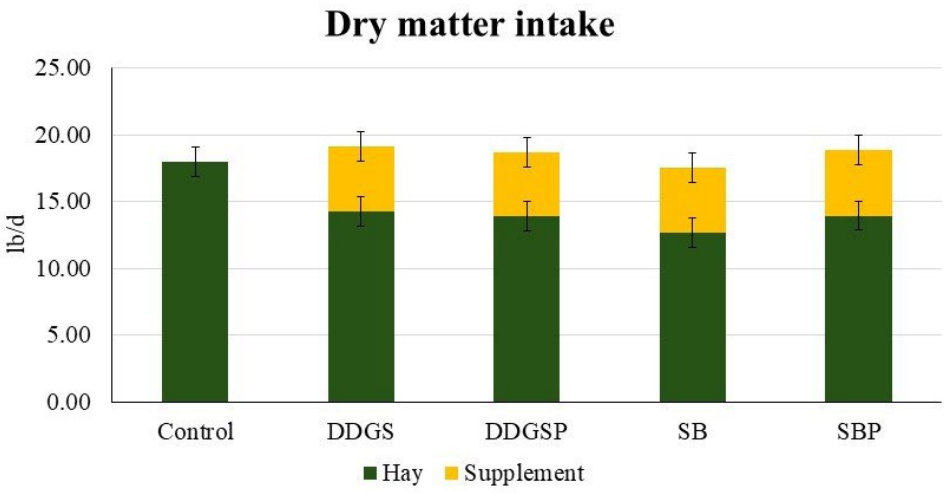

Figure 1. Dry matter (DM) intake (lb/day) in steers fed grass hay and supplemented at 0.5 % of body weight with or without either soybean-based or DDGS-based protein supplements, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with dried distillers grains with solubles in meal form; DDGSP = hay supplemented with dried distillers grains with solubles in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form.

DM, OM and CP increased with supplementation ($P < 0.05$). Pelleting tended to reduce DM and NDF digestibility in the small intestine ($P = 0.074$ and $P = 0.047$, respectively). Large intestine digestibility was not affected, except for CP, which increased with supplementation when expressed relative to ileal flow ($P = 0.018$), suggesting more efficient absorption earlier in the tract.

Apparent total-tract digestibility of DM, OM and CP increased with supplementation ($P < 0.001$, Figure 2) and pelleting ($P < 0.01$), with no effect of protein source. For NDF, total-tract digestibility was greater with DDGS ($P = 0.006$) and with pelleting ($P = 0.004$), but was unaffected by supplementation. Despite similar NDF ruminal digestibility, this improvement in total-tract NDF digestibility may be due to post-ruminal effects or better synchronization between nutrient availability and microbial activity.

Ruminal VFA concentrations were mostly unchanged, although acetate concentration ($P = 0.037$) and acetate-propionate ratio ($P = 0.004$) were greater with soybean-based supplements, while butyrate was greater with DDGS ($P = 0.009$). Pelleting tended to lower the acetate-propionate ratio ($P = 0.055$), suggesting subtle shifts in fermentation.

In conclusion, protein supplementation increased crude protein intake and total-tract digestibility of DM, OM and CP without affecting total DM intake. However, supplementation reduced hay intake, indicating a substitution effect that may require attention in forage-based systems.

Differences in nutrient intake and flow were observed between supplement sources, likely reflecting their distinct protein levels and composition. While DDGS-based supplements increased CP intake and duodenal NDF flow, soybean-based treatments led to greater ruminal CP digestibility and shifts in fermentation profile. Pelleting enhanced total-tract digestibility but tended to reduce small intestine NDF digestion. These results highlight the importance of considering both composition and physical form when evaluating protein supplements for cattle fed forage-based diets.

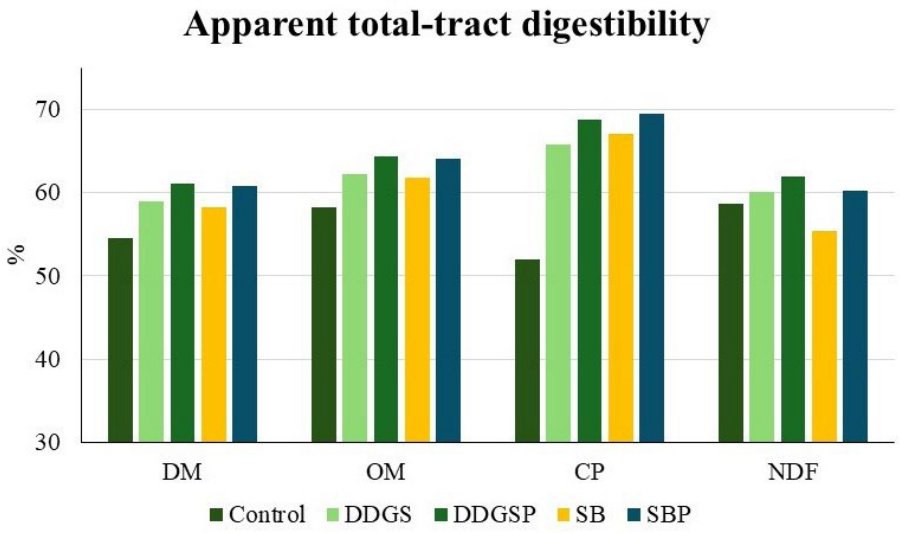

Figure 2. Nutrient apparent total-tract digestibility (% of intake) fed grass hay and supplemented at 0.5 % of body weight with or without either soybean-based or DDGS-based protein supplements, offered in meal or pelleted form. Control = hay only; DDGS = hay supplemented with dried distillers grains with solubles in meal form; DDGSP = hay supplemented with dried distillers grains with solubles in pellet form; SB = hay supplemented with soybean-based supplement (52.5% soybean meal and 47.5% soyhulls) in meal form; SBP = hay supplemented with soybean-based supplement in pellet form.

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