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# Dried Ruminal Contents as a Substitute for Alfalfa Hay in Growing-Finishing Diets for Feedlot Cattle

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**Abstract:** Eight Holstein steers (458±14 kg) with cannulas in rumen and proximal duodenum were used in a crossover design experiment to determine the feeding value of air Dried Rminal Contents (DRC). Treatments consisted of a steam-flaked corn-based growing diet containing (DMB) 30% of either Alfalfa hay (ALF) or DRC. The ALF contained 93.4% DM, 17.1% CP, 36.7% ADF, 1.0% EE and 7.3% ash. The DRC contained 92.8% DM, 12.5% CP, 44.3% ADF, 3.8% EE and 5.9% ash. Ruminal contents were obtained at a local cattle slaughtering facility. The material was first conveyed over a screen to separate liquids and solids. Solids were then spread over a concrete surface and allowed to air-dry. Dry matter intake was restricted to 9.6 kg head$^{-1}$. Substituting DRC for ALF in the diet decreased ruminal digestion of OM 18% ($p<0.01$) and ADF (46.3%, $p<0.01$), postruminal digestion of OM (17.7%, $p<0.01$), total tract digestion of OM (15.4%, $p<0.01$), ADF (32.3%, $p<0.01$), N (12.0%, $p<0.01$) and DE, Mcal kg$^{-1}$ (11.5%, $p<0.01$). Substituting DRC for ALF in the diet increased ($p<0.01$) ruminal microbial efficiency (24.2%, $p<0.01$) and ruminal N efficiency (19.8%, $p<0.01$). The estimated DE value of DRC was 1.21 Mcal kg$^{-1}$, approximately 51% of medium-quality alfalfa hay.

**Key words:** Ruminal contents, digestion, metabolism, cattle, alfalfa, ruminal digestion

## INTRODUCTION

The rising costs of waste removal are forcing the slaughterhouses to rethink their present concepts for slaughterhouse by-product management. Approximately 2.7-3.5 kg (DM basis) of ruminal contents are removed from cattle during slaughter (Prokop *et al*., 1974; Dominguez *et al*., 1994). El-Yassin *et al*. (1991) reported the following chemical composition of dried Ruminal Contents (RC) from feedlot steers: CP, 14.4%; EE, 4.2%; ADF, 41.1% and ash, 9.7%.

Although, it has been demonstrated that rumen contents combined or alone can be replaced partially protein or energy sources in diets offered to rabbits (Togun *et al*., 2009), pullet chicks (Adeniji and Jimoh, 2007) and ruminants (Messersmith *et al*., 1974; Prokop *et al*., 1974; El-Yassin *et al*., 1991; Salinas-Chavira *et al*., 2007), the feeding value of DRC as a replacement for forage in growing-finishing diets for feedlot cattle has not been examined.

The objective of this experiment was to evaluate comparative feeding value of DRC vs. Alfalfa hay (ALF) as a forage source at level of 30% in a growing-finishing steam-flaked corn-based diet for feedlot cattle.

## MATERIALS AND METHODS

Animal care and handling techniques were carried according to approved local official techniques of animal care.

**Processing of ruminal contents:** Ruminal contents were obtained at local cattle slaughtering facility from harvested cattle came from the commercial finishing feedlot located 14 km from the slaughterhouse. Cattle slaughter was performed according to approved local techniques and rumen contents was collected fresh from the abattoir slab immediately the visceral of the cattle was opened. The material was first conveyed over a screen to separate liquids and solids. Solids were then spread (distributed in a 3 cm layer) over a concrete surface and allowed to sun air-dry to reduce the moisture content to 10% (90% DM). Test forages (dried ruminal contents and alfalfa hay) were ground to pass through a 7.6 cm screen and were added to the mixer as the second step in diet preparation. Diets were formulated to contain 15-17% FDA (DMB). Experimental diets are shown in Table 1. Chromic oxide (0.24%) was added during mixing as an inert digesta marker.

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Table 1: Composition of experimental diets fed to steers (DM basis)

| Item | Treatments DRC | ALF |
|---|---|---|
| **Ingredient composition (%[b])** | | |
| Alfalfa hay | - | 30.32 |
| Dried ruminal contents | 30.32 | - |
| Steam-flaked corn (0.28 kg $L^{-1}$) | 59.77 | 59.77 |
| Cane molasses | 4.47 | 4.47 |
| Yellow grease | 2.59 | 2.59 |
| Urea | 0.87 | 0.87 |
| TM salt | 0.44 | 0.44 |
| Limestone | 1.30 | 1.30 |
| Chromic oxide | 0.24 | 0.24 |
| **Nutrient composition (DMB %)** | | |
| Crude protein | 13.85 | 12.52 |
| FDA | 15.52 | 17.44 |
| Ether extract | 5.92 | 6.21 |
| Calcium | 0.90 | 0.95 |
| Phosphorus | 0.25 | 0.36 |

DRC = Dried Ruminal Contents; ALF = Alfalfa hay; DMB = Dry Matter Basis; TM = Trace Mineral sal contained: $CoSO_4$, .068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052% and NaCl 92.96%; Nutrient composition was estimated based on tabular values for individual feed ingredients (NRC, 2000) with exception of ALF and DRC which were assigned values obtained by analysis performed in our laboratory (Table 2)

**Animals, diets and sampling procedure:** Eight Holstein steers (458±14 kg) with cannulas in rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a crossover design experiment to determine the feeding value of air Dried Ruminal Contents (DRC). Animals were maintained in individuals pens with access to water at all times. DM intake was restricted to 9.6 kg $day^{-1}$. Diets were fed at 0800 and 2000 daily. Experimental periods consisted of a 10 days diet adjustment period followed by a 4 days collection period.

During the collection period duodenal and fecal samples were taken from all steers, twice daily as follows: day 1, 0750 and 1350; day 2, 0900 and 1500; day 3, 1050 and 1650 and day 4, 1200 and 1800. Individual samples consisted of approximately 500 mL duodenal chyme and 200 g (wet basis) of fecal material. Samples from each steer and within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer 4 h postprandial via the ruminal cannula.

Ruminal fluid pH was determined on fresh samples. Samples were strained through 4 layers of cheese cloth. About 2 mL of freshly prepared 25% (w/v) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000× g for 10 min) and supernatant fluid stored at -20°C for VFA analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Bergen *et al*., 1968).

**Analytical procedure:** Samples were subjected to all or part of the following analysis: DM (oven drying at 105°C until no further weight loss); ash, Kjeldahl N, ammonia N (AOAC, 1984); purines (Zinn and Owen, 1986); GE (adiabatic bomb calorimeter); VFA concentrations of ruminal fluid (gas chromatography; Zinn, 1988); chromic oxide (Hill and Anderson, 1958); ADF (Gorring and Van Soest, 1970) and starch (Zinn, 1990). Microbial Organic Matter (MOM) and Microbial N (MN) leaving the abomasums were calculated using purines as a microbial marker (Zinn and Owen, 1986).

Organic Matter Fermented in the rumen (OMF) was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and thus includes any endogenous contributions. Nitrogen efficiency was considered equal to daily duodenal non-ammonia N reached duodenum divided by N intake, g $day^{-1}$. The trial was analyzed as a crossover design experiment (Morris, 1999) and means were compared with the Multiple Range Test (minimum significance difference).

## RESULTS AND DISCUSSION

Likewise, Hironaka (1975), Dominguez *et al*. (1994) and Salinas-Chavira *et al*. (2007), all diets were readily accepted by steers (there were no feed refusals) and no digestive disturbances were noted during the experiment. Composition of DRC and ALF are shown in Table 2. The ALF used in the experiment was similar in composition to that designated (NRC, 2000) as mid bloom alfalfa hay. Chemical composition of DRC was lower in CP (13.0%), EE (10.2%), ash (38.0%) and higher in ADF (6.6%) than previously reported values given by El-Yassin *et al.* (1991) and Dominguez *et al.* (1994).

However values shown in Table 2 are similar to those values reported by Fleming and McAlpine (2004) and somewhat higher with exception of ash than values reported by Rafaelli *et al.* (2006). Chemical composition of DRC may be varying by diet type and period of fasting prior to slaughter (Cole and Hutcheson, 1985; Cole, 1991). In this sense, the DRC used as forage source in the experiment was obtained of cattle that fed, at least 50 days prior to slaughter, similar diets than experimental diets used here (concentrate: forage ratio of 70:30). On another hand, cattle are fasted for roughly 24 h before slaughter. Ruminal fermentation continues during fasted period, removing readily digestible substrate. Thus,ruminal contents are primarily comprised of indigestible OM and ruminal micro organisms (Fluharty *et al*., 1994).

Table 2: Characteristics of alfalfa hay and ruminal contents fed to steers

| | Treatments | |
|---|---|---|
| Item | DRC | ALF |
| Dry matter (%) | 92.880 | 93.47 |
| **Chemical composition (DM basis %)** | | |
| Crude protein | 12.520 | 17.10 |
| ADF | 44.340 | 36.69 |
| Ether extract | 3.770 | 0.95 |
| Ash | 5.980 | 7.31 |
| Density, kg $L^{-1}$ | 0.144 | 0.228 |

DRC = Dried Ruminal Contents; ALF = Alfalfa hay

Table 3: Treatment effects on characteristics of ruminal and total tract digestion

| | Treatments | | |
|---|---|---|---|
| Item | DRC | ALF | EEM |
| Replicates | 8 | 8 | - |
| **Intake (g $days^{-1}$)** | | | |
| OM | 9,075 | 9,075 | - |
| Starch | 3,877 | 3,992 | - |
| ADF | 1,775 | 1,228 | - |
| N | 177 | 210 | - |
| GE (Mcal $days^{-1}$) | 43.7 | 42.5 | - |
| **Ruminal digestion (%)** | | | |
| OM | 53.2[a] | 64.9[b] | 1.60 |
| Starch | 84.7 | 87.9 | 4.70 |
| ADF | 22.4[a] | 41.7[b] | 5.10 |
| Feed N | 71.4 | 75.2 | 6.30 |
| Microbial efficiency | 32.2[a] | 24.4[b] | 2.70 |
| Nitrogen efficiency | 1.16[a] | 0.93[b] | 0.03 |
| **Postruminal digestion (%)** | | | |
| OM | 48.1[a] | 58.5[b] | 1.70 |
| Starch | 90.4 | 93.8 | 1.30 |
| ADF | 11.2 | 5.9 | 4.60 |
| N | 71.0 | 73.1 | 1.10 |
| **Total tract digestion (%)** | | | |
| OM | 66.9[a] | 79.1[b] | 1.10 |
| Starch | 98.4 | 98.8 | 3.10 |
| ADF[b] | 31.4[a] | 46.4[b] | 1.50 |
| N | 64.9[a] | 73.8[b] | 1.50 |
| DE | 68.6[a] | 76.4[b] | 1.00 |
| DE (Mcal $kg^{-1}$) | 2.99[a] | 3.38[b] | 0.05 |

DRC = Dried Ruminal Contents; ALF = Alfalfa hay; Means in the same row with different superscripts differ significantly ($p<0.01$); Microbial efficiency = Microbial N, g $kg^{-1}$ OM fermented; Nitrogen efficiency =Duodenal non-ammonia N/N intake

Treatment effects on ruminal and total tract digestion of OM, N, starch and ADF are shown in Table 3. The difference on chemical composition between DRC and ALF source resulted in lower intakes of N (15.7%) and higher intakes of ADF (30.8%) for DRC than for ALF. Ruminal starch digestion averaged 86.3% in good agreement with previous studies evaluating steam-flaked corn (Corona *et al*., 2006; Plascencia *et al*., 2007) and was not affected ($p>0.05$) by inclusion of DRC. Substituting DRC for ALF resulted in lowered ($p<0.01$) ruminal digestibility of OM (18%) and ADF (46.3%). The lower ruminal digestibility of OM is largely a reflection of the decreased ruminal ADF digestibility. Barajas *et al.* (1995) using nylon bag technique determined 32% DM ruminal digestion in lambs fed cracked corn-based diet contained 30% forage. The results obtained in present study and by Barajas *et al.* (1995) are similar to others where ALF has been compared to low-quality forage (Moore *et al*., 1990; Marshall *et al*., 1992). Ruminal digestion of feed N was not affected ($p>0.05$) by treatments. Daily N intake from ALF and DRC averaged 58 and 89 g $day^{-1}$, respectively. Assuming that the Rumen Degradable Protein (RDP) of ALF was 78% (NRC, 1985) then the RDP of DRC was 74%. Ruminal degradable protein value of DRC has not been reported previously in the literature, however, this value is very similar to the average RDP value (72.3%) indicated for straws proteins by NRC (2000).

As result that the microbial N and non-ammonia N flow was similar ($p = 0.68$) between treatments (average 200 and 149 g $day^{-1}$, respectively), ruminal microbial efficiency (microbial N, g $kg^{-1}$ OM fermented in rumen) and ruminal protein efficiency (duodenal non-ammonia N/N intake) were greater (24.2 and 19.8%, respectively, $p<0.01$) for DRC then for ALF. The basis for this effect is uncertain. Zinn *et al.* (1981) observed that as the rate of passage of OM from the rumen increased efficiency of MP synthesis also increased. Passage rate was not measured in the present study; however increases in fiber passage rate in macerated low-quality forages have been observed previously (Lopez-Soto *et al*., 2006). They observed that in cows fed steam-flaked corn-based diet containing 40% forage as ground versus macerated straw, maceration increased ruminal NDF turnover rate by 52%. Maceration is a process designed to simulate chewing, or mastication (Plascencia *et al*., 2005). The same effect could be result in DRC because its fiber fraction had been modified similar.

Total tract digestibility of OM (15.4%, $p<0.01$), ADF (32.3%, $p<0.01$) and DE, Mcal $kg^{-1}$ (11.5%, $p<0.01$) were greater for ALF then for DRC. Very little information exists in the literature regarding the total tract digestibility of DRC as a replacement of forage in growing-finishing diets for beef cattle. However, DM total tract digestibility of 52.7% has been reported previously for lambs fed dried rumen contents as entire diet (Hironaka, 1975). Apparent total tract digestibility of N was lower (12%, $p<0.01$) for DRC. This effect is due in part to differences (58 and 89 g $day^{-1}$ for DRC and ALF, respectively) in level of N intake and in part to high true digestibility of alfalfa N (90%; Onstad and Fick, 1983).

The high proportion of DRC-N that is microbial in origin and true digestibility of MN is low (74%; Orskov, 1992). Given that the DE value of ALF was 2.46 Mcal $kg^{-1}$ (NRC, 2000) the replacement DE value of DRC treatment can be estimated as follows: DE of DRC, Mcal $kg^{-1}$ = ([(DE in DRC diet-DE in ALF diet)/0.3032) + 2.46. The constant 0.3032 represents the amount of DRC that

Table 4: Treatment effects on ruminal pH and VFA molar proportion 4 h after feeding

| Item | Treatments | | |
|---|---|---|---|
| | DRC | ALF | EEM |
| pH | 5.41 | 5.49 | 0.05 |
| **Ruminal, VFA (mol/100 mol)** | | | |
| Acetate | 54.4 | 60.9 | 2.60 |
| Propionate | 31.9 | 24.1 | 3.30 |
| Butirate | 13.7 | 15.0 | 1.90 |

DRC = Dried Ruminal Content; ALF = Alfalfa hay

replace ALF in diet and 2.46 is the DE value of ALF (NRC, 2000). Accordingly, the comparative DE value for DRC was 1.21 Mcal $kg^{-1}$. El-Yassin fed lambs with a combination in equal parts of rumen contents blood straw silage (proportion 45:15:40, respectively) and a basal diet composed by orchard grass and corn grain. The estimated DE of the ruminal contents plus blood combination calculated by difference was 1.942 Mcal $kg^{-1}$. Considering that the proportion of combination between rumen contents and blood was 75:25 and the DE of blood is 2.91 Mcal $kg^{-1}$ (NRC, 2000); thus the DE value to ruminal contents was 1.22 Mcal $kg^{-1}$. These DE value are in good agreement to 1.21 of DE value to DRC obtained here.

Treatment effects on ruminal pH and VFA profiles 4 h after feeding are shown in Table 4. Treatment effects were non-significant although molar proportions of acetate tended ($p = 0.09$) to be lower and molar proportions of propionate tended ($p = 0.07$) to be higher for DRC.

## CONCLUSION

Dried ruminal contents may be substituted for forage in a growing-finishing diet (30% forage level) for feedlot steers without negative effects on diet acceptability. The digestible energy value of dried ruminal contents is 1.21 Mcal $kg^{-1}$.

## REFERENCES

AOAC, 1984. Official Methods of Analysis. 12th Edn., AOAC, Washington DC, USA.

Adeniji, A.A. and A. Jimoh, 2007. Effect of replacing maize with enzyme-supplemented bovine rumen content in the diet of pullet chick. Int. J. Poult. Sci., 11: 814-817.

Barajas, C.R., L.R. Flores and J.E. Dominguez, 1995. Rumen degradation in sheep of ruminal contents from beef cattle slaughtered in abattoir of Culiacan Sinaloa. http://www.uasnet.mx/centro/profesional/emvz/41-50.htm#PP41.

Bergen, W.G., D.B. Purser and J.H. Cline, 1968. Effect of ration on the nutritive quality of rumen microbial protein. J. Anim. Sci., 27: 1497-1497.

Cole, N.A. and D.P. Hutcheson, 1985. Influence of realimentation diet on recovery of rumen activity and feed intake in beef steers. J. Anim. Sci., 61: 692-701.

Cole, N.A., 1991. Effects of animal to animal exchange on ruminal contents of the feed intake and ruminal characteristics of fed and fasted lambs. J. Anim. Sci., 69: 1795-1803.

Corona, L., F.N. Owens and R.A. Zinn, 2006. Impact of corn vitreousness and processing on site and extent of digestion by feedlot cattle. J. Anim. Sci., 84: 3020-3031.

Dominguez, J.E., L.R. Flores and J.F. Obregon, 1994. Nutritional and microbiological characteristics of ruminal contents from slaughterhouse located at Culiacan, Sinaloa. Memorias del VII Congreso Nacional de Produccion Ovina. Toluca, Mexico, pp: 87-88. http://www.uasnet.mx/centro/profesional/emvz/41-50.htm#PP41.

El-Yassin, F.A., J.P. Fontenot and H. Chester-Jones, 1991. Fermentation characteristics and nutritional value of ruminal contents and blood ensiled with untreated or sodium hydroxide-treated wheat straw. J. Anim. Sci., 69: 1751-1759.

Fleming, R. and M. McAlpine, 2004. Composting Paunch Manure with Solid Cattle Manure. Blaemar Ltd., Orangeville, Ontario, pp: 1-12.

Fluharty, F.L., S.C. Loerch and B.A. Dehority, 1994. Ruminal characteristics, microbial population and digestive capability of newly weaned, stressed calves. J. Anim. Sci., 72: 2969-2979.

Gorring, H.K. and P.J. Van Soest, 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and Some Applications). Agricultural Handbook 379, Agricultural Research Service, United States Department of Agriculture, Washington, DC., pp: 1-20.

Hill, F.W. and D.L. Anderson, 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutr., 64: 587-603.

Hironaka, R., 1975. Use of dried paunch residue in ruminant diets. Can. Anim. Sci., 55: 471-472.

Lopez-Soto, M.A., G.E. Arellano, A. Barreras, V.M. Gonzalez, D.M. Garcia, A. Plascencia and R.A. Zinn, 2006. Influence of exogenous fibrolytic enzyme supplementation and maceration process in a low-quality forage on digestion parameters and rumen function in dry Holstein cows. Vet. Mexico, 37: 275-289.

Marshall, S.A., C.P. Campbell, I.B. and J.W. Mandell, 1992. Effect of source and level of dietary neutral detergent fiber on feed intake, ruminal fermentation, ruminal digestion *in situ* and total tract digestion in beef cattle fed pelleted concentrates with or without supplemental roughage. J. Anim. Sci., 70: 884-893.

Messersmith, T.L., W.R. Fulton and T.J. Klopfenstein, 1974. Dried paunch feed as a roughage source in beef finishing ration. J. Anim. Sci., 39: 246-249.

Moore, J.A., M.H. Poore and R.S. Swingle, 1990. Influence of roughage source on kinetics of digestion and passage and on calculated extent of ruminal digestion in beef steers fed 65% concentrate diets. J. Anim. Sci., 68: 3412-3420.

Morris, T.R., 1999. Experimental Design and Analysis in Animal Sciences. CABI Publishing, New York, USA.

NRC. (National Research Council), 2000. Nutrient Requirements of Beef Cattle. 7th Edn., National Academy Press, Washington, DC., USA.

NRC., 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, D.C.

Onstad, D.W. and G.W. Fick, 1983. Predicting crude protein, *in vitro* true digestibility and leaf proportion in alfalfa herbage. Crop Sci., 23: 961-964.

Orskov, R.R., 1992. Protein Nutrition in Ruminants. 2nd Edn., Academic Press, San Diego, CA, USA.

Plascencia, A., A.M. Lopez-Soto, M.F. Montano, J. Serrano, R.A. Ware and R.A. Zinn, 2007. Influence of surfactant supplementation and maceration on the feeding value of rice straw in growing-finishing diets for Holstein steers. J. Anim. Sci., 85: 2575-2581.

Plascencia, A., G.E. Arellano, R.A. Ware and R.A. Zinn, 2005. Influence of partial substitution of alfalfa hay with ground versus macerated rice straw on dry matter intake and performace of lactating Holstein cows. J. Anim. Vet. Adv., 4: 694-697.

Prokop, M.J., T.J. Klopfenstein and T. Messersmith, 1974. Blood and paunch meal in ruminant rations. J. Anim. Sci., 39: 250-250.

Rafaelli, P.M., L. Sangines-Garcia, R.F. Perez-Gil and O. Larrosa, 2006. Documentos de trabajo. Facultad de Ciencias Agrarias, pp: 1-7. http://www.ub.edu.ar/investigaciones/dt_nuevos/158_rafaelli.pdf.

Salinas-Chavira, J., M. Dominguez-Munoz, R. Bernal-Lorenzo, R.F. Garcia-Castillo and C. Arzola-Alvarez, 2007. Growth performance and carcass characteristics of feedlot lambs fed diets with pig manure and rumen contents. J. Anim. Vet. Adv., 6: 505-508.

Togun, V.A., G.O. Farinu, O.O. Ojebiyi and A.I. Awotunde, 2009. Effect of replacing maize with a mixture of rumen content and blood meal on the performances of growing rabbits: Initial study with mash feed. World Rabbit Sci., 17: 21-26.

Zinn, A.R. and F.N. Owen, 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. Can. J. Anim. Sci., 66: 157-163.

Zinn, R.A. and A. Plascencia, 1993. Interaction of whole cottonseed and supplemental fat on digestive function in cattle. J. Anim. Sci., 71: 11-17.

Zinn, R.A., 1988. Comparative feeding value of supplemental fat in finishing diets for feedlot steers supplemented with and without monensin. J. Anim. Sci., 66: 213-227.

Zinn, R.A., 1990. Influence of steaming time on site of digestion of flaked corn in steers. J. Anim. Sci., 68: 776-781.

Zinn, R.A., L.S. Bull and R.W. Hemken, 1981. Degradation of supplemental proteins in the rumen. J. Anim. Sci., 52: 857-866.