# NYLON BAG DIGESTIBILITY AND RATE OF PASSAGE OF DIGESTA IN MOOSE, WAPITI AND CATTLE

Lyle A. Renecker, Robert J. Hudson and Russ Berzins
Department of Animal Science, University of Alberta, Edmonton, Alberta T6G 2P5

Abstract: Fistulae were established in two wapiti and one moose in late summer, using two procedures. Post-operative recovery from ruminal fistulation was rapid. However, some problems were encountered later which required selection of different cannulae. Dry matter digestibility and rate of passage of three diets by fistulated moose (*Alces alces*), wapiti (*Cervus elaphus nelsonii*) and cattle were studied during late winter. The animals were fed diets of grass hay/alfalfa, alfalfa and aspen/alfalfa consecutively. Moose ranked between cattle and wapiti in their ability to digest the three diets estimated with the nylon bag technique. Potential digestibility of aspen browse in moose was 57%, approximately 14% less than alfalfa. Excretion of dysprosium, a particulate-phase marker, peaked earliest for diets best utilized by that ruminant species.

ALCES VOL. 18, 1983.

Based on digestive adaptations, ruminants can be assigned to one of three categories: (1) grass or roughage feeders (grazers), (2) intermediate mixed feeders, or (3) concentrate feeders or browsers (Hofmann 1973). The efficiency of ruminal digestion in each group depends upon the rate and potential extent of digestion as well as the rate of passage of food particles through the gastro-intestinal tract.

Rumen fermentation is usually studied by one of two techniques. The *in vitro* digestion method involves the incubation of a feed sample with ruminal innoculum in a suitably controlled environment (Pearson 1970).





The nylon bag technique, first explored by Quin et al. (1938), was developed as an *in vivo* method, whereby feed samples are placed in nylon bags and incubated in the rumen of a fistulated animal. Ruminal fistulation, a common procedure in domestic species, has been successfully performed in reindeer (*Rangifer tarandus*) (Person et al. 1980b), bison (*Bison bison*) (Hawley et al. 1981), white-tailed deer (*Odocoileus virginianus*) (Ruggiero and Whelan 1976; Short 1962), red deer (*Cervus elaphus*) (Sanchez-Hermosillo and Kay 1979) and wapiti (Robbins, C. pers. comm.). We are aware of one other attempt to fistulate moose by A. Franzmann at the Moose Research Center in Alaska (Schwartz, C. pers. comm.).

Our interest in the nylon bag technique was stimulated by the wish to compare rates of digestion and potential (asymptotic) digestibility of feedstuffs in three species of ruminants. Sources of variation due to bag features, sample characteristics, rations, washout procedures, and replications have been studied extensively (Mehrez and Orskov 1977; Orskov et al. 1980; McBride 1980; Hawley 1981). However, if the sources of error are considered, this technique has the advantage of being inexpensive, simple, and reasonably accurate.

Studies of digestive function suggest that passage of digesta may be regulated by specific anatomical and physiological characteristics of the gastro-intestinal tract (Clemens and Stevens 1980; Poppi et al. 1980; Kay et al. 1980). Poppi et al. (1981) found that lignin of stem particles was retained in the rumen of sheep and cattle for a longer period than leaf particles. Particles rarely pass through the reticulo-omasal orifice of sheep if they exceed a critical size of 1.18 mm (Poppi et al. 1980). Hjeljord et al. (1982) determined that food passage rate in moose decreased with diet digestibility. Milchunas et al. (1978) suggested that mule deer, as browsers, are under greater pressure to increase their rate of passage to obtain adequate nutrients from low quality feedstuffs.

In an attempt to understand the specific digestive adaptations of a browser, intermediate feeder and grazer, this study was initiated to examine dry matter disappearance and rate of passage of particulate digesta in moose, wapiti and cattle.

## METHODS

### Animals and Feeding Regimes

Two adult wapiti steers, two adult Charolais-cross steers and two adult moose were surgically fitted with ruminal cannulae. Weights (kg) of wapiti, cattle and moose varied between 300-340, 575-640, and 265-275, respectively. These animals were used in trials from January to April 1982.

Feeding occurred twice daily between 0800-1000 and 1700-1900 hours at a level of intake equal to 2% of body weight (an estimated level greater than voluntary intake) and had free access to water and cobalt-iodized salt blocks. The three chopped diets consisted of a) 1:1 mixture of alfalfa and timothy-brome hay, b) 100% alfalfa and c) 1:1 combination of alfalfa and trembling aspen twigs (*Populus tremuloides*). Alfalfa and timothy-brome hay were chopped (approx. 10 cm in length) with a New Holland Tub Grinder. The browse consisted of the current annual growth of trembling aspen saplings, which were cut in late March and early April and chopped into 2-3 cm lengths.





One of three diets was fed in each trial period to the five animals. Daily ration mixtures were weighed, hand-mixed and offered to each animal. Uneaten portions were removed before each feeding, weighed and remixed into the ration. Each trial lasted 26 days and consisted of a 4-day diet transition, a 7-day pretrial period, and fecal collection during the last 15 days.

### Cannulation Techniques

Ruminal fistulae were established in the 2 wapiti and 2 moose in September 1981. The 4 animals had been hand-reared. Feed was withheld 24 hours prior to surgery.

Ruminal fistulation of wapiti was performed in a one-step procedure. Each wapiti was blind-folded and anesthetized with sodium thiamylal (Biotal 0.02 g/kg) and maintained with halothane via a cuffed endotracheal tube. The left paralumbar fossa, located between the hipbone and the posterior rib, was prepared surgically in a routine manner (Turner and McIlwraith 1982). A circle of the desired size was drawn on the area and a trocar placed into the rumen at the center to relieve bloat.

A circular section of skin (10 cm dia) was removed and abdominal muscles were split by blunt dissection. The peritoneum was then incised and the rumen wall was pulled through the incision. Abdominal muscles were retracted with several stay sutures as well as being anchored to the rumen wall. Finally, the skin was secured to the ruminal serosa with closely placed, interrupted, non-absorbable sutures (Braunamid nylon No. 0). Blood vessels in the exposed rumen wall were electrocauterized and a model 1C (10.2 cm diameter) rumen cannula (Bar Diamond, Inc.) was inserted into the fistula. Antibiotics were given topically (Nitrofurazone) and intramuscularly (Combiotic) for 1 week and sutures removed after 10 days.

Ruminal fistulation of two moose was by a two-step procedure to reduce induction time. Step one was required to fix the rumen to the body wall and then allow adhesions to form. Perforation of the rumen and insertion of the cannula was carried out in step two. Since moose were resistant to anesthesia with intravenous sodium thiamylal (0.02 g/kg), we used a mixture of etorphine (0.04 mg/kg) and xylazine (0.66 mg/kg) which was reversed with an intravenous dose of diprenorphine (0.07 mg/kg). Surgery was performed in a pasture. A cuffed endotracheal tube was not used due to the small pharynx and narrow mandible of the moose. The surgical field was clipped and scrubbed. A 10 cm dorso-ventral incision was made through the skin and the muscle layers were separated by blunt dissection. The peritoneum and abdominal muscles were attached to the rumen wall and the skin incision was closed.

Ten days later the fistulae were completed by removing a circle of skin and the underlying portion of the rumen wall. A model 8C (7.6 cm diameter) cannula (Bar Diamond, Inc.) was inserted into the fistula.

### Nylon-Bag Technique

Dry matter digestibility was compared among the three species for each of the three feeds using bags made of Nitex monofilament nylon bolting cloth (10 x 15 cm when laid flat) with a mesh size of 10 µ (B. & S.H. Thompson and Co., Ltd.). Forage samples were dried at 60°C for 48 hours. The dried feeds of timothy-brome hay, alfalfa and aspen twigs were ground





through a 3 mm screen of a 8 inch Laboratory Mill (Norris & Christy Ltd.). Approximately 3 g were weighed into each bag and tied with a drawstring (Orskov et al. 1980). Fourteen bags for each forage type were attached to a 250 ml sample bottle filled with sand and positioned in the ventral sac of the rumen. Two bags were removed after 3, 6, 12, 24, 36, 48, and 72 hours, washed, and dried (Orskov et al. 1980). Dry matter digestibility was calculated as the percent change in the dry weight of the bag contents.

### Rate of Passage

Forages were labelled with dysprosium (Dy) by soaking 675 g of the feed in distilled water containing 28 m M (10.1 g) $DyCl_3.6H_2O$. The mixture was soaked for 24 hours, rinsed for an additional 6 hours, and air-dried (Ellis et al. 1981). A predetermined weight of the Dy-labelled feedstuff was placed in a paper bag and introduced into the rumen (via cannula) as a pulse dose. This sample had a concentration of approximately 11 mg of Dy/g DM. This dosage was required to give a concentration of Dy in the feces of about 10 µg Dy/g DM after 5 days of sampling.

Rectal grab samples were collected at 3 hour intervals for the first 12 hours of day 1 and then every 6 hours until 48 hours. From day 3 through day 5 fecal samples were taken once daily. Fecal samples were oven-dried at 60°C for 48 hours, ground in a micro mill (Kurzzeitbeitrieb, Inc.), accurately weighed into irradiation vials which were heat sealed.

Feed samples were also ground in a micro mill and then dry-ashed in a muffle oven at 550°C for 4 hours. The precipitate was dissolved in a 6 M HCl and diluted with deionized water to 100 ml. An aliquot of 0.25 ml was dried on No. 3 filter paper and sealed in irradiation vials.

All samples were irradiated for 45 sec in the Canadian slowpoke reactor and counted with instrumental neutron activation analysis for 60 sec.

## RESULTS AND DISCUSSION

### Fistulation and Cannulation

Fistulae were prepared by single and two-step methods. Although our experience was limited to two moose and two wapiti, the single stage procedure was preferred because: (1) a subcutaneous pocket of granulation tissue formed subsequent to step one of the two-stage method, and (2) the single method reduced the risk of anesthesia. The one mortality that occurred (moose bull) was caused by aspiration pneumonia.

Several commercial cannulae were evaluated. In the immediate post-operative period, a loose-fitting cannula encouraged wound healing but failed to seal the fistula. Pressure of rumen contents occasionally expelled the cannula when the animal was in sternal recumbency. A silastic collar was designed to fit between the skin and the outside flange to add to the thickness of the body wall and obtain a better seal, but this increased the weight and size. Custom design of a ruminal cannula for moose and wapiti is necessary because of the relatively short distance between the hip and the posterior rib. The fistula must be placed near the posterior curvature of the rumen.

Post-operative healing was rapid when infection was controlled by topical ointments (Udderfax and Furall). Animals regained good body condition. However, 7 months later when animals were at their seasonal nadir of weight and presumable muscle tone, irritation and local infection





reappeared around the dorsal area of the fistula in the wapiti. This was treated by daily washing, drying, and applications of topical ointments (Duracaine and Furall). The placement of a wooden horse cradle around the neck of the infected animal reduced chewing of the irritated area. The problem resolved with improved food intake and body condition in early summer.

### Digestive Studies

Preliminary results on the comparative digestive characteristics of moose (browser), wapiti (mixed feeders) and cattle (grazers) are outlined in this communication. One winter trial has been conducted and a second summer trial is underway in order to evaluate possible seasonal differences in digestive function.

During the winter trial, the moose maintained body weight, the Charolais-cross steers gained weight, and the wapiti lost approximately 25 kg while on the three diets. Voluntary intakes of moose and wapiti were greatest on the alfalfa/browse diet and lowest on the alfalfa/grass hay diet (Table 1). Cattle consumed greatest amounts of alfalfa/grass hay and alfalfa diets and least of the alfalfa/browse diet (Table 1).

Dry matter disappearance, determined using the nylon bag technique, showed only slight differences among species (Fig. 1, 2 and 3). Grass hay and alfalfa appeared to have high asymptotic digestibilities. Breakdown was most rapid and complete in wapiti which may have resulted from their adaptability as an intermediate feeder. Alfalfa was rapidly digested particularly by wapiti and moose. Aspen browse was digested rapidly and comparably by all three species, reaching a relatively low asymptotic digestibility.

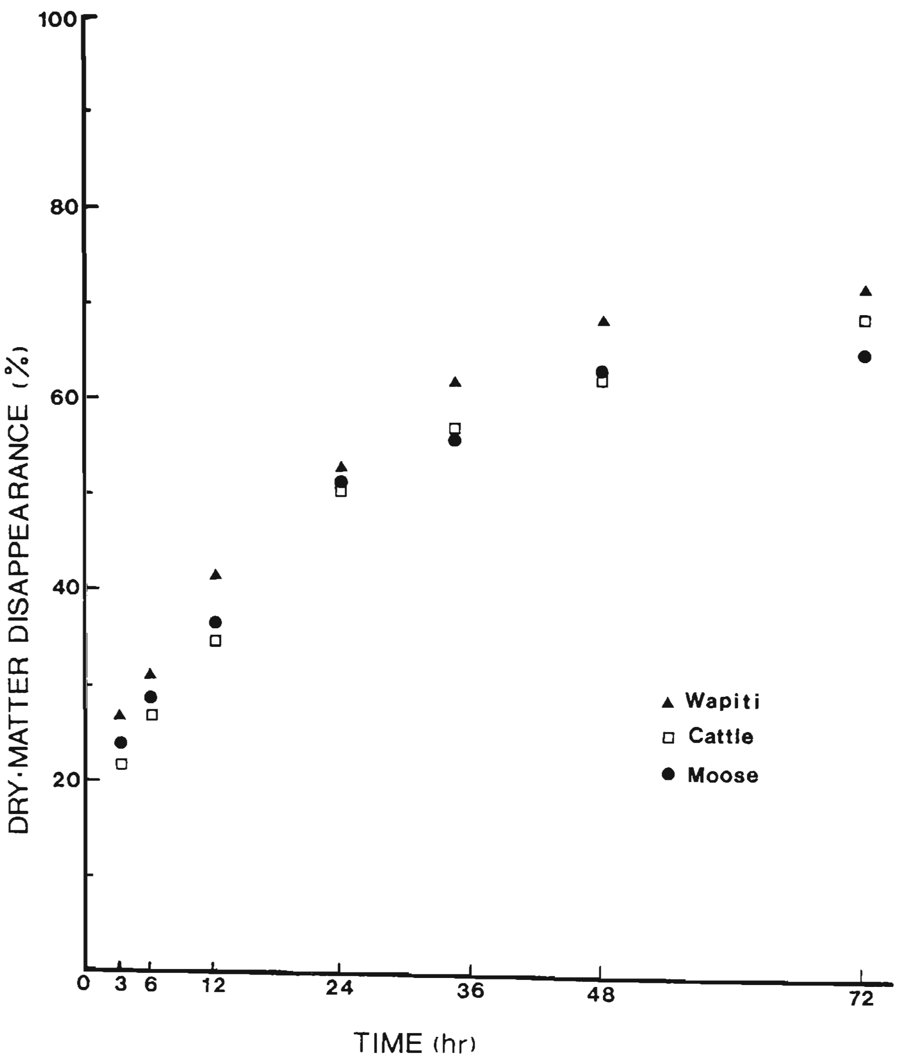


Fig. 1. Nylon bag dry matter disappearance of ground timothy-brome hay in moose, wapiti, and cattle.



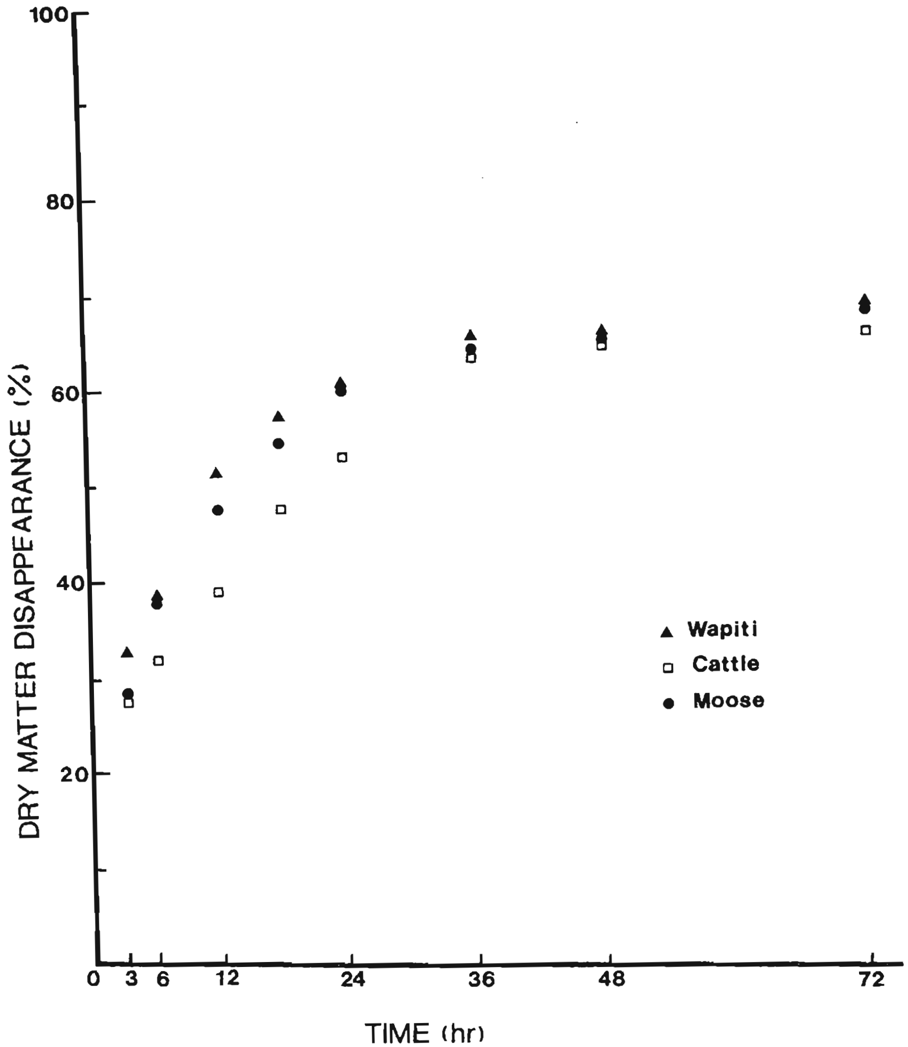


Fig. 2. Nylon bag dry matter disappearance of ground alfalfa hay in moose, wapiti, and cattle.

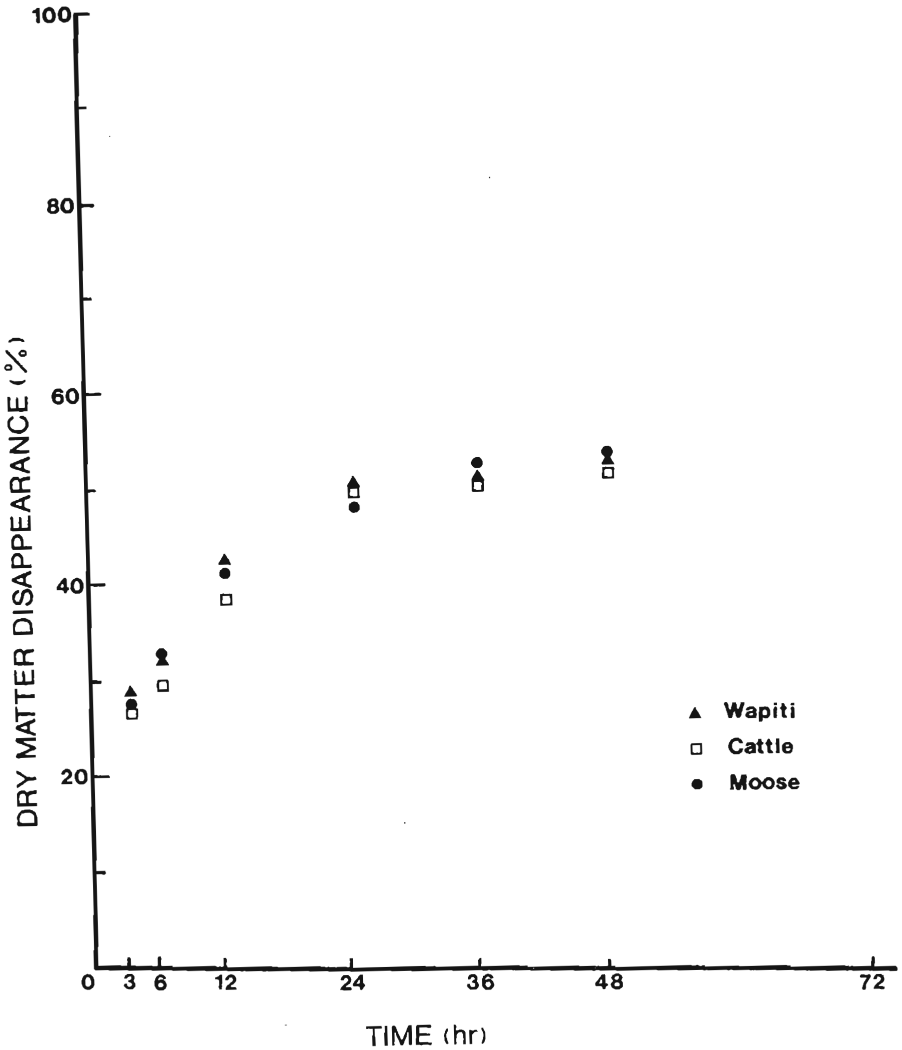


Fig. 3. Nylon bag dry matter disappearance of ground trembling aspen browse in moose, wapiti, and cattle.





Table 1. Voluntary intake (g/kg $W^{0.75}$) of three diets by moose, wapiti and cattle during winter.

| Species | Diets Alfalfa/Grass Hay | Alfalfa | Alfalfa/Browse |
|---|---|---|---|
| Moose | 66.1 | 68.6 | 78.8 |
| Wapiti | 50.3 | 55.8 | 66.0 |
| Cattle | 99.0 | 96.4 | 62.0 |

Plant chemical constituents have often been used to reflect characteristics of digestibility (Short 1966; Minson 1971; Oldemeyer et al. 1977). Grasses have higher cell wall and lower lignin contents than alfalfa (Smith et al. 1971; Milchunas et al. 1978; Person et al. 1980a). The lignin content of shrubs tends to be noticeably higher than that of grasses, lichens (Person et al. 1980a; Oldemeyer et al. 1977), or timothy-fescue-clover hay (Hjeljord et al. 1982). Alfalfa nylon-bag digestibility may have reached an asymptote more rapidly because of greater cell content. Also, cell walls of alfalfa may be more fragile due to greater lignin content, thereby generating more surface area for breakdown.

A second factor influencing digestive efficiency is rate of passage. This is examined using the pulse dose technique of an external marker (Uden 1978; Schwartz et al. 1981; Teeter 1981). Although the rate constants have not been calculated, relative rates of passage of particulate matter can be illustrated by comparing times for peak dysprosium excretion (Table 2). Wapiti exhibited short and similar times for the peak excretion of Dy in the feces on all three diets. Moose appeared to be affected by rumen bulk as reflected by late excretion peaks on grass and alfalfa diets.

Table 2. Time (hr) of peak excretion of dysprosium in the feces of moose, wapiti and cattle fed three diets.

| | Diets | | |
|---|---|---|---|
| Species | Alfalfa/Grass Hay | Alfalfa | Alfalfa/Browse |
| Moose | 36 | 36 | 30 |
| Wapiti | 24 | 24 | 24 |
| Cattle | 36 | 30 | 36 |

Future plans include a summer trial to compare seasonal changes in digestive capacity. Particle size distribution, as well as passage of particular size fraction, will be examined to determine if browsers have the ability to propel large particles through the gastro-intestinal tract at a faster rate than grazers. Knowledge of these parameters is essential to model the food passage rates of ruminants of comparable body size.

## ACKNOWLEDGEMENTS

Portions of this study were financed by the Natural Sciences and Engineering Research Council, Alberta Environmental Research Trust and the Alberta Recreation, Parks and Wildlife Foundation. We wish to thank the Saturday morning hockey team for assistance during sampling. Special thanks to Donna Renecker for help with chemical preparations. Acknowledgement is made to the University of Alberta Slowpoke Facility.





## REFERENCES

CLEMENS, E.T., and C.E. STEVENS. 1980. A comparison of gastrointestinal transit time in ten species of mammal. J. Agric. Sci. 94: 735-737.

ELLIS, W.C., C. LASCANA, R.G. TEETER, and F.N. OWENS. 1981. Solute and particulate flow markers. Oklahoma State Univ. Protein Symp. (In press).

HAWLEY, A.W.L. 1981. Effect of bag location along a suspension on nylon bag digestibility estimates in bison and cattle. J. Range Manage. 34: 265-266.

HAWLEY, A.W.L., D.G. PEDEN, H.W. REYNOLDS, and W.R. STRICKLIN. 1981. Bison and cattle digestion of forages from the Slave River Lowlands, Northwest Territories, Canada. J. Range Manage. 34: 126-130.

HJELJORD, O., F. SUNDSTOL, and H. HAAGENRUD. 1982. The nutritional value of browse to moose. J. Wildl. Manage. 46: 333-343.

HOFMANN, R.R. 1973. The Ruminant Stomach. East African Monographs in Biology, 2, East African Literature Bureau, Nairobi. 354 pp.

KAY, R.N.B., W.V. ENGLEHARDT, and R.G. WHITE. 1980. The digestive physiology of wild ruminants. In: Digestive Physiology and Metabolism in Ruminants. MTP Press Inc., Falcon House, England. p. 743-761.

MCBRIDE, B.W.T. 1980. Utilization of aquatic plants, wood fiber, fish hydrolysate, and food processing waste as livestock feeds. M.Sc. Thesis, University of Guelph, Guelph, Ontario. 205 pp.

MEHREZ, A.Z. and F.R. ORSKOV. 1977. A study of the artificial fiber bag technique for determining the digestibility of feeds in the rumen. J. Agric. Sci. 88: 645-650.

MILCHUNAS, D.G., M.I. DYER, O.C. WALLMO, and D.E. JOHNSON. 1978. In vivo/in vitro relationships of Colorado mule deer forages. Colorado Div. of Wildl., Special Rep. No. 43, 44 pp.

MINSON, D.J. 1971. Influence of lignin and silicon on a summative system for assessing the organic matter digestibility on Panicum. Aust. J. Agr. Res. 22: 589-598.

OLDEMEYER, J.L., A.W. FRANZMANN, A.L. BRUNDAGE, P.D. ARNESON, and A. FLYNN. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41: 533-542.

ORSKOV, E.R., F.D. DEB HOVELL, and F. MOULD. 1980. The use of the nylon bag technique for the evaluation of feedstuffs. Trop. Anim. Prod. 5: 195-213.

PEARSON, H.A. 1970. Digestibility trials: In-vitro techniques. In: Range and Wildlife Habitat Evaluation, A Research Symposium. USDA For. Serv. Misc. Publ. No. 1147. p. 85-92.

PERSON, S.J., R.G. WHITE, and J.R. LUICK. 1980a. Determination of nutritive value of reindeer-caribou range. Proc. 2nd Int. Reindeer/Caribou Symp., Roros, Norway. p. 224-239.

PERSON, S.J., R.E. PEQUA, R.G. WHITE, and J.R. LUICK. 1980b. In-vitro and nylon bag digestibilities of reindeer and caribou forage. J. Wildl. Manage. 44: 613-622.

POPPI, D.P., B.W. NORTON, D.J. MINSON, and R.E. HENDRICKSON. 1980. The validity of the critical size theory for particles leaving the rumen. J. Agric. Sci. 94: 275-280.

POPPI, D.P., D.J. MINSON, and J.H. TERNOUTH. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. III. The retention time in the rumen of large particles. Aust. J. Agric. Res. 32: 123-137.





QUIN, J.I., J.G. VAN DER WATH, and S. MYBURGH. 1938. Studies on the alimentary canal of merino sheep in South Africa. 4. Description of experimental technique. Onderstepoort J. of Vet. Sci. and Anim. Ind. 11: 341-600.

RUGGIERO, L.F., and J.B. WHELAN. 1976. A comparison of in-vitro and in-vivo feed digestibility by white-tailed deer. J. Range Manage. 29: 82-83.

SANCHEZ-HERMOSILLO, M., and R.N.B. KAY. 1979. Retention time and digestibility of milled hay in sheep and red deer (Cervus elaphus). Proc. Nutr. Soc. 38: 123A.

SCHWARTZ, C.C., A.W. FRANZMANN, and D.C. JOHNSON. 1981. Moose nutrition and physiology studies. Vol. XII. Project Progress Rep. Fed. Aid in Wildl. Restoration Proj. W-21-2, Job 1.28R. 42 pp.

SHORT, H.L. 1962. The use of a rumen fistula in a white-tailed deer. J. Wildl. Manage. 26: 341-342.

SHORT, H.L. 1966. Effects of cellulose levels on the apparent digestibility of feeds eaten by mule deer. J. Wildl. Manage. 30: 163-167.

SMITH, L.W., H.K. GOERING, D.R. WALDO, and C.H. GORDON. 1971. In-vitro digestion rate of forage cell wall components. J. Dairy Sci. 54: 71-76.

TEETER, R.G. 1981. Indigestible markers: Methodology and applications in ruminant nutrition. Ph.D. Thesis, Oklahoma State University, Stillwater, Oklahoma. 161 pp.

TURNER, A.S., and C.W. MCILWRAITH. 1982. Techniques in large animal surgery. Lea & Febiger, Philadelphia, Pennsylvania. 333 pp.

UDEN, P. 1978. Comparative studies on rate of passage, particle size, and rate of digestion in ruminants, equines, rabbits, and man. Ph.D. Thesis, Cornell University, Ithaca, N.Y. 242 pp.