

INVESTIGATIONS OF AN ALTERNATIVE METHOD OF MEASURING
FORAGE DIGESTIBILITY OF RUMINANTS 1/

W. J. Pryor 2/, R. J. Raleigh, Joe D. Wallace, and J. E. Oldfield
Oregon Agricultural Experiment Station, Corvallis, and
Squaw Butte Experiment Station, Burns, Oregon 3/

Methods of evaluating the forage of grazing animals has been a subject of research for several decades. In vitro and in vivo methods have been compared and evaluated, with certain adaptations and modifications increasing the reliability of the estimates. Total collection trials with range animals are both tedious and costly. Artificial rumen and nylon bag techniques for determining digestibility have their limitations because of the lack of standardized procedure.

The possibility of a new technique to determine digestibility was investigated. The object was to pass through the alimentary tract small bags of nylon or other materials which would permit the free flow of ruminal and intestinal juices. The bags were filled with plant material from a steer fitted with a rumen fistula which would act as a "harvester" and would be placed in the test steer(s) also through a rumen fistula. Sufficient bags would be used to ensure their discovery in the feces even under range conditions. It would seem reasonable to expect digestibility thus obtained would be almost identical to that obtained by conventional trials.

Several biological obstacles such as regurgitation, blockage, or disintegration in the alimentary tract, hazards in chemical environment and the ability of the bags to leave the rumen needed to be considered. Though there have been extensive recent studies on rumination (Pearce and Moir, 1964, and Pearce 1965), there has apparently been no study of the effect on regurgitation of objects which would approximate the size of the proposed bags. The most likely points for blockage in the alimentary tract would be the reticulo-omasal orifice, omasum, pylorus, and the ileocecal valve. Preliminary observations in tracts from slaughtered cattle showed that a structure one inch in diameter could easily be pushed through these orifices of yearling steers.

Factors that favor rate of passage have been reviewed by Balch and Campling (1964). They state that size is probably the most important factor in determining how rapidly particles will leave the reticulo-rumen, but the specific gravity also may be expected to influence the chances of individual particles being carried through the reticulo-omasal orifice. Campling and Freer (1962) found methyl methacrylate particles 4.8 mm in diameter were held in the reticulo-

- 1/ Contribution of the W-34 regional project on range livestock nutrition.
- 2/ Present address, Department of Animal Husbandry, University of Queensland, Brisbane, Australia.
- 3/ Squaw Butte Experiment Station is jointly operated by the Oregon Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U.S.D.A.

rumen for 91 hours and those 3.2 mm were held 80 hours. Studies with rubber and plastic particles ranging from 1.04-1.40 showed that those of specific gravity 1.1-1.2 passed through the gut most rapidly, and that mean retention time in the rumen was inversely proportional to the specific gravity. These values are close to the specific gravity of the digesta of the reticulo-rumen of cows fed hay which they report to be 1.04.

EXPERIMENTAL PROCEDURE

The possibility of passing small bags of nylon or acetate through the alimentary tract was tested in 13 experiments. Nine of the experiments used 2 rumen fistulated, mature Hereford steers, 3 trials used sheep that could be sacrificed and 1 was a laboratory experiment to determine the effect of abomasal juice on deterioration of bag materials.

The steers were kept tied to mangers over a concrete floor so regurgitated materials could be found. Rye hay was fed at a rate so the feed bunk would empty daily and permit observation of regurgitated bags or particles.

The feces were carefully sifted for bags or bag fragments several times daily. Bags were made of one of 6 types of material to give some variety and include materials known to be satisfactory in the nylon bag techniques. Materials used, thread counts measured, and specific gravities are given in Table 1.

Table 1. Bag material showing thread count and specific gravity.

Material	Thread count/inch		Specific Gravities
	Warp	Filling	
Red spot nylon (A)	102	86	1.14
Pink nylon (B)	110	84	0.96
White nylon parachute cloth (C)	106	72	0.94
Red cellulose acetate (D)	188	56	1.27
Yellow cellulose acetate (E)	184	62	1.29
Tricot acetate (F)	48	28	1.32

Bags were made by sewing with nylon thread using a double seam. The top was closed by a purse string of ten-pound test nylon fishing line, the latter being also used to attach the bag to the fistula bung when this was done. Unless otherwise stated the bags were approximately 3 3/4" x 1 1/4", filled with 5 to 6 gm fresh rumen contents and placed free in the rumen near the cardia. As the rumen contents were added to the bags immediately before use in the field, it was not possible to determine the specific gravity of every bag. However, an estimate was obtained for comparable ones by a water displacement technique giving a value of approximately 1.05. Polyethylene pellets (15 mg, 0.95SG) were placed in some bags to indicate bag destruction if this occurred.

RESULTS AND DISCUSSION

Two of the regular bags were loosely filled with rumen contents and placed in the rumens of two fistulated steers. The feces were screened for bags or bag particles for 11 days following and the rumen was evacuated at 7 days. A similar experiment using smaller 2" x 2" bags followed. No bags or fragments of bags were found in the feces or in the rumen contents in either trial, nor was there any evidence of regurgitation.

Following this, bags made of the 6 materials were tied to the fistula bung by 13 inches of nylon line in 1 steer and by lengths of 13, 17, 21, 25, and 29 inches, respectively in the other steer. Rumen evacuation at 10 days showed all bags undamaged either in the dorsal blind sac of the rumen or in the reticulum. A further experiment using 66 inches of line to permit exit from the reticulo-omasal opening, or regurgitation, resulted in the bags remaining in the rumen with the line very twisted and it was considered that this twisting prevented passage. However, in another experiment where the line was on a reel which would freely unwind similar results were obtained. An experiment in which the bag was tied by two feet of line to a piece of smooth wood free in the rumen again resulted in failure of the bags to leave the rumen.

Polyethylene pellets were put in bags made of nylon (A), cellulose acetate (E), and tricot acetate (F) and placed in the rumen of each steer. Pellets appeared in the feces from 24 hours onwards suggesting bag destruction in earlier experiments rather than lodging in the alimentary tract. Rumen evacuation on the fourth day revealed one tattered bag, only, and pellets. Some of the pellets were flattened, suggestive of chewing and, therefore, regurgitation. A repetition of this experiment showed pellets in the feces from 40 hours onwards; ruminal evacuation at three days revealed 1 tattered bag plus some flattened pellets indicating regurgitation had occurred though the SG of these bags was approximately 0.98.

Tests were later conducted on bag size and specific gravity. White polyethylene pellets were put in normal size bags and red polyethylene pellets in small bags (1 1/4" x 3/8") along with rumen contents and placed in the rumen. Red pellets were recovered in the feces within 2 days indicating almost immediate damage to the small bag, whereas white pellets first appeared at 4 1/2 days. When the rumen was evacuated on the third day 1 large bag was intact and red pellets, but no white pellets were found. The presence of red pellets indicates breakdown of the small bag in the mouth or rumen and the absence of free white pellets in the rumen, indicates that the other larger bag passed from the rumen and broke down later.

Three normal size nylon bags with 0, 4, and 8 steel spheres of 1/4" diameter, respectively, along with white polyethylene pellets and rumen contents were put in the rumen of the other steer. The first white pellet appeared at 30 hours; others continued to appear in the feces up to the seventh day. One steel sphere was found on the fourth day. Rumen evacuation on the fifth day revealed the intact bag with 8 spheres in the ventral sac of the rumen, plus 3 white pellets including a flattened one which suggested the possibility of regurgitation of 1 or 2 of the bags.

One fistulated steer became available for slaughter. Three days before slaughter, 1 large and 1 small bag of each of the 6 materials plus 2 more small white nylon (C) bags were put in the rumen using colored glass and colored polyethylene beads for identification. From 30 hours onwards all 3 colors of polyethylene pellets were found in the feces. Rumen evacuation was carried out at 2 1/2 days and 2 polyethylene colors and 1 glass color were found. One large (D) bag intact and chewed-up pieces of 1 (C) bag were the only other findings. These were removed. This latter bag accounted for 1 of the polyethylene colors; thus, overall, at least 1 bag was regurgitated and 2 others were damaged in the mouth or rumen.

Following slaughter quite a number of 2 types of glass beads, red and green, were found in the reticulum. A few red beads were found in the leaves of the omasum plus one type of polyethylene color, originating from the smaller bags. There were occasional beads or pellets of all colors through the small and large intestine. Thus, the disappearance of the bags was confirmed, though the manner of their disappearance was not. One, at least, was damaged by regurgitation with 2 others probably so since destruction in the rumen has been consistently absent in tied bags and was presumably also absent here. The beads of 2 types in the reticulum would ordinarily permit confirmation of their bag destruction in the mouth, rumen, or reticulum.

Experiments with sheep using pieces of bag material, empty bags (2" x 1"), bags filled with alfalfa chaff, and bags filled with concentrate feed yielded similar results as those with cattle. Bag material or empty bags were placed in the anterior end of the esophagus. Slaughter at 3 days showed all bags intact in the rumen. Bags filled with either alfalfa chaff or a concentrate mix showed evidence of apparent teeth holes or chewing when the animals were slaughtered 3 days later. Regurgitation appeared almost certain, yet to eliminate the possibility of bag damage at dosage, an additional experiment was carried out where bags were placed surgically in the rumen of 1 ewe. Slaughter at 3 days revealed the bags still in the rumen, with 1 showing severe chewing, proving that regurgitation occurs, thus ruling out the use of this method in sheep. In sheep the size of the alimentary tract orifices would be a far more restrictive factor than in cattle had there been no other problems. A further experiment in the laboratory showed that abomasal secretions caused some loss in bag materials upon incubation.

The failure of any of the bags to pass the forestomachs makes it extremely unlikely such a proposed method will be of value. Sheep experiments show quite clearly that regurgitation occurs frequently with that species. Experiments with the steers were less conclusive. Although beads were found in the reticulum in the final slaughter experiment, the results of 2 experiments where intact bags were found in the reticulum makes it very unlikely that breakdown occurs there. Stevens *et al.* (1960) reported that backflow in the omasum occurs at rare intervals, and thus this finding does not entirely preclude bag breakdown in the omasum or abomasum. However, no other evidence supports this possibility. Several experiments showed that bags will remain in various parts of the rumen intact for at least ten days; thus, this organ is extremely unlikely to be responsible for bag breakdown.

Evidence for regurgitation in cattle comes from two experiments where polyethylene pellets only were contained in the bag and the final slaughter experiment. Ruminal evacuation was carried out at 4, 3, and 2 1/2 days, respectively, for these experiments. In other experiments where ruminal evacuation was carried out after 5 days no intact or tattered bags were found. In fact, the only intact bag found after a third day evacuation was that containing 8 stainless steel balls. Bags with 4 or no balls were not found. The loss of a high percentage of the free bags in the mouth or rumen in all probability prevented observations on the ability of large particles to pass from the reticulum to the lower stomachs, and thus largely prevented our testing the validity of extrapolating the data of Campling and Freer (1962).

A working hypothesis may be advanced which is in agreement with these experimental facts. The bags with rumen contents, placed in the rumen, are regurgitated usually within 3 days, the tattered remnants are swallowed, having assumed a

size and already having a specific gravity which the rumen can propel through the omasal orifice. In the omasum and/or abomasum these fragments are dissolved.

If the bags are not regurgitated they will remain in the rumen for long periods of time as they are unable to meet the size required by the rumen mechanics to propel them through the orifice. Though the accuracy of our specific gravity measurement of the bags may be questioned, by virtue of their uneven shape and possible entrapment of gases the values of 0.95-1.05 in view of studies of Campling and Freer (1962) would lead one to expect that the bags would eventually leave the rumen if size is right. Hence it can be reemphasized that in our bag studies, size has been the primary problem in the case of bags remaining intact in the rumen.

It seems possible that if the specific gravity of the bag were increased by the use of denser contents, the likelihood of regurgitation might be reduced. On the other hand it might equally reduce the chance of passage through the alimentary tract. Dewey *et al.* (1958) in the development of the cobalt pellet for sheep and cattle found that pellets with a specific gravity of 4.0 were retained in the reticulum for many months or even years and that aluminium pellets of 2.7 specific gravity were rejected at the rate of 23% in the first month.

SUMMARY

A series of experiments were carried out to test the possibility of passing small bags made of nylon and cellulose acetate through the alimentary tract of cattle and sheep as a means of evaluating digestibility under range conditions.

Attempts to change the specific gravity by addition of small steel spheres to rumen contents in the bags or by sole use of polyethylene pellets in the bags did not enhance their movement through the digestive tract.

The rumen evacuation technique was used in each experiment at periods varying between 2 1/2 to 7 days. In only 2 cases were whole bags recovered when placed free in the rumen. In 3 additional cases bags were found tattered, and in some cases there were crushed polyethylene pellets indicating regurgitation. In all cases where the bags were tied to a fistula bung no damage occurred. In 2 sheep experiments using smaller bags, regurgitation was strongly suggested. In a third sheep experiment where bags were placed within the rumen surgically, regurgitation was positively confirmed.

In a final experiment with 1 fistulated steer which was slaughtered, the use of colored polyethylene pellets and glass beads within the bags confirmed that many, if not all, bags were destroyed, in the mouth, rumen, or reticulum. As other experiments had shown no damage to bags in the latter 2 organs, a hypothesis is proposed that all the bags not found intact were regurgitated usually within 3 days, the shreds of material resulting were of such a weight and specific gravity to allow passage through the omasal opening and subsequent digestion in the lower tract.

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