THE DISTRIBUTION OF DIGESTA PARTICLES AND MEAN PARTICLE SIZE OF DIGESTA OBTAINED FROM THE DIVERSE PARTS OF THE GASTROINTESTINAL TRACT OF RUMINANTS

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Summary

Three cattle, a sheep and a goat were slaughtered to determine the distribution of digesta particles and mean size of digesta particles. Aliquot samples of digesta in the diverse sites of the digestive tracts were fractionated by a wet sieving technique. Fractionated particles were analyzed by the magnetic grid analyzer system constructed by authors. Results showed that the proportion of particles in digesta was similar among the omasum, abomasum cecum, colon and rectum, but that for the reticulo-ruminal digesta was different from the others. The pattern of the mass base frequency distribution of particles was also similar in the post-ruminal digesta. Average Heywood's diameter (the diameter equivalent to that of a circle with equal area to a projected area of a given particle) was about 1.2 mm in the reticulo-ruminal digesta and decreased to 0.65 mm for cattle or to about 0.35 mm for sheep and goat in the omasal digesta. Average Heywood's diameter was about the same in the post-ruminal digesta. It is concluded that mean particle size and particle distribution in digesta of the rectum or feces reflect those in digesta of the omasum.

(**Key Words**: Particle Distribution, Heywood's Diameter, Mass Base Frequency, Cattle, Sheep, Goat)

Introduction

Most of studies on particle size distribution of digesta in ruminants have been adopted sieving method for determining sizes of feed particles in digesta of the gastrointestinal tracts. Sieving technique, however, may have some difficulties to clarify the accurate size of particles passing through the digestive tracts of ruminants (Poppi et al., 1980, Kerley et al., 1985).

Oura and Sekine (1988) have digitized the diameter of particles in a sieved fraction of digesta of a goat using an image analyzer. The diameter of feed particle has been inferred to be expressed by the Heywood's diameter which is equivalent to the diameter of a circle with equal area to a projected area of a given particle. To increase accuracy of determination, Oura and Sekine (1989) have constructed a magnetic grid analyzer (MAGA) system for digitization of particles in sieved fractions. Using this system a more precise consideration may be done on the distribution of particle size of digesta in the digestive tracts.

The present study was to determine the distribution of digesta particles and mean particle size of digesta of ruminants in combination of a wet sieving technique and a MAGA system to clarify the distribution of feed particles in the diverse alimentary tracts.

Materials and Methods

Animals used were 2 Holstein cows weighing 734 and 727 kg, a Japanese Black steer weighing 563 kg, a Suffolk × Corriedale ram weighing 36.4 kg and a castrated Japanese native male goat weighing 34.7 kg. Cattle were fattened with the ration consisting of 65% of formula feed for fattening, 23% of 2nd cut Italian ryegrass hay and 12% of rolled barley for about 12 months and slaughtered at 40 hours after feeding. Sheep and goat were fed 2nd cut Italian ryegrass hay

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Received October 29, 1990

Accepted November 19, 1991

for more than 7 days and slaughtered at 2 hours after feeding. Contents of the gastrointestinal tracts were separately collected after ligation with strings between the proximal and distal sites of organs and weighed for the reticulo-rumen, the omasum, the abomasum, the small intestine, the cecum, the colon and the recum. Contents of the colon of cattle were composited to those of the cecum because of too small amounts to analyze. Aliquot samples of digesta of each alimentary tract with diverse proportions were obtained and fractionated into 4 fractions by a wet sieving technique with sieve aperture of 1180, 300 and 45 μm.

Samples retained on each sieve were dispersed in the beaker filled with known amounts of deionized water and weighed. Stirring with magnetic stirrer to suspend particles evenly in the liquid, a part of suspension was sucked into a glass or plastic tube and the beaker was again weighed to calculate a weight of suspension. Then, the sucked suspension was poured on filter paper in the case of samples retained on 1180 μm sieve or on a glass slide in the case of those on 300 and 45 μm sieves. Particles were manually spread on the paper or slide to avoid lying upon each other and dried. After drying, the paper and slide were wrapped with transparent plastic sheet to prevent particles peeling off in the course of measurements of particle size. Four to 6 replicates were made for each sieved fraction to determine particle size. The rest of particles in the beaker was recovered using 45 μm sieve and then dried in a forced-air oven at 55℃ for analysis of chemical composition. Unsieved digesta samples were also dried as described above and ground with Wiley mill through 1 mm screen for further analyses.

Determinations of particle size were done using the system constructed with an equipment with magnetic grid to digitize the length or area of an irregular shape, a microscope and a microcomputer for the execution of digitizing (Magnetic grid analyzer system, MAGA system). Samples of particles retained on 1180 μm sieve were measured after enlarged by 4 times using a high precision copying machine with laser (Laser Copying Machine, Canon Co.). Those of particles retained on 300 and 45 μm sieves were measured under the microscope equipped with a camera lucida at magnifications of 40 and 100, respectively. More than 334 particles on each sample were traced on the MAGA system and processed by the microcomputer to digitize Heywood's diameter of each particle measured. Mean particle weight, number base frequency distribution and mass base frequency distribution were calculated with methods described by Oura and Sekine (1988, 1989).

Samples of unsieved digesta, feed and sieved fractions were analyzed for dry matter (DM), acid detergent fiber (ADF) and acid detergent lignin (ADL) (Goering and Van Soest, 1970). The amount and composition of the fraction less than 45 μm were calculated by subtracting the sum of residues remained on sieves from that determined on unsieved samples. Statistical analysis was done by the method described by Snedecor (1965).

Results

Table 1 shows mean amounts of DM ingested on the basis of metabolic body size, contents of ADF and ADL in rations and digestibilities of DM and ADF calculated using ADL as an index. Intakes of DM were about the same level among animals with tendency to be lower in dairy cattle. Digestibilities of DM for cattle were higher than those observed in sheep and goat, while those for ADF were higher in sheep and goat than in cattle.

Figure 1 shows dry-matter proportion of 4 sieved fractions of digesta in the diverse alimentary tracts of cattle, sheep and goat. Particles retained on 1180 μm sieve occupied a greater proportion of digesta in the reticulorumen than those in any other sites of the gastrointestinal tracts irrespective of animal species. This particle fraction decreased considerably in the omasum and stayed at about the same level in the lower digestive tracts of cattle, sheep and goat. The proportion of particles larger than 1180 μm in the post-ruminal tracts, however, tended to be higher in cattle than in sheep and goat. Fractions retained on 300 and 45 μm sieves appeared to be similar in any sites of the digestive tracts, although those in the reticulo rumen and the small intestine tended to be smaller in all animal species. The fraction less than 45 μm was greater in the small intestine than in the other tracts. The pattern of DM percentage distribution appe-

TABLE 1. DRY MATTER INTAKE AND DIGESTIBILITY OF DRY MATTER (DM) AND ACID DETERGENT FIBER (ADF) FOR CATTLE, SHEEP AND GOAT TOGETHER WITH ADF AND ACID DETERGENT LIGNIN (ADL) CONTENTS IN A RATION

	Daily DM intake	Digestibility (%)		Content (% DM)	
	$g/kg^{0.75}$	DM	ADF	ADF	ADL
Beef cattle	55.4	75.2	40.0	15.5	2.2
Dairy cattle	40.0	80.9	43.7	12.3	1.8
Sheep	49.1	55.3	50.2	36.7	4.1
Goat	50.9	52.6	47.0	36.7	4.1

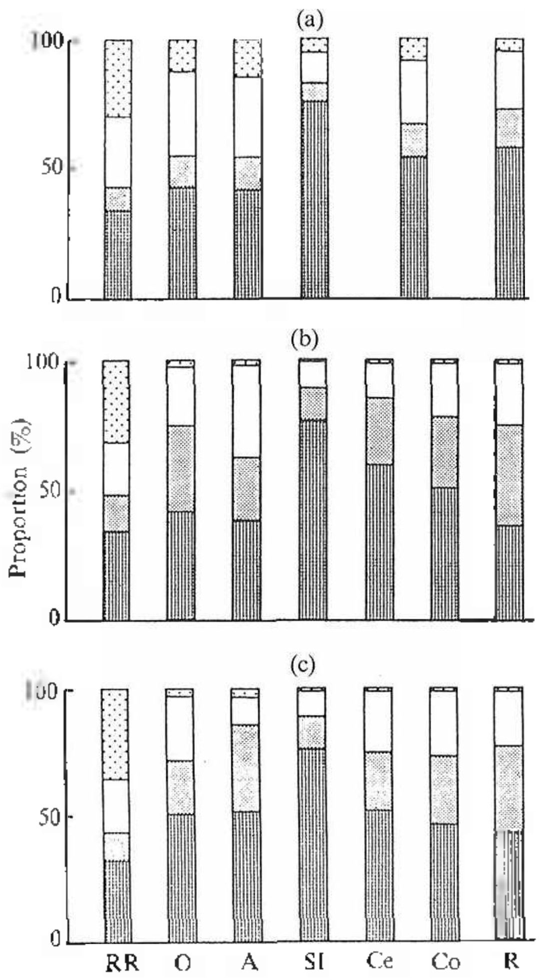

Figure 1. Dry-matter percentage of four sieved fractions (< 45, 45-300, 300-1180, > 1180 μm) of digesta in the reticulo-rumen (RR), omasum (O), abomasum (A), small intestine (SI), cecum (Ce), colon (Co) and rectum (R) of cattle (a), sheep (b) and goat (c).

ared to be very similar among animal species.

On determination of particle size by MAGA system, some protozoa were observed in samples of digesta of the reticulo-rumen, but were not included in the results of particle size determina-

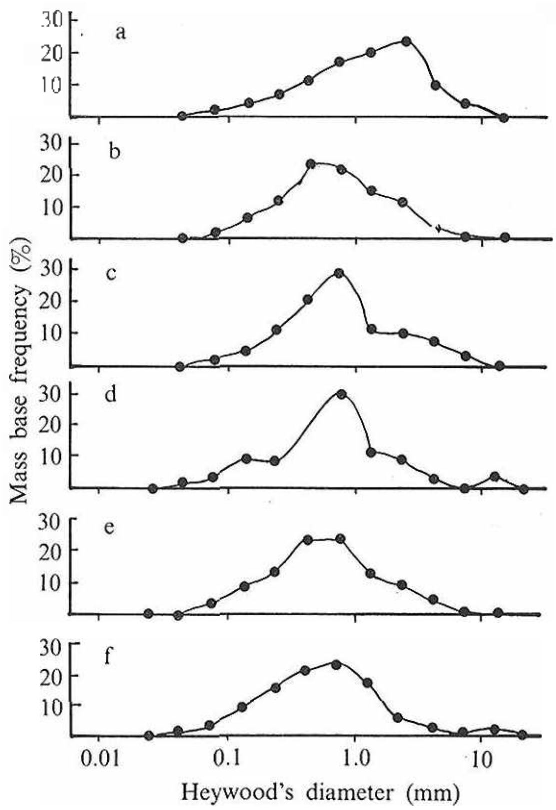

Figure 2. Pattern of mass base frequency distribution of particles of digesta in the reticulo-rumen (a), omasum (b), abomasum (c), small intestine (d), cecum and colon (e), and rectum (f) of cattle slaughtered at 40 hours after feeding.

tion. Mass base frequency distributions of particles of digesta were shown in figure 2 for cattle, figure 3 for sheep and figure 4 for goat. The pattern of mass base frequency distribution of digesta of the reticulo-rumen apparently differed from those found in the lower tracts irrespective of animal species. In the omasal digesta, frequencies of larger particles than 1.0 mm decreased compared with the reticulo-ruminal digesta in all animals. Patterns of the frequency distribution of particles were similar in the post-ruminal tracts irrespective of animal species. Results for sheep and goat showed a close agreement in the distribution of pattern of particles in the gastrointestinal tracts.

Figure 5 shows average Heywood's diameter of particles of digesta in the diverse sites of the digestive tracts of cattle, sheep and goat. Average Heywood's diameter was about 1.2 mm for the reticulo-ruminal digesta for animals of three species. In the omasum it decreased to 0.65 mm for cattle or to 0.34 and 0.37 mm for sheep and goat, respectively, and stayed at about a constant level in the posterior tracts to the omasum. Cattle tended to have a greater average Heywood's diameter in the post-ruminal tracts than sheep and goat.

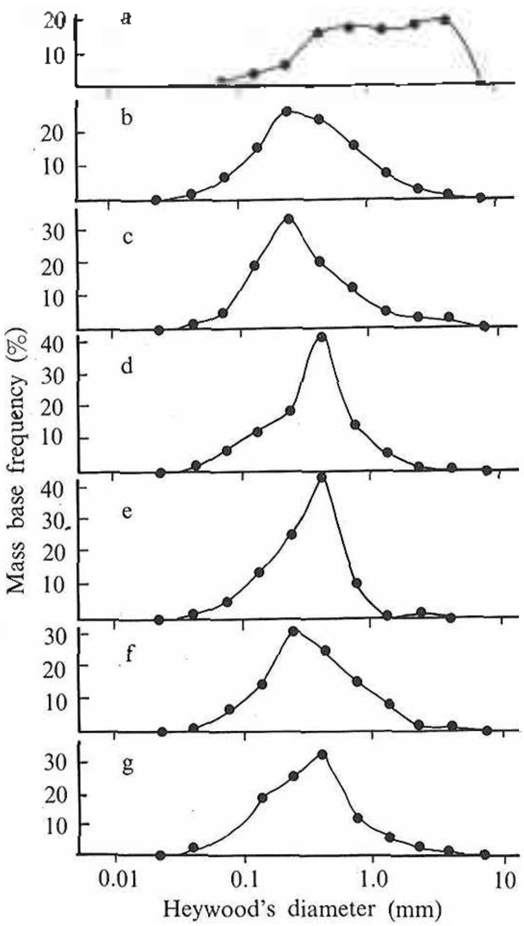

Figure 3. Pattern of mass base frequency distribution of particles of digesta in the reticulo-rumen (a), omasum (b), abomasum (c), small intestine (d), cecum (e), colon (f) and rectum (g) of sheep slaughtered at 2 hours after feeding.

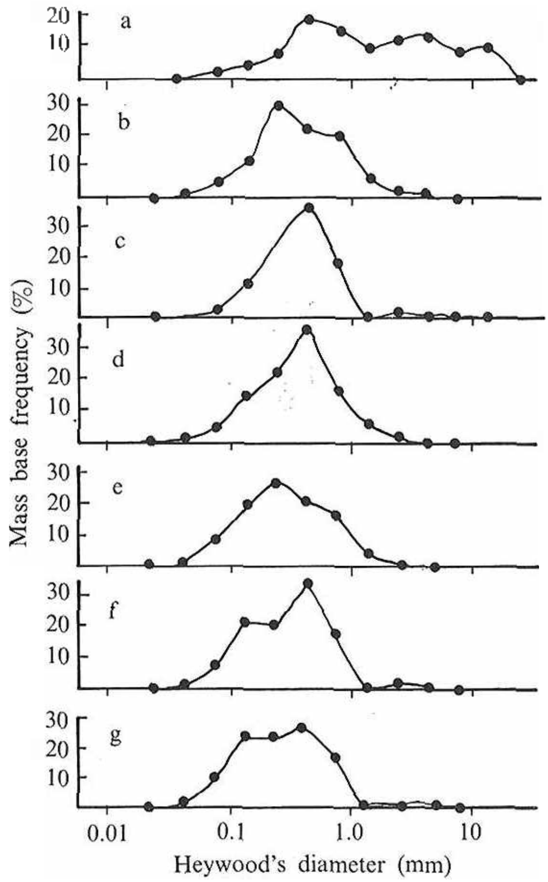

Figure 4. Pattern of mass base frequency distribution of particles of digesta in the reticulo-rumen (a), omasum (b), abomasum (c), small intestine (d), cecum (e), colon (f) and rectum (g) of goat slaughtered at 2 hours after feeding.

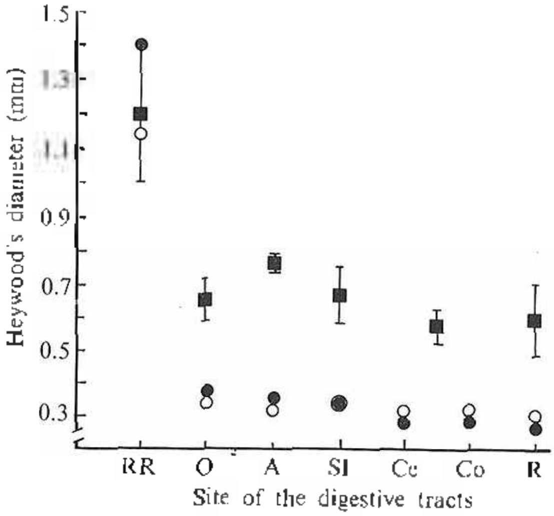

Figure 5. Average Heywood's diameter of particles of digesta in the reticulo-rumer (RR), omasum (O), abomasum (A), small intestine (S), cecum (Ce), colon (Co) and rectum (R) of cattle (■), sheep (○) and goat (●) Vertical lines indicate the standard deviation.

Discussion

Although the size and feeding regimes differed among animals used, intakes of DM on the basis of metabolic body size were similar among animals. Contents of ADF and ADL in a ration, however, considerably differed between cattle and sheep or goat because of different composition of the ration. Nishida et al. (1989) observed that DM digestibility increased as the proportion of concentrate in a ration increased from 0 to 85 %, while ADF digestibility decreased. Therefore, difference in constituents of ration is inferred to be responsible for higher DM and lower ADF digestibilities in cattle than sheep and goat.

One of functions of the omasum has been considered to trap larger feed particles and to reduce their size by the movement of Pila omasi (Kandatsu and Suto, 1987). Stevens et al. (1960) reported that large particles trapped in the omasum were returned to the reticulo-rumen through the reticulo-omasal orifice. Particle distribution of digesta in the omasum differed from that of content in the reticulo-rumen, but was similar to those of the abomasum, cecum, colon and rectum, irrespective of animal species. The proportion of particles larger than 1180 μm in the omasal digesta was considerably smaller than that in the reticulo-ruminal content, irrespective of animal species (figure 1). The mass base frequency distribution showed that particles larger than 1 mm contributed a small portion of the distribution in the post-ruminal tracts irrespective of animal species (figure 2, 3 and 4). The structure around the reticulo-omasal orifice may give a great difficulty to regurgitate large particles from the omasum to the reticulo-rumen bacause uncinate papillae around the reticulo-omasal orifice project toward the omasum as if they were preventing particulates passing through. The video tape recording cordially provided by Dr. McBride (1990) clearly showed that large plastic particles were prevented to pass through the reticulo-omasal orifice by the uncinate papillae around the orifice. Therefore, the regurgitation of large particles may not be the significant function of the omasum, if it may happen. The distribution of particles larger than 1180 μm in the post-ruminal tracts suggests that the omasum plays a minor role to trap and reduce the size of large particulate materials passed from the reticulo-rumen. It is inferred that the reticulo-rumen per se and/or the reticulo-omasal orifice may have an important role to limit the flow of large particles to the omasum.

The pattern of the mass base frequency distribution of particles in digesta was found to be similar among animal species in any sites of the digestive tracts except for the reticulo-rumen (figure 2, 3 and 4). Sekine et al. (1990) found that the particles larger than 1180 μm in the reticulo-rumen of sheep decreased in amounts and the percentage as the time elapsed after feeding commenced. The time after feeding, however, gave little influence upon amounts and proportion of particle fractions of the post-ruminal tracts. Cattle were slaughtered at 40 hours after feeding, while sheep and goat at 2 hours in the present study. Therefore, the time after feeding is inferred to have little effect on the pattern of the mass base frequency distribution of particles in digesta of the post-ruminal tracts of ruminants. The proportion of sieved fractions, however, showed that particles larger than 1180 μm tended to occupy a greater proportion in cattle than sheep and goat (figure 1). Average Heywood's diameters of particles in the digestive tracts were greater in cattle than sheep and goat except for that of the reticulo-rumen (figure 5), while those for sheep and goat were almost the same size in the diverse sites of the digestive tracts. The ration for cattle consisted of about 80% of concentrate with Italian ryegrass 2nd cut hay but that fed to sheep and goat was solely Italian ryegrass 2nd cut hay. Thus, results may give no clear evidence whether difference in average Heywood's diameter has caused by the size of animal species per se or difference in rations fed.

Average Heywood's diameter for ruminal particles was about the same among cattle, sheep and goat (figure 5). The proportion of particles larger than 1180 μm in the reticulo-rumen decreased as time after feeding increased (Sekine et al., 1990). The time at slaughter was 40 hours after feeding for cattle and 2 hours for sheep and goat. Thus, the length of time after feeding is inferred to have contributed to the reduction in average Heywood's diameter of the particulates in the ruminal digesta of cattle and resulted in no difference in the diameter among animal species. From above discussion, we have concluded that the proportion of particles in the post-ruminal digesta is similar, while it considerably differs from that of the reticulo-rumen. The pattern of mass base frequency distribution of particles is similar in the post-ruminal digesta, but it is considerably different from that of the reticulo-rumen. Average Heywood's diameter of particles in digesta is about the same in the post-ruminal tracts of ruminants. Thus, mean particle size and the particle distribution in digesta of the rectum or feces reflect those in digesta of the omasum.

Acknowledgements

This research was partly supported by the Fund of the Ministry of Education, Japan (01304024).

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