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Passage of large plastic particles through the digestive tract of lactating and dry cows*

J. Třináctý[1], M. Šimek[1], L. Zeman[2] and J. Harazim[3]

[1] *Research Institute of Animal Nutrition, Ltd.*
Videňská 699, 691 23 Pohořelice, Czech Republic
[2] *Mendel University of Agriculture and Forestry*
Zemědělská 1, 613 00 Brno, Czech Republic
[3] *Central Institute for Supervising and Testing in Agriculture*
Jaselská 16, 746 01 Opava, Czech Republic

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ABSTRACT

In five trials carried out on two lactating and two dry cows three sets of particle sizes were used: in the first set particles with a diameter of 9 mm and length of 4, 6, 8 and 10 mm, in the second set particle sizes of 8/8, 11/11, 14/14 and 17/17 (diameter/length) mm, and the third set 8/8, 9/9, 10/10, 11/11 and 12/12 mm particles. In the first set the lactating cows had a significantly higher mean recovery (97.8 vs 75.9 %) and a significantly shorter total tract mean retention time (TMRT) (53.0 vs 96.6 h) than the dry cows (P<0.05). In the second trial with lactating cows the main differences in recovery were found between 11/11 and 14/14 mm particles, significant at 48 h after administration (63.8 vs 31.3 %; P<0.05). Regurgitation of 17/17 mm particles was 27.5 % in lactating cows and 80% in dry cows in the course of 384 h. In the third set did not yield significant results, except 36 h (P<0.05) after placing. It is concluded that relatively good recovery and TMRT can be achieved in lactating cows with plastic particles of a size larger than 11/11 mm but smaller than 14/14 mm.

KEY WORDS: plastic particles, passage, recovery, retention time, cow

INTRODUCTION

Particle passage through the digestive tract of cattle depends on the specific gravity of the particles. The optimum density of plastic particles was established by King and Moore (1957). Their trials with steers showed that the highest speed of

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particle passage was achieved with a particle density of about 1.2 g/cm^3. Campling and Freer (1962) found that the lowest ruminal mean retention time was achieved with a particle specific gravity of 1.1-1.2 g/cm^3. Stetter Neel et al. (1995) reported that the ruminal passage rate of 1 and 3 mm inert particles grew (from 0.68 to 5.79 %/h) when their specific gravity increased from 0.9 to 1.32 g/cm^3. From the above values, the ideal range of 1.2-1.3 g/cm^3 was derived for our plastic particles.

Larger particles pass more slowly through the digestive tract of cattle. This was confirmed by trials performed by Moore et al. (1992) and Mambrini and Peyraud (1997) where ground hay showed shorter total tract mean retention time (TMRT) than particles of long hay. Similar results were found with plastic particles. In a trial with dry cows, Campling and Freer (1962) related the 3.2, 4.0 and 4.8 mm size of particles directly to TMRT (80, 86 and 91 h). When cylindrical nylon particles of 1, 3 and 5 mm length were placed in the rumen of steers by Prigge et al. (1990), ruminal retention time was 17.4, 20.7 and 61.36 h.

The passage of large plastic particles has not been sufficiently tested. Welch and Smith (1978) fed steers with 5, 10, 15 and 20 mm rubber strips and achieved 0.9 % recovery of nonruminated 20 mm particles. Ehle and Stern (1986) introduced 3.2, 6.4 and 12.7 mm spheres into the rumen of heifers achieving recovery of 78.2, 79.5 and 68.8 %.

In 1995 the nylon capsule method was presented for the first time (Třináctý et al., 1995a,b). The presented method was based on 10 mm nylon capsules made of nylon cloth filled with feed samples and orally inserted into the animal. The questions remained which is the optimum capsule size to use and which maximum size of particles will pass through the digestive tract of cattle with satisfactory recovery and total tract mean retention time (TMRT). The plastic particles in this study were tested as a model for nylon capsules. Because the passage of particles depends on dry matter (DM) intake, the trials were conducted on dry (with smaller DM intake) and lactating cows (with higher DM intake). The aim was to evaluate the passage of large plastic particles given to lactating and dry cows.

MATERIAL AND METHODS

Animals

Two lactating crossbred cows and two dry crossbred cows were used (Czech Pied >75 % x Black Friesian <25 %). The liveweight of the lactating cows at the beginning of the trials was 550 and 535 kg. The diet consisted of 20 kg of maize silage with 29.8 % dry matter (DM), 4 kg of lucerne hay and 6 kg of a mixture (%: maize meal 25, soyabean meal 23, oat meal 17, wheat meal 12, lucerne meal 12, wheat bran 8, dicalcium phosphate 2.5, and sodium chloride 0.5). The diet was calculated according to the performance of the cows (ČSN 467070), components of the ration were fed separately. The mean daily consumption by the two lactating cows during the trials was 14.83 kg of DM, 2.54 kg of crude protein and 3.01 kg of crude fibre with small refusals (0.28 kg, s.e. 0.14, respectively, 0.22 kg, s.e. 0.07). The mean milk yield was 12.48 (s.e. 0.13) and 15.01 kg (s.e. 0.14), respectively.

The liveweight of the dry cows at the beginning of the trials was 525 and 510 kg. The diet consisted of 6 kg of lucerne hay and 1.4 kg of a mixture (%: barley meal 32, maize meal 32, wheat meal 32, mineral supplement 2 and sodium chloride 2). With dry cows no refusals were found, the mean daily feed intake being 6.43 kg of DM, 1.17 kg of crude protein and 1.64 kg of crude fibre. The diets of the lactating and the dry cows were fed twice daily, at 5.00 a.m. and 3.00 p.m.

Plastic particles

Cylindrical plastic particles were used. They were made of polypropylene with limestone as the filler (Chirana, Brno). The specific gravity of the particles was 1.25 ± 0.05 g/cm^3. In five trials three sets of particle sizes were used: in trials 1L (lactating cows) and 1D (dry cows) the particle diameter was 9 mm and the height of the cylinders (i. e. the length of the particles) was 4, 6, 8 and 10 mm. Fifty particles of each size (together 200 pieces) were given to one cow at one time. The particles in 1L and 1D trials were given in two periods.

Experiment with cows

In trials 2L and 2D 8/8, 11/11, 14/14 and 17/17 mm (diameter/length) particles were used. The total number of particles simultaneously given to one cow was 80, with 20 particles of each size. Except for particles 17/17, which were given only to the lactating cows in the first period, the remaining particles were given in two periods.

In trial 3L a set of 8/8, 9/9, 10/10, 11/11 and 12/12 mm particles was applied in four periods. Thirty pieces of each size (150 particles in all) were introduced into one cow at one time.

Each application and cow had its own particle colour. Plastic particles were administered orally by the "balling gun" device (Corio, 1976) after feeding at 8.00 a.m. as a paper bolus. Excrements were collected into pots within the 24 h service. The collection intervals were 12 h in the first 3 days and 24 h in the following days with the lactating cows, and 24 h in the dry cows.

One period lasted 168 h in the lactating cows (except for trial 2L, where it was 384 h) and 384 h in the dry cows. The interval between applications of particles was generally 21 days, except for trial 3L, where it was 14 days. Excrements were washed under running water using a 4 mm screen. The regurgitated particles were found by the 24-h service near the forelegs of the animals.

The results were evaluated by multifactor analysis of variance using Statgraphic version 5.0 software; the sources of variability were the following factors: size of particles, period, cow and time interval. TMRT was calculated according to Thielemans et al. (1978) by means of the following formula:

$$TMRT = \Sigma(Q_t \times t \times dt)/\Sigma(Q_t \times dt),$$

where Q_t the quantity of particles in faeces found during the faecal collection interval, the time interval after particles application and t the faecal collection interval.

RESULTS

The differences between the recovery and TMRT of the individual particle sizes in 1L and 1D trials were not significant (P>0.05; Table 1). The differences between the total means of all particle size recoveries in lactating and dry cows combined were significant for all time intervals. At the time interval of 192 h it was 97.8 vs 75.9% (P<0.05). In the dry cows, the particle passage was significantly slower (P<0.05), 192 h after application TMRT was 53.0 h in the lactating cows vs 96.6 h in the dry cows (P<0.05). The results of the 1L and 1D trials are also shown in Figure 1. The courses of the cumulative recovery of particles are ordered according to their size in the lactating and the dry cows.

Based on the results of 1L and 1D trials a larger range of particle sizes was selected in trials 2L and 2D. Table 2 shows that with the lactating cows no significant differences occurred (P>0.05) between particles 8/8 and 11/11. Significantly lower recovery (P<0.05) was found with the 14/14 particles after 48, 72 and 96 h,

TABLE 1

Mean cumulative recovery (%) and TMRT (h) of 4/9, 6/9, 8/9 and 10/9 mm particles[1] in 1L and 1D trials

Hours	Lactating cows (trial 1L)				Dry cows (trial 1D)				Total mean	
	4/9	6/9	8/9	10/9	4/9	6/9	8/9	10/9	1L	1D
24	4.0	7.0	5.0	5.5	0.0	0.0	0.0	0.0	5.4	0.0
48	58.5	57.5	60.5	63.5	0.5	0.6	0.0	0.0	60.0[a]	0.3[b]
72	87.0	89.0	85.5	81.0	33.0	32.6	26.1	25.2	85.6[a]	29.2[b]
96	90.0	92.0	88.5	87.0	49.0	49.7	47.9	40.5	89.4[a]	46.8[b]
192	98.5	99.0	97.5	96.0	84.5	76.9	73.3	69.0	97.8[a]	75.9[b]
384[2]	–	–	–	–	94.9	87.7	86.3	80.0	–	87.2
TMRT192 h[2]	50.5	50.0	55.1	56.5	98.4	93.7	97.6	96.5	53.0[a]	96.6[b]
TMRT 384 h[2]	–	–	–	–	115.6	117.7	132.3	130.2	–	124.0

[1] length/diameter ratio

[2] TMRT calculated up to 192 h after application (or 384 h, respectively)

a, b – P<0.05

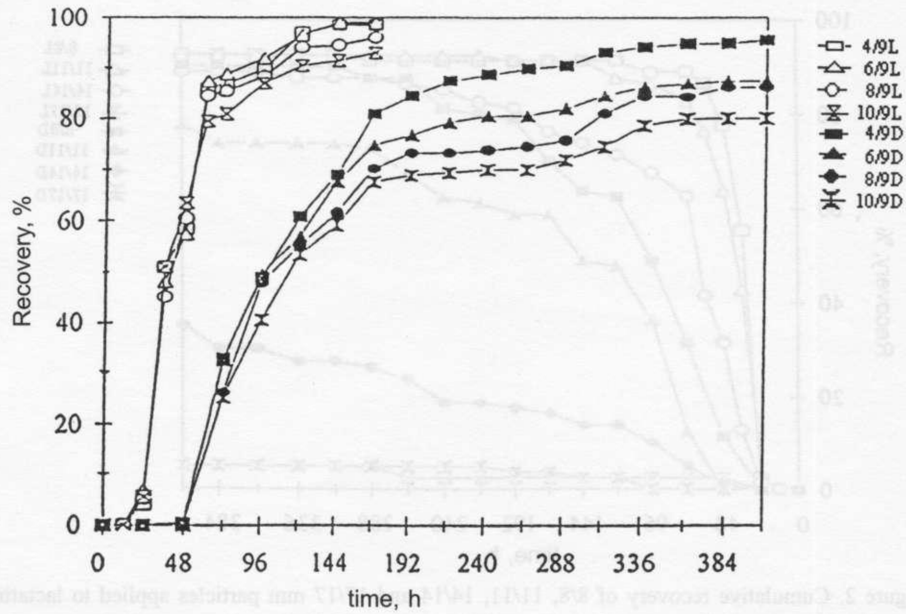

Figure 1. Cumulative recovery of 4/9, 6/9, 8/9 and 10/9 mm particles applied to lactating (L – dark marks) and dry (D – light marks) cows in trials 1L and 1D

TABLE 2

Mean cumulative recovery (%) and TMRT (h) of 8/8, 11/11, 14/14 and 17/17 mm particles[1] in 2L and 2D trials

Hours	Lactating cows (trial 2L)[2]				Dry cows (trial 2D)[2]			
	8/8	11/11	14/14	17/17	8/8	11/11	14/14	17/17
24	2.5	2.5	1.3	0.0[3]	0.0	0.0	0.0	0.0
48	77.5[a]	63.8[a]	31.3[b]	2.5	11.3	0.0	1.3	0.0
72	88.8[a]	82.5[ab]	62.5[b]	2.5	31.3	12.5	5.0	0.0
96	88.8[a]	86.3[ab]	67.5[b]	2.5	48.8[a]	36.3[ab]	10.0[b]	0.0
192	91.3	91.3	81.3	2.5	78.8[a]	58.8[a]	17.5[b]	3.8
384	92.5	92.5	88.8	5.0	90.0[a]	73.8[a]	30.0[b]	5.0
TMRT 384 h	47.0	53.8	95.6	–[4]	115.8	132.7	170.7	–[4]

[1] length/diameter ratio

[2] particles 17/17 were not included in the statistical evaluation

[3] in trial 2L particles 17/17 were only applied in the first period

[4] TMRT was not calculated (see in the text)

a, b – P<0.05

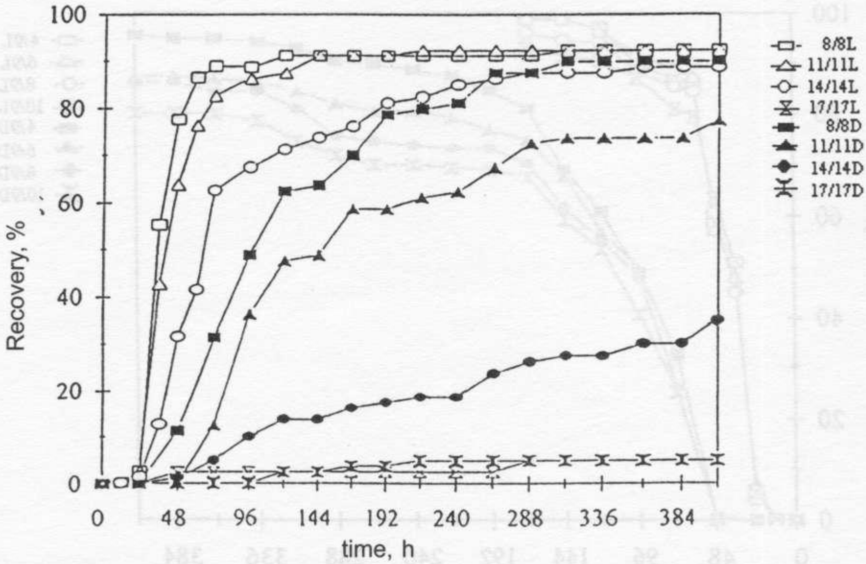

Figure 2. Cumulative recovery of 8/8, 11/11, 14/14 and 17/17 mm particles applied to lactating (L – dark marks) and dry cows (D – light marks) in trials 2L and 2D

these differences can also be seen in Figure 2. This fact is in agreement with the TMRT values, which were 53.8 for the 11/11 particles and increased to 95.6 h for the 14/14 particles. The values for the 17/17 mm particles were excluded from statistical evaluation because in the lactating cows this size of particles was used only in the first period and their recovery as well as regurgitation (as mentioned below) was too small.

In the dry cows and trial 2D significant differences ($P<0.05$) were found between 8/8, 11/11 and 14/14 particles for the 192 and 384 h time intervals. The recovery value of the 14/14 particles was only 30.0 % with a relatively high TMRT value of 170.7 h. Also with the dry cows the obtained recovery of the 17/17 particles was only 5.0%.

When the recovery in trials 2L and 2D (Table 2) is compared for the 384 h interval, one can see that the biggest difference between the lactating and the dry cows was found for the 14/14 particles where the values were 88.8 and 30.0 %, respectively. The TMRT values of 8/8 and 11/11 particles in lactating cows were more than twice as small as in dry cows, which means that the particles passed through the digestive tract of lactating cows more than twice as fast. In the lactating cows the 14/14 particles passed more quickly than the 8/8 in the dry cows, the TMRT value being 95.6 vs 115.8 h, respectively.

TABLE 3

Mean cumulative regurgitation (%) of 11/11, 14/14 and 17/17 mm particles[1] in 2L and 2D trials

Hours	Lactating cows (trial 2L)			Dry cows (trial 2D)		
	11/11	14/14	17/17	11/11	14/14	17/17
24	0.0	0.0	2.5[2]	1.3[a]	10.0[ab]	23.8[b]
48	1.3	3.8	10.0	2.5[a]	31.3[b]	42.5[b]
72	1.3	5.0	10.0	2.5[a]	32.5[b]	46.3[b]
96	1.3	6.3	20.0	3.8[a]	32.5[b]	50.0[b]
192	1.3	7.5	22.5	5.0[a]	36.3[b]	71.3[c]
384	1.3	7.5	27.5	5.0[a]	40.0[b]	80.0[c]

[1] length/diameter ratio

[2] particles 17/17 were only applied in the first period

a, b – $P<0.05$

In the 2L and 2D trials particle regurgitation increased with increased particle size. There was a relatively low number of regurgitated particles in the lactating cows (Table 3); for the 11/11 particles it was only 1.3%. The 17/17 particles were regurgitated in 27.5%. The dry cows showed considerably higher values of regurgitation; 40.0% for the 14/14 particles and 80.0% for the 17/17 ones ($P<0.05$).

Table 4 shows the results of the 3L trial with lactating cows. Although the application was repeated four times and the particle sizes ranged from 8/8 to 12/12 mm, the only significant differences in recovery were found with the 36 h interval ($P<0.05$). TMRT increased non significantly ($P>0.05$) from 40.3% for the 9/9 particles to 47.6% for the 12/12 particles.

TABLE 4

Mean cumulative recovery (%) and TMRT (h) of 8/8, 9/9, 10/10, 11/11 and 12/12 mm particles[1] in the 3L trial

Hours	Lactating cows (trial 3L)					Total mean
	8/8	9/9	10/10	11/11	12/12	
24	8.3	8.8	10.8	2.9	5.4	7.3
36	57.7[a]	56.8[a]	57.4[a]	43.3[b]	44.3[b]	51.9
48	80.3	78.4	73.9	69.8	70.7	74.6
72	93.3	93.6	92.3	90.2	88.0	91.5
96	95.8	96.6	94.8	96.5	93.1	95.4
192	97.9	97.9	97.3	99.6	98.2	98.2
TMRT 192 h	40.5	40.3	42.0	47.0	47.6	43.5

[1] length/diameter ratio

a, b – $P<0.05$

DISCUSSION

In both lactating and dry cows recovery increased with the decreased plastic particle size. This is in agreement with the findings of Welch and Smith (1978) and Stetter Neel et al. (1995) who tested the influence of the plastic particle size on their recovery. For all the sets of particle sizes applied, TMRT was significantly higher for larger particles ($P<0.05$, except for the 3L trial), as found by Mambrini and Peyraud (1997) with feed particles and by Prigge et al. (1993) with plastic particles.

The influence of the feed intake level on the increase of the speed of the feed particle passage from the rumen was described by Okine and Mathison (1991). This effect leads to a decrease of TMRT, as found by Luginbuhl et al. (1994) with feed particles in steers, and by Rothfuss et al. (1997) in a trial with cows. Our trials have also confirmed this effect. For example, in lactating cows with a higher intake level (14.8 kg DM/day) the TMRT for the 14/14 particles was 95.6 h, while in dry cows with a lower intake level (6.43 kg DM/day) it was 170.7 h.

There is little information in the literature about large particle passage through the digestive tract of cattle. Welch and Smith (1978) used polypropylene ribbon 20 mm in length, 2.5 mm in width and 0.008 mm in thickness with a density of 0.9 g/cm^3 and found only a small recovery of 0.9% of the nonruminated particles. These results are hardly comparable with our values because the particles were of a different shape and specific gravity. Ehle and Stern (1986) used 12.7 mm particles with a 1.34 g/cm^3 density. Their relatively low recovery (68.8%) was probably caused by the low level of feed intake by heifers. Another limiting factor of large particle passage through the digestive tract can also be the size of the reticulo-omasal orifice, which, according to Welch (1982), is larger than 20 mm in cattle.

Regurgitation of spheres 12.7 mm in size and with a 1.34 g/cm^3 density was evaluated in heifers by Ehle and Stern (1986), with a resulting value of 15.5%. Their result is similar to our value achieved in the 2D trial with dry cows and 11/11 and 14/14 particles. Our values were 5.0 and 40.0%, respectively. The higher regurgitation by dry cows of all sizes of particles is probably related to the fact that the passage of all particles was quicker in the lactating cows. This influence was confirmed especially for the larger 14/14 and 17/17 particles, where regurgitation was 40.0 and 80.0 %, respectively, in dry cows.

We have noticed that the corresponding recoveries of 8/8 and 11/11 particles in trials 2L and 3L were different (Tables 2 and 4). The recovery values were non significantly ($P>0.05$) higher for the 3L trial in all time intervals. For example, in the 2L trial the 8/8 and 11/11 particles showed 91.3 and 91.3% recovery in the interval of 192 h after administration, while in the 3L trial it was 97.9 and 99.6%, respectively. Because in 3L larger amounts of similar particles were applied simultaneously, we assume that in this case the particles were mutually moved forward, or "raked", which increased recovery. This interaction was labeled with the working name of "rake effect".

CONCLUSIONS

It can be concluded that in lactating cows with a daily intake of 14-15 kg DM relatively good recovery and retention time can be achieved with plastic particles of a size larger than 11/11 mm but smaller than 14/14 mm. The use of 17/17 mm and larger particles is not recommended because recovery is negligible and most of the particles are regurgitated. The administration of large plastic particles to dry cows showed substantially lower recovery and longer retention time.

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STRESZCZENIE

Przechodzenie dużych plastikowych cząstek przez przewód pokarmowy krów produkujących mleko i zasuszonych

W pięciu doświadczeniach, przeprowadzonych na 2 krowach produkujących mleko i 2 zasuszonych, badano tempo przechodzenia plastikowych cząstek w zależności od ich wielkości: w pierwszej serii cząstki o średnicy 9 mm i długości 4,6,8 i 10 mm, w drugiej 8/8, 11/11, 14/14 i 17/17 mm (średnica/długość) i w trzeciej serii 8/8, 9/9, 10/10, 11/11 i 12/12 mm. W pierwszej serii u krów mlecznych odzyskano więcej cząstek (97,8 vs 75,9%) oraz istotnie krótszy był u nich średni czas przechodzenia cząstek przez przewód pokarmowy (TMRT) (53,0 vs 96,6 godz.) niż u krów zasuszonych ($P < 0,05$). W drugiej serii, na krowach mlecznych, największe różnice stwierdzono w odzyskaniu cząstek o wielkości 11/11 a 14/14 mm, które było istotne po 48 godz. (63,8 vs 31,3%; $P \leq 0,05$). Zwracanie cząstek o wielkości 17/17 mm w ciągu 384 godz. wynosiło 27,5% u krów mlecznych i 80% u zasuszonych. W trzeciej serii istotne różnice w odzyskaniu cząstek stwierdzono tylko po 36 godz.

Na podstawie otrzymanych wyników stwierdzono, że odzyskiwanie cząstek plastikowych oraz TMRT jest stosunkowo dobre przy wielkości cząstek większych niż 11/11 mm i mniejszych niż 14/14 mm.