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MASS DENSITY OF OAT HAY AND LUCERNE HAY AS A FEED EVALUATION CHARACTERISTIC

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OPSOMMING: MASSADIGTHEID VAN HAWERHOOI EN LUSERNHOOI AS 'N VOEREVALUERINGSEIENSKAP

Tydens 'n ondersoek van die voedingswaardes van plaalik geproduseerde ruvoere is betekenisvolle verskille ($P \leq 0,05$) in vrywillige innames van hawerhooi en lusernhooi deur skape, opgemerk. Moontlike verklarings vir hierdie verskille was geleë in verskille in proteieninhoud en smaaklikheid. Toe die dinamiek van die 2 voere egter in die spysverteringskanaal van skape bestudeer is, het dit geblyk dat die ruimtevullende eienskappe en die spoed van deurgang van onverteerde voedsel ook grootliks verskil het.

In proepe wat op die bogenoemde gevolg het, is die massadigthede (g/cm^3) van monsters van die 2 voere wat deur verskillende groottes hamermeulsiwwe gemaal is, bepaal. Dit het gewissel van 0,097 g/cm^3 vir hawerhooi wat deur 'n 32 mm sif gemaal is, tot 0,333 g/cm^3 vir lusernhooi wat deur 'n 3 mm sif gemaal is. Hierdie digthede is in verband gebring met die vrywillige innames van die verskillende fisiese vorms deur skape. Waar die massa-innames van lusernhooi en hawerhooi, wat deur diselfde grootte hamermeul gemaal is, 80,3 en 41,8 g/kg $W^{0,75}$ / dag, onderskeidelik, bedra het en betekenisvol verskil het ($P \leq 0,05$) was die volume-innames 426 en 437 cm^3/kg $W^{0,75}$ / dag en klaarblyklik nie verskillend nie. Die skape kon dus 'n groter massa van lusernhooi, maar nie 'n groter volume, as van hawerhooi inneem nie. Die gevolgtrekking is dat die ruimtevullende eienskappe van ruvoere miskien belangriker invloede op inname het as sommige van die ander faktore wat gewoonlik oorweeg word.

SUMMARY:

In the course of studies designed for evaluation of locally produced forages, significant differences ($P < 0,05$) in voluntary intakes of lucerne hay and oat hay by sheep, were found. These differences could be partly explained by differences observed in protein content, digestibility and even palatability. However, when the dynamics of the digesta of the 2 feeds in the digestive tract of sheep were considered, it became apparent that there were important differences in space filling capacity and rate of fermentation.

In further studies, the mass densities of samples of the 2 feeds, milled through different sized hammer mill screens, were determined. These varied from 0,097 g per cm^3 in oat hay milled through the 32 mm screen, to 0,333 g per cm^3 in lucerne hay milled through the 3 mm screen. These densities were then related to the voluntary intakes of the different physical forms of the two feeds by sheep. It was found, for example, that the intake of lucerne hay and oat hay milled through the same screen, were, respectively, 80,3 and 41,8 g per kg $W^{0,75}$ per day, while the volume intakes were 426 and 437 cm^3 per kg $W^{0,75}$ per day, respectively. It was concluded that space occupying characteristics of milled forages may have more important effects on voluntary intake than some of the other attributes usually taken into consideration.

The necessity for a standardized physical description of feeds is obvious to anybody who has some experience of forage evaluation. Two feeds milled through the same hammer mill screen may differ substantially in fineness and physical appearance. These differences have effects on the dynamics of feed and undigested residues in the digestive tract of the ruminant and on voluntary intake and digestibility of the feed in question. In order to refine the relationship between ration nutritive value and voluntary intake, Montgomery & Baumgardt (1965) and Baumgardt (1970) have included density in addition to digestibility of dry matter in the description of ration nutritive value. This was done on the assumption that, at a given level of digestibility, the feed with the higher density will have the more rapid rate of digestion, more rapid rate of passage and will occupy less space in the digestive tract per unit weight.

It was found in the course of studies designed for the evaluation of locally produced forages, that significant differences in voluntary intake of oat hay and lucerne hay by sheep, could be attributed to differences in protein content (5 and 15% respectively) and even palatability (lucerne 'flavour' enhanced intake of oat hay), but that the digestibility of organic matter of the 2 hays, when fed at the same levels, were very similar.

Despite the similarity of organic matter digestibility, the digestibility of the crude fibre fraction differed significantly i.e. 59,3% in oat hay and 35,8% in lucerne hay, when both were fed at the *ad libitum* level.

This observation pointed to a possibile difference in rate of digestion. When this was investigated by means of the two-stage *in vitro* technique of Tilley & Terry (1963) as applied to South African forages by Engels & Van der Merwe (1967), it was found (Van Niekerk, 1977) that 75% of the fermentation of lucerne hay was completed after 24 hours incubation with rumen inoculum, compared to only 61% of oat hay.

With these observations in mind, it was decided to investigate the fineness of grinding, mass density and certain aspects of the passage through the digestive tract of sheep of samples of the 2 hays milled through different sized screens.

Procedure

Sufficient quanitites of lucerne hay and oat hay for a series of trials were milled through hammer mill screens with 32 mm, 12,5 mm and 3 mm sized apertures. Visually and according to their respective chemical analyses, the 2 batches of hay were more or less typical of the average lucerne hay and oat hay of this area.

Determination of physical fineness

The best available dry-sieve method is probably that of A.S.A.E. (1967). Whereas A.S.A.E. (1967) used a series of 7 A.S.T.M. type sieves, in the present experiment 3 circular sieves of 20 cm diameter and 5 cm height with screen apertures of 2,38; 1,0; and 0,5 millimetres, respectively, were used. These were stacked on top of each other above a pan and shaken mechanically (ro-tap action) for exactly 60 seconds after samples of either 50 grams lucerne hay or 30 grams oat hay were placed on the top sieve. The index of fineness was calculated on a scale from 10 to 238. A value of 10 would indicate that all of the material passed through the top 3 screens and was collected in the pan (100 x 0,1 = 10), while a value of 238 would indicate that none of the material passed through and that 100% (100 x 2,38 = 238) remained on the top screen.

In order to relate physical fineness of the feed to physical fineness of wet digesta samples, a wet-sieve technique was employed. In this case 4 circular sieves of 20 cm diameter and 5 cm height, with screen openings of 2,38 mm; 1,0 mm; 0,5 mm and 0,25 mm, respectively, were stacked on top of each other above a pan. A container filled with water equal to ten times the weight of dry matter in the sample was positioned 40 cm above the top sieve and connected with a spray nozzle with 64 apertures of mean diameter 0,8 mm. The nozzle was positioned 10 cm above the mat of the top sieve. After it was sprayed with water, the percentage of the original dry matter found on every one of the 3 top screens and on the bottom screen plus the pan, was multiplied by the corresponding screen aperture size and added to obtain an index of fineness.

Determination of mass density of the feed

An accurately weighed, representative sample of the dry, ground hay was transferred to a plastic measuring cylinder. After the cylinder had been dropped 5 times in an upright position from a height of 10 centimeters between the bottom of the cylinder and the bench, the volume occupied by the feed sample was noted in grams per cm^3. This arbitrary procedure was different to the procedure followed by Montgomery & Baumgardt (1965). They filled a cylinder and swirled it between the palms of the hands for 15 seconds, refilled and swirled for 10 seconds, refilled and swirled for 5 seconds before it was finally refilled and the weight of material per cm^3 was noted.

Feeding and slaughter trial

With the object of studying the dynamic behaviour of oat hay and lucerne hay in the course of digestion by sheep, by comparing the volume and mass of the material present in different sections of the tract, lucerne hay and oat hay, each milled through 2 hammer mill screens with 3 mm and 32 mm apertures, were fed to groups of 4 S.A. Mutton Merino wethers in individual pens. In an attempt to establish a regular routine and to achieve a steady state within the limits of this routine, the feeds were offered *ad libitum* (15% refusal level) for 5 hours from 08h00 each day. Water was available throughout the day.

After 30 days of this regimen, 2 sheep from each group were killed at 08h00, just before the remaining 2 were fed as usual. The latter were observed continuously and slaughtered after, in the opinion of the investigators, they had stopped eating for 5 minutes. It was previously observed that the animals ate actively for about 2 to 3 hours after the daily meal was offered and then stopped eating for one to 2 hours. In their first eating episode, they ingested about 60 to 70% of the total daily DM-intake. Half of the animals were slaughtered before and half after the first meal in order to compare the movement of oat hay and lucerne hay in the digestive tract 19 hours after and about 2 hours after meals.

Slaughter procedure

Within 5 minutes of killing, the sheep was eviscerated and the digestive tract bound in strategic positions. These were: (a) between mouth and reticulorumen; (b) between reticulorumen and omasum; (c) between

Table 1

Index values for fineness of lucerne hay and oat hay ground through 3 different sized hammer mill screens

Feed	Oat hay			Lucerne hay		
Hammer mill screen:	32	12	3	32	12	3
Dry sieve:	162,2 ± 2,5	125,4 ± 1,35	53,2 ± 1,9	130,4 ± 3,9	83,2 ± 2,8	37,6 ± 1,1
Wet sieve:	162,3 ± 3,6	–	56,8 ± 3,5	121,5 ± 1,4	–	47,2 ± 1,4

omasum and abomasum; (d) immediately behind pyloric sphincter; (e) immediately in front of ileocaecal junction; (f) in the seventh turn of the colon.

After the entire digestive tract with contents had been weighed, it was sectioned at the bound-off positions, the contents of each section weighed, the volume of the contents measured and sampled. Samples were stored at 0°C for later determination of dry matter, mass density, volume and indexes of fineness.

Statistical analysis

The results of the slaughter experiment were analysed as a 2 x 2 x 2 factorial according to the procedure suggested by Snedecor & Cochran (1967). In the tables, figures in the same column with different superscripts differ significantly at the 5% level of probability.

Results and Discussion

Indeces for fineness of the 2 feeds

The average index for fineness of oat hay and lucerne hay, determined according to both dry – and wet sieve methods are presented in Table 1.

The indeces obtained with the dry- and wet sieve technique, respectively, were surprisingly similar. With both feeds, different sized hammer mill screen apertures yielded clearly different indeces, as expected. According to these indeces milled lucerne hay was in each case finer than milled oat hay. When the 2 hays were handled in the coarse form, lucerne hay appeared to be more brittle than oat hay. Microscopically milled lucerne hay particles show more cubic forms than milled oat hay.

Mass densities of the 2 feeds

In Table 2 the mass densities of oat hay and lucerne hay are presented and compared with those of some other common feeds.

The data in Table 2 show clear differences in mass density between lucerne hay and oat hay on one hand and

Table 2

Mass densities of oat hay and lucerne hay ground through 3 different sized hammer mill screens compared to those of a number of other feeds

Feed	Volume of 100 g cm^3	Mass of 100 cm^3 g	Mass density g/cm^3
Oat hay (H 32)	1030	9,7	0,097
Oat hay (H 12)	710	14,0	0,140
Oat hay (H 3)	520	19,3	0,193
Lucerne hay (L 32)	555	18,0	0,180
Lucerne hay (L 12)	420	23,8	0,238
Lucerne hay (L 3)	300	33,3	0,333
Wheat bran	380	26,3	0,263
Molasses meal	199	50,6	0,505
Oat grain	180	54,8	0,548
Fish meal	143	70,2	0,702
Peanut oilcake meal	117	85,0	0,850
Maize meal	113	89,0	0,890

Table 3

Mean masses and volumes of 2 physical forms of oat hay and lucerne hay ingested by sheep over the last 10 days of a 30 day period (mean of 4 sheep) and as a single meal until the first signs of satiety appeared (means of 2 sheep)

Feed	Mean daily DM-intake of 4 sheep over 10 days		Mean dry matter intakes of 2 sheep in a single meal	
	Mass $g/kgW^{0,75}$	Volume $cm^3/kgW^{0,75}$	Mass $g/kgW^{0,75}$	Volume $cm^3/kgW^{0,75}$
Oat hay				
O 3	$56,6^a$	300^a	$34,6^a$	183^a
O 32	$41,8^b$	437^b	$28,6^b$	299^b
Lucerne hay				
L 3	$85,6^c$	278^a	$51,8^b$	168^a
L 32	80,3	426^b	$62,6^b$	322^b
Mean intakes				
Oat hay	$49,2^a$	$368,5^{ab}$	$31,6^a$	241^{ab}
Lucerne hay	$83,0^c$	$352,0^{ab}$	$57,2^b$	250^{ab}
$\frac{\text{Lucern hay}}{\text{Oat hay}} \times 100$	168,7	95,9	181,0	103,7
SE	2,7	8,3	3,1	6,9

a, b, c: Figures within same column with different superscripts significantly at the 5% level

between samples of different fineness of the 2 feeds on the other. Milled oat hay had a consitently lower density than lucerne hay. With the exception of wheat bran, the concentrated feeds listed in Table 2 fall into a clearly different category as far as mass density is concerned.

Mass and volume of dry matter intakes

The primary object of this study was to relate mass density of a milled forage to its voluntary intake by sheep and to its behaviour in the digestive tract. Each of the 2 hays in 2 different physical forms was fed to 4 sheep at the 15% refusal level for 5 hours per day over a period of 30 days. Over the last 20 days the sheep were in a relatively steady state as far as dry matter intakes were concerned. the mean mass and volume intakes of the 4 types of hay are presented in Table 3.

There were significant differences ($P \leq 0,05$) in the mass of dry matter ingested between the 2 physical forms of oat hay and between oat hay and lucerne hay. However, there were no significant differences ($P \leq 0,05$) in the volumes ingested of oat hay and lucerne hay of the same degree of fineness. This applied to the mean intakes over the last 10 days of the 30-day feeding period as well as the last single meal. In terms of mass a significant ($P \leq 0,05$) 68% more lucerne hay than oat hay was ingested over the last 10 days and 81% more during the last meal. In terms of volume the average intakes nearly reached parity (96% and 104% over the last 10 days and for the last meal, respectively).

From these results it was not clear why different volumes of the 2 physical forms of the same hay were ingested. Part of the answer to this phenomenon was found in the results of the slaughter trial.

Mass and volume of material in different sections of the digestive tract

Two of the sheep in each group were slaughtered just before and the remaining 2 just after the last meal. The object was to examine the contents of different sections of the digestive tract. Dry mass and volume of digesta are presented in Tables 4 and 5 respectively.

Despite the significant differences ($P \leq 0,05$) in dry matter intake of lucerne hay and oat hay noted in Table 3, there were no significant differences at the 5% level, between either the dry mass of material or the volume of material present in the regiculorumen of the sheep slaughtered before their usual morning meal.

Table 4

Dry mass of digesta (g) in different sections of the digestive tract of sheep fed oat hay and lucerne hay in 2 physical forms and slaughtered either before or after a last meal (means of 2 sheep per physical form of hay)

Feed	Time	Rumen	Omasum	Abomasum	Duodenum	Caecum	Rectum	Total tract
Oat hay								
O 3	Before	1012,9[a]	123,6	127,7	133,6	208,2	107,8	1713,8[a]
O 3	After	1714,4[b]	108,5	95,4	116,8	187,8	108,7	2331,6[ab]
O 32	Before	1103,4[a]	80,4	80,7	83,0	147,6	103,4	1598,5[a]
O 32	After	1982,3[b]	117,6	108,4	108,4	190,2	102,8	2609,7[b]
O 32 x 100 / O 3		113,1	85,3	84,8	76,4	85,3	95,3	104,0
Lucerne hay								
L 3	Before	1034,9[a]	63,0	64,2	121,8	236,8	125,2	1645,9[a]
L 3	After	1949,5[b]	105,2	137,3	147,4	209,8	138,0	2687,2[b]
L 32	Before	1223,8[a]	77,4	84,6	117,0	222,2	147,8	1872,8[a]
L 32	After	2491,4[b]	125,2	131,4	128,0	196,9	85,3	3158,2[b]
L 32 x 100 / L 3		124,5	120,4	107,1	91,0	93,9	88,6	116,1

a, b = figures in the same column with different superscripts differ significantly at the 5% level

Table 5

Volume of digesta (in cm^3) in different sections of the digestive tract of sheep fed oat hay and lucerne hay in 2 physical forms and slaughtered either before or after a last meal (means of 2 sheep per physical form of hay)

Feed	Time	Rumen	Omasum	Abomasum	Duodenum	Caecum	Rectum	Total in digestive tract
Oat hay								
O 3	Before	10 850	880	1 124	1 750	1 882	593	17 079
O 3	After	12 855	712	890	1 530	1 791	682	18 490
O 32	Before	12 493	556	621	1 142	1 234	553	16 599
O 32	After	17 630	960	898	1 174	1 656	572	22 890
O 32 x 100 / O 3		126,9	95,2	75,5	70,6	78,7	88,1	111,0
Lucerne hay								
L 3	Before	8 900	365	697	1 177	1 781	527	13 447
L 3	After	14 330	620	1 036	1 378	1 468	668	19 500
L 32	Before	10 720	484	926	1 255	1 520	702	15 607
L 32	After	19 320	777	1 100	1 423	1 455	428	24 503
L 32 x 100 / L 3		129,3	128,0	117,0	104,8	91,6	94,5	121,7

When the results of the 4 sheep on each physical form of hay were pooled, the volume of digesta in the reticulorumen of sheep on O 32 was on the average 27% larger than in sheep on O 3. With sheep on lucerne hay the difference was of the same order viz. 29%. Likewise in the sheep slaughtered after their morning meal there were no significant differences ($P \leq 0,05$) in either the volumes or dry mass of digesta in the reticulorumen of the different groups although there was a stong tendency for the volume of material to be larger in sheep fed the coarser forms of hay.

In Tables 4 and 5 there are clear indications that sheep tend to eat for a relatively constant fill of the digestive tract – more so in terms of dry matter than in terms of volume. The latter is probably more variable because of variable water intake.

In sheep fed the coarse and less dense, oat hay (O 32) relatively more dry matter was found in the reticulorumen than in the rest of the digestive tract compared to sheep on the fine oat hay (O 3). It was remarkable that the omasum and abomasum of sheep on finely ground oat hay (O 3) contained more dry matter before than after feeding while the opposite applied to sheep on O 32 and on both forms of lucerne hay. From this it would appear that, although oat hay milled through a 3 mm screen can move rather rapidly out of the rumen, it will still be retained in the omasum and abomasum for further dimunition. In other words, the coarser O 32 are retained in the reticulorumen while the finer O 3 can pass through the rumen more rapidly to be retained in the lower digestive tract. With lucerne hay ground through the same sized screens as oat hay, the mass of dry matter ingested of 2 physical forms did not differ but, as with oat hay, the volumes did. In sheep on L 3 the omasum and abomasum contained smaller amounts of dry matter after slaughter than in sheep on L 32. However, the duodenum carried a heavier load on L 3 than on L 32. This implies that L 3 was retained to a lesser extent in the omasum than O 3.

Apparently the physical form of L 3 particles was different to those of O 3. Troelsen & Campbell (1968) found finely ground lucerne particles to be more cubic and grass more elongated. In this connection it was interesting to note that, despite the fact that sheep ingested on the average 68,7% more lucerne hay than oat hay, the digestive tracts of sheep on lucerne hay contained only 13,4% more dry matter than sheep on oat hay. This becomes even more significant when it is noted that, although the sheep ingested 35,4% more of O 3 than of O 32 and 68,7% more of lucerne hay than of oat hay, the intake of L 3 was only 6,6% higher than L 32. This is in accordance with Blaxter's (1961) contention that, even on different diets fed *ad lib.* the total mass of dry matter in the digestive tract tends to remain constant after ingestion of a meal. When mass densities of oat hay and lucerne hay are taken into account it becomes apparent that sheep on lucerne hay, in both physical forms, could accomodate a larger mass of lucerne hay, but not volume, compared to oat hay. In other words, the space filling characteristics of roughages are perhaps more important in determining intake than some of the other factors usually considered.

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