ELSEVIER

Animal Feed Science and Technology
84 (2000) 265–277

ANIMAL FEED SCIENCE AND TECHNOLOGY

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Effect of selective consumption on voluntary intake and digestibility of sorghum (*Sorghum bicolor* L. Moench) stover, cowpea (*Vigna unguiculata* L. Walp.) and groundnut (*Arachis hypogaea* L.) haulms by sheep

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Received 8 July 1998; received in revised form 22 December 1999; accepted 7 February 2000

Abstract

Three experiments with 12 animals each, were conducted to measure the effect of selective consumption on intake of organic matter (IOM), crude protein (CP) content and digestibility of ingested organic matter (DOM), and intake of digestible organic matter (IDOM) of sorghum (*Sorghum bicolor* L. Moench), stover (SS), cowpea (*Vigna unguiculata* Walp.) (CH) haulms and groundnut (*Arachis hypogaea* L.) haulms (GH) by sheep. On organic matter (OM) basis, SS contained 70.6% stems, 15.5% leaf sheaths, 6.5% leaf blades, 6.0% leaf central nerves and 1.4% ears; CH contained 64.2% stems and 35.8% leaves, and GH 50.1% stems and 49.9% leaves. Forages were not chopped and a wide range of feeding levels (amount of offered organic matter, OOM) was applied. The lowest and highest OOM (g $kg^{-0.75}$ per day) were: 30–110 for SS, 37–189 for CH and 30–194 for GH. Maximum IOM values (estimated by non-linear regression analysis) were 47.3, 85.9 and 81.6 g $kg^{-0.75}$ per day for SS, CH and GH, respectively. Selective consumption of leaves caused significant increases in the CP content of ingested OM for CH and GH, and increased DOM for SS and CH. The amount of digestible OM for production (IDOM — maintenance requirements) per unit of feed OM offered (value for animal production (VAP)) was used as the criterion for optimum feeding levels. For CH and GH, the maximum value (VAP_{max}) (0.32 and 0.26, respectively) was reached at feeding levels of 96 and 91 g OM $kg^{-0.75}$ per day, respectively. At these levels of OOM, 80 and 84% of the offered OM was eaten. Corresponding IDOM values were 54.3 and 48.0 g $kg^{-0.75}$ per day. In the case of SS, a very high feeding level

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PII: S0377-8401(00)00115-2

(OOM=87 g $kg^{-0.75}$ per day) where only 53% was eaten, was required to reach the maintenance level of IDOM.

Keywords: Selective consumption; Voluntary intake; Digestibility; Optimum feeding levels; Sorghum stover; Cowpea haulms; Groundnut haulms

1. Introduction

About 80% of the rural population of semi-arid West Africa raise ruminants (Winrock International, 1992). The main constraint to livestock production is the limited availability of suitable feeds. Especially in the dry season (November–June), the digestibility, concentration of crude protein and edibility of range-land forages are very low. The concentration of crude protein may fall to well below 6% (<1% N). Also the quantity of forage available decreases by 25–50% as compared to the rainy season (Wolf et al., 1991). Crop residues are an important alternative to overcome shortages in that period. The main crop residues are stover of cereals, such as sorghum (*Sorghum bicolor* L. Moench), maize (*Zea mays*) and millet (*Pennisetum typhoides*), haulms of leguminous crops such as cowpea (*Vigna unguiculata* L. Walp.), groundnut (*Arachis hypogaea* L.), and bambara groundnut (*Voandzeia subterranea*), and other straws, such as rice (*Oriza sativa*) and cotton (*Gossipium hirsutum*). The amount produced in Sub-Saharan West Africa ranges from 2 to 3 t ha^{-1} (Sansoucy, 1992; Smartt, 1994; MARA, 1996; Williams et al., 1997).

The utilisation of straws depends on their nutritive value, feeding strategies and the eating behaviour of animals. Under conditions of in situ grazing, about 60% of the straws may be wasted due to trampling, termites and nutrient depletion by weathering (Sansoucy, 1992). Hand-feeding is now becoming a widespread practice in many areas. It is important to find suitable feeding methods for optimal utilisation of stored residues (Lufadeju, 1992). Much work has been done to improve the nutritive value of crop residues, including studies on physical, chemical or biological treatment of these materials. The major treatments are chopping and treatment with urea or ammonia. An alternative is to supplement low-quality feeds with concentrates. However, the rate of adoption of these technologies by farmers remains low. Some of the reasons of this low adoption are the risks involved (intoxication with urea/ammonia), high costs of materials and high labour requirements (Sundstøl and Owen, 1984; Schiere and Nell, 1993).

Several authors have shown that intake of coarse heterogeneous forages can be considerably increased by excess feeding and stimulating selective consumption. This applies to green and dried leguminous forages (Zemmelink, 1980; Mero and Udén, 1998b), as well as grasses (Zemmelink et al., 1972; Schiere et al., 1990; Mero and Udén, 1998a), and cereal straws (Wahed et al., 1990; Badurdeen et al., 1994) and stovers (Subba Rao et al., 1994; Fernández-Rivera et al., 1994; Osafo et al., 1997). The relationship between the amount of feed offered and the corresponding intake of digestible dry matter (or organic matter) can be used to derive optimum feeding levels, giving maximum intake of digestible energy for production (and, consequently, maximum animal production) per unit of feed available (Zemmelink, 1986; Bosman et al., 1995; Mbile and Udén, 1997; Mero and Udén, 1998a, b; Zemmelink and ‘t Mannetje, 2000). The present study was conducted to obtain response lines for important crop residues in Burkina Faso, i.e. sorghum stover, and cowpea and groundnut haulms.

2. Material and methods

The feeds were tested in three experiments with 12 rams of the Djallonké breed (Dumas and Raymond, 1974) weighing 20–22 kg and averaging 18 months of age. In all experiments, animals were randomly allocated to 12 levels of feed allowance, ranging from 30 to 110 g organic matter (OM) $kg^{-0.75}$ per day for sorghum stover (SS), 37 to 189 g OM $kg^{-0.75}$ per day for cowpea haulms (CH), and 30 to 194 g OM $kg^{-0.75}$ per day for groundnut haulms (GH). Each experiment consisted of an adaptation period of 2 weeks, followed by a measurement period of 10 days. Animals were weighed at the beginning and at the end of the measurement periods. The average of these two weights was used to calculate metabolic weight (kg live weight to the power of 0.75).

The forages were not chopped, but sorghum stover was cut into three parts of about 60 cm length for accommodation in the feeding troughs. All forages had been bound in bundles of about 4 kg before storage. Every second day of the measurement period, one whole bundle of the offered feed was analysed for morphological composition. Sorghum stover was cut into three parts (bottom, middle and top) and each of these was divided into stems, leaf sheaths, leaf blades, central leaf nerves and (for the top part) ears (empty of grains). For cowpea and groundnut haulms, three components (bottom stems, other stems and leaves) were distinguished. Feed refusals were kept separate per individual animal. Refusals collected on two consecutive days (days 1 and 2, days 3 and 4, etc.) were mixed for sampling and analysis. The same sampling procedure was followed for faeces. Feed refusals were analysed for the same morphological fractions as the offered feed, but no distinction was made between bottom, medium and top part of the sorghum plant. Samples (morphological components) of offered and refused feed, and faeces were ground and analysed for dry matter (DM), organic matter (OM) and crude protein (CP, 6.25N). Chemical analysis was conducted according to AOAC (1975). Amounts of refused OM (ROM) were deducted from offered OM (OOM) to calculate intake of OM (IOM) by individual animals. Similarly, the amount digested (intake of digestible organic matter (IDOM)) was estimated by subtracting faecal OM from IOM.

The NLREG programme (Sherrod, 1994) was used to fit the model of Zemmelink (1980) for the relationship between IOM (y) and OOM (x):

$$y = m\left[1 - \exp\left(-\left(\frac{px}{m}\right)^{h}\right)\right]^{1/h} \tag{1}$$

where m is the upper limit (asymptote) for y, p the edible fraction of the forage and h a shape parameter, such that at the critical level of feeding $x=m/p$, and $y=m(1-e^{-1})^{1/h}$.

The effect of selective consumption on digestibility of ingested organic matter (DOM, %) was studied by relating DOM to the level of excess feed (ROM) expressed as a proportion (%) of OOM, using the model:

$$\mathrm{DOM} = a + b\mathrm{ROM} \tag{2}$$

where *a* represents DOM under conditions of non-selective consumption and *b* the linear increase in DOM at increasing levels of ROM. The effect of selective consumption on the concentration of CP in the ingested feed (CP, % of IOM) was studied in the same way. Least squares estimates of IDOM as a function of OOM were derived by relating actual IDOM values to IOM predicted by Eq. (1) (IOMpr), using the model:

$$\text{IDOM} = \text{IOMpr}(a + b\text{ROM}) \quad (3a)$$

or

$$\text{IDOM} = \text{IOMpr}(a + b\text{ROMpr}) \quad (3b)$$

where ROM is the actual level of refusal, and ROMpr is the predicted level of refusal: 100(OOM−IMOpr)/OOM. In both cases, the parameter *a* represents again DOM under conditions of non-selective consumption and *b* the linear increase in DOM at increasing levels of ROM, but in models (3a) and (3b) the estimates result from least squares models for IDOM instead of DOM itself, as in Eq. (2). Model (3b) has the advantage that not only IOM, but also DOM and IDOM can be predicted from OOM alone and that predicted values for the three variables are mutually consistent at all levels of OOM. Least square estimates of IDOM, according to Eq. (3b), were also used to calculate the relative value for animal production (VAP) (Zemmelink, 1986; Zemmelink and ‘t Mannetje, 2000):

$$\text{VAP} = \frac{(\text{IDOM} - \text{IDOM}_{\text{mt}})}{\text{OOM}} \quad (4)$$

where IDOM_{mt} is the amount of digestible organic matter required for maintenance. IDOM_{mt} was assumed to be 24 g $\text{kg}^{-0.75}$ per day. Optimum levels of feeding, giving maximum animal production per unit of feed available (including both, the material eaten and that which is not eaten), may be defined as the level of OOM when VAP reaches its maximum (VAP_{max}). VAP_{max} values were used as the criterion for comparison of the three feeds.

3. Results

3.1. Morphological and chemical composition of feeds

Sorghum stover (SS) consisted of 70.6% stems, 15.5% leaf sheaths, 12.5% leaves (subdivided in 6.5% blades and 6.0% nerves) and 1.4% ears (Table 1). CH contained 64.2% stems (including 4.1% bottom stems) and 35.8% leaves, while these proportions for GH were 50.1 and 49.9%, respectively. In the case of sorghum stover, leaf blades were highest in CP and stems lowest. The CP of leaf nerves and leaf sheaths was only slightly higher than that of stems. Leaves of the top and medium parts of the plant were higher in CP (9.0–9.4% in DM) than leaves of the bottom part (5.3%). Similar, but smaller differences were found for the other fractions: 1.5–2.1% for stems, 1.8–3.4% for leaf sheaths, and 2.4–3.6% for nerves. Ears had intermediate CP concentrations (mean value 5.9%). The fractions with >5% CP in DM (leaf blades and ears, mean CP content 7.8%) represented only 7.9% of the total organic matter. The CP concentration in CH was much

Table 1
Morphological and chemical composition of sorghum stover, cowpea and groundnut haulms

Morphological component	Proportion (% of OM[a])		OM (% in DM[b])		CP[c] (% in DM)	
	Mean	S.E.[d]	Mean	S.E.	Mean	S.E.
Sorghum						
Stems						
Bottom	40.1	0.53	95.3	0.41	2.0	0.09
Medium	20.4	0.20	95.5	0.11	1.5	0.34
Top	10.1	0.03	94.3	0.35	2.1	0.26
Sheaths						
Bottom	3.9	0.68	87.5	0.92	1.8	0.11
Medium	6.5	0.40	87.7	1.36	2.2	0.48
Top	5.1	0.60	87.7	0.93	3.4	0.37
Leaf Blades						
Bottom	1.6	0.29	89.5	0.98	5.3	0.64
Medium	2.9	0.41	88.9	1.61	9.0	0.67
Top	2.0	0.12	88.3	1.99	9.4	0.58
Leaf nerves						
Bottom	1.6	0.32	92.9	0.51	2.4	0.18
Medium	2.9	0.67	95.3	0.58	3.6	0.52
Top	1.5	0.50	95.4	0.77	3.6	0.62
Ears	1.4	0.38	95.3	0.60	5.9	2.70
Whole straw	100	0.76	94.9	0.46	3.9	0.35
Cowpea						
Bottom stems	4.1	0.08	92.9	0.39	8.0	0.22
Other stems	60.1	0.61	93.1	0.34	11.1	0.91
Leaves	35.8	0.44	89.4	0.36	18.1	1.02
Whole straw	100	0.13	91.8	0.77	12.4	1.94
Groundnut						
Bottom stems	19.5	0.25	86.7	0.86	8.9	0.46
Other stems	30.6	0.18	90.8	0.15	9.5	1.01
Leaves	49.9	0.20	86.7	0.37	11.2	0.26
Whole straw	100	0.26	88.1	0.65	9.9	0.45

[a] Organic matter.
[b] Dry matter.
[c] Crude protein.
[d] Standard error.

higher: 8.0% for bottom stems, 11.1% for other stems and 18.1% for leaves. For GH, these values were 8.9, 9.5 and 11.2%, respectively.

3.2. Intake of organic matter

For all three feeds, the parameter p in Eq. (1) was estimated at 1. This implies that there were no really inedible portions. For CH and GH, this is in agreement with the fact that animals on the lowest levels of feeding ate the full amounts of leaves and stems offered (Fig. 1). In the case of SS, however, even animals on extremely low feeding levels refused some of the stems. At feeding levels up to about 100 g OM $kg^{-0.75}$ per day, animals still

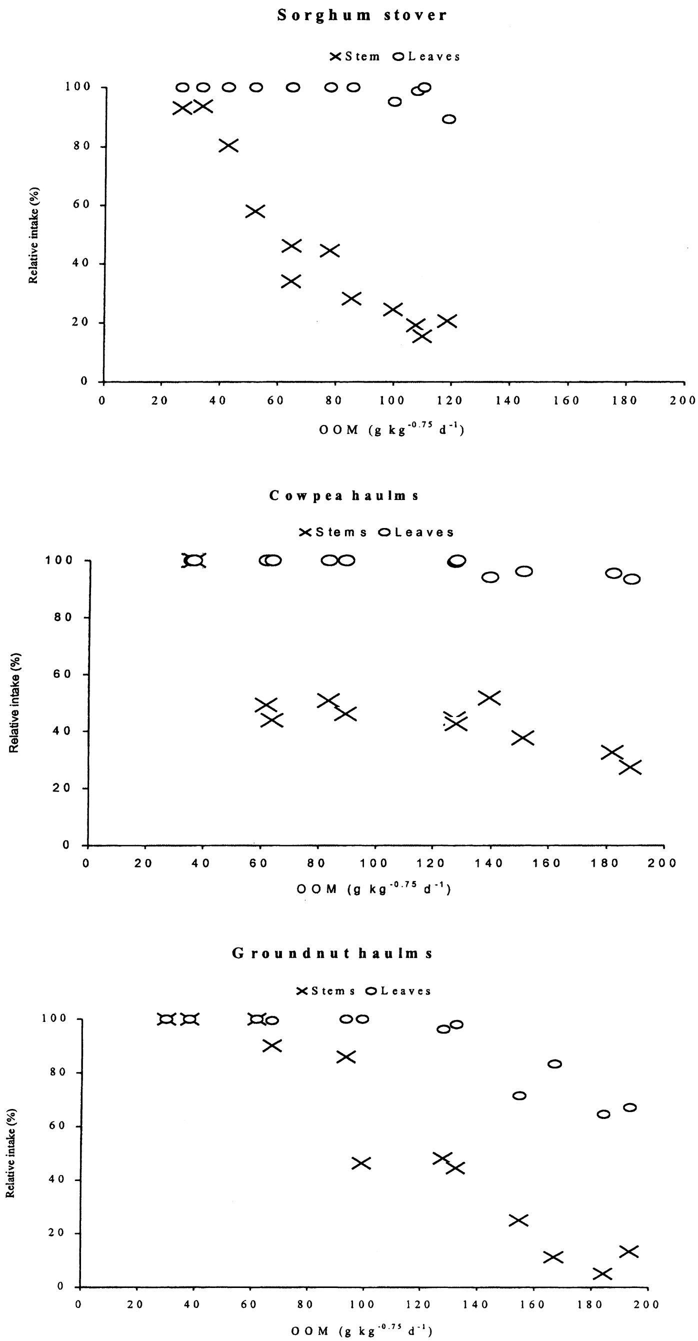

Fig. 1. Effect of level of feeding (amount of offered organic matter, OOM) on relative intake of leaves and stems (RI: amount consumed expressed as proportion of amount offered).

ate (nearly) all the leaves, but much less than the full amount of stems offered. In the case of SS, intake of stems decreased to <20% of the amount offered. This was also true for GH, but only at higher levels of feeding when also considerable amounts of leaves were refused. The estimated maximum IOM (m) was much lower for SS (47.3 g $kg^{-0.75}$ per day) than for CH and GH (85.9 and 81.6 g $kg^{-0.75}$ per day, respectively) (see Table 2).

Table 2
Least squares estimates (±S.E.) of parameters of the models describing intake of organic matter (IOM), concentration of crude protein (CP) in IOM, digestibility of consumed organic matter (DOM) and intake of digestible organic matter (IDOM)[a,b]

Parameter	Sorghum stover	Cowpea haulms	Groundnut Haulms
IOM (g $kg^{-0.75}$ per day)[c]			
m	47.3±1.52	85.9±4.04	81.6±3.3
h	1.75±0.16	2.76±1.12	3.88±2.49
rsd	2.53	8.03	8.12
R^2	0.906	0.863	0.856
Probability	<0.001	<0.001	<0.001
CP in IOM (%)[d]			
a_{cp}	2.7±0.16	14.8±0.45	11.7±0.42
b_{cp}	0.006±0.004	0.080±0.014	0.059±0.012
rsd	0.25	0.97	0.89
R^2	0.210	0.763	0.716
Probability	>0.05	<0.01	<0.01
DOM(%)[e]			
a_{dom}	39.5±4.29	66.4±1.30	60.2±2.62
b_{dom}	0.272±0.103	0.172±0.041	0.390±0.073
rsd	6.43	2.78	5.56
R^2	0.410	0.644	0.027
Probability	<0.05	<0.01	>0.05
IDOM (g $kg^{-0.75}$ per day)[f]			
a_{idom}	43.4±5.51	68.2±1.92	64.9±2.78
b_{idom}	0.194±0.122	0.138±0.054	–0.050±0.072
rsd	2.72	2.32	3.56
R^2	0.831	0.983	0.949
Probability	>0.05	<0.05	>0.05
IDOM (g $kg^{-0.75}$ per day)[g]			
a_{idom}	43.3±6.78	67.4±6.10	62.6±0.03
b_{idom}	0.191±0.149	0.151±0.165	–
rsd	3.13	6.93	7.82
R^2	0.777	0.850	0.741
Probability	>0.05	>0.05	>0.05

[a] OOM, offered organic matter (g $kg^{-0.75}$ per day).
[b] ROM, refused organic matter (% of OOM).
[c] $IOM = m\,(1-\exp(-((OOM/m)^h)))^{1/h}$ (model 1 in text).
[d] $CP = a_{cp} + b_{cp} ROM$ (model 2).
[e] $DOM = a_{dom} + b_{dom} ROM$ (model 2).
[f] $IDOM = IOMpr(a_{idom} + b_{idom} ROM)$ (model 3a).
[g] $IDOM = IOMpr(a_{idom} + b_{idom} ROMpr)$ (model 3b).

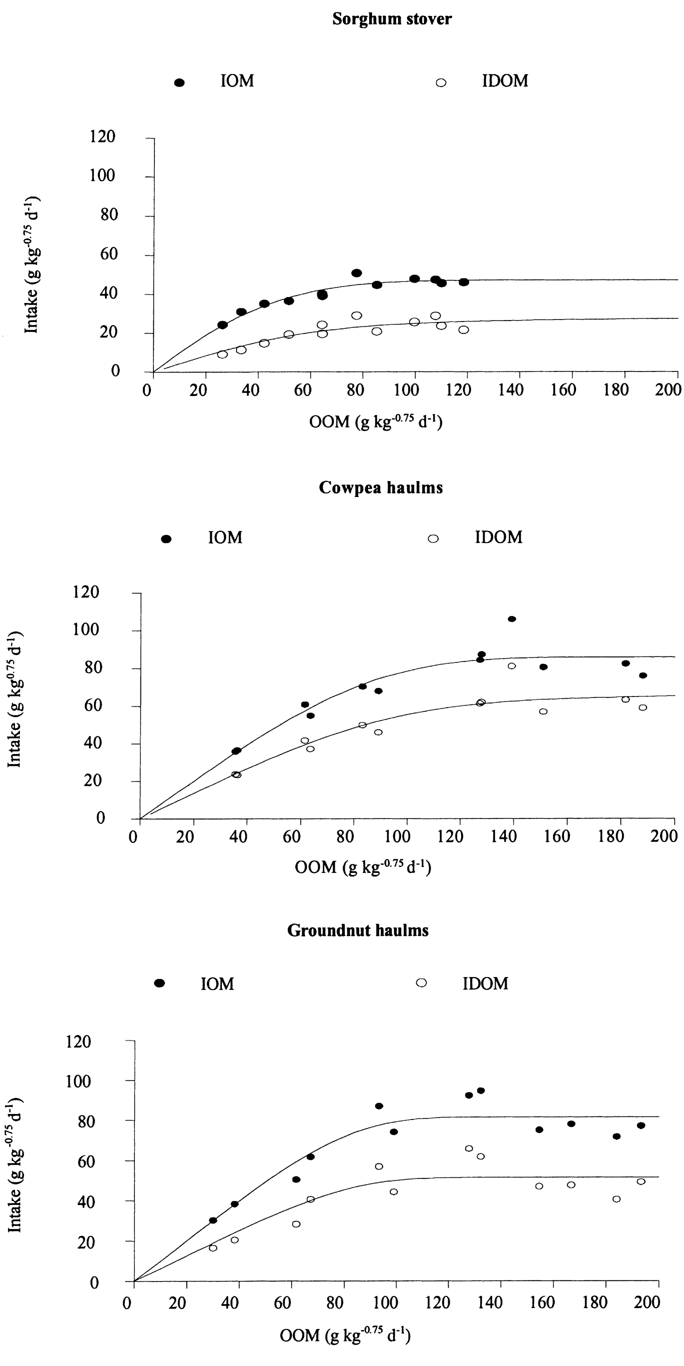

Fig. 2. Effect of level of feeding (amount of offered organic matter, OOM) on intake of organic matter (IOM) and intake of digestible organic matter (IDOM).

Also the parameter *h* was lower for SS (1.75) than for CH (2.76) and GH (3.88), implying that when the amount of organic matter offered equalled *m*, animals refused a larger fraction of the SS (23%) than of CH (15%) and GH(11%) (see also Fig. 2).

3.3. Concentration of crude protein and digestibility of ingested organic matter

The increasing leaf/stem ratio in the consumed material at higher levels of excess feed led to significant increases in the concentration of CP in the ingested organic matter for CH and GH (p<0.01), but not in the case of SS (p>0.05) (Table 2). Changes in DOM (when this itself was treated as dependent variable) with level of excess were found significant for SS (p<0.05) and CH (p<0.01), but not for GH (p>0.05). When changes in DOM were studied with models where IDOM was the independent variable, estimates of the coefficients of regression of DOM on level of excess feeds were somewhat lower, especially in the case of SS (0.19 as compared to 0.27; see Table 2).

3.4. Intake of digestible organic matter

Individual IDOM values are plotted against level of feeding (OOM) in Fig. 2, together with least squares curves according to the model based on Eq. (3b). Animals on SS reached the maintenance level of intake (IDOM=24 g kg$^{-0.75}$ per day) only at high levels

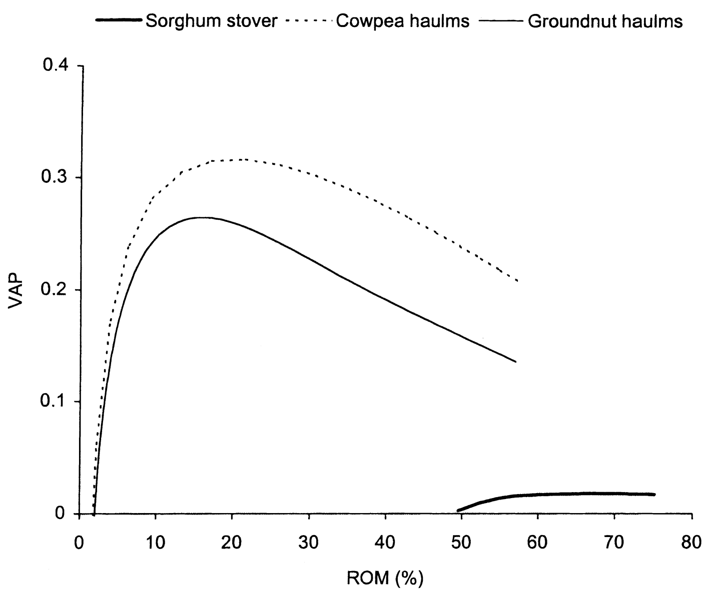

Fig. 3. Effect of level of excess (proportion of refused organic matter, ROM) on VAP (value for animal production).

of feeding (87 g OM $kg^{-0.75}$ per day) where nearly half (47%) of the offered feed was refused. At that point VAP=0 (by definition). For CH and GH, this point was reached at much lower feeding levels (36 and 39 g OM $kg^{-0.75}$ per day, respectively), where nearly all was eaten (<2% refusal). The estimated maximum value for animal production (VAP_{max}) for SS is very low (0.02) and was only reached at OOM=160 g $kg^{-0.75}$ per day, where animals ate only 30% of the offered OM (70% refusal). VAP_{max} for CH and GH (0.32 and 0.26, respectively) was reached at OOM values of 96 and 91 g $kg^{-0.75}$ per day where animals left 20 and 16% of the offered OM uneaten (Fig. 3). IDOM values for SS, CH and GH at the feeding level, where VAP_{max} was reached, were 26.8, 54.3 and 48.0 g $kg^{-0.75}$ per day, respectively, or 1.1, 2.3 and 2.0 times maintenance. For CH and GH these levels of IDOM were accompanied by satisfactory levels of CP (ratio intake of CP/IDOM 0.233 and 0.202, respectively). For SS, this value was very low (<0.06) at all levels of feeding.

4. Discussion

Feed intake is the first parameter that determines animal production; it is a function of animal, feed and environmental factors. This study examined the effect of selective consumption on intake of crop residues by sheep. Laredo and Minson (1973) showed that, when leaves and stems of grass are separated, animals eat more of the leaves than of the stems. Also, when these two fractions are not separated mechanically, animals are effective in selecting for leaves. This holds for grasses and legumes, and for sheep as well as cattle (Zemmelink et al., 1972; Zemmelink, 1980; Mbwile and Udén, 1997; Osafo et al., 1997; Mero and Udén, 1998a, b). For most forages, leaves are more nutritious (higher N content, higher digestibility) than stems (see also Van Soest, 1994, pp. 100–101). The leaf/stem ratio is, therefore, an important factor determining the value of forages and care should be taken that appropriate methods are used for collection and storage of feeds in order to minimise loss of leaves (Schiere et al., 1994). Higher leaf fractions not only increase the average quality of the whole forage, but increase the amount of the fraction that is preferred by the animal.

Selective consumption is a complicating factor in the measurement of intake and digestibility of forages. Therefore, chopping is traditionally combined with low levels of excess feed to assure that animals do not select (Minson, 1990). Under practical farming conditions, however, coarse tropical forages are often consumed selectively and the response curves for sorghum stover, observed in this study, confirm the importance of that. When selection was avoided by offering only small amounts of excess, intake of digestible organic matter was far below maintenance requirements. Feeding at that level cannot be continued for any length of time. When larger amounts were offered, intake of sorghum stover was still too low to support animal production, but due to selective consumption of leaves, intake of organic matter as well as digestibility increased, and energy requirements for maintenance could be met. Similar increases in IDOM by increasing feed allowance were obtained in feeding barley straw to goats or sheep (Wahed et al., 1990), finger millet stover to cattle (Subba Rao et al., 1994), rice straw to cattle (Badurdeen et al., 1994) and pearl millet stover leaves to sheep (Fernández-Rivera et al., 1994). The magnitude of improvement was in many cases comparable to that which is usually achieved by treating straw with alkali (Bhargava et al., 1988; Wahed et al., 1990). Allowing selective consumption of basal rations may also reduce the amount of scarce supplements needed to produce a certain amount of animal product, because it is then avoided that a large part of the supplement is used for body maintenance. The disadvantage of the smaller number of animals that can be fed must be weighted against the higher level of energy intake that can be achieved. Leftovers of feed can be used for bedding or composted and used as a source of soil organic matter. Farmers also use feed refused by sheep for feeding donkeys.

The results for cowpea and groundnut haulms are indicative of the high value of these feeds. The amount of OM required to meet energy requirements for maintenance is less than half the amount of sorghum stover needed for the same purpose, and the VAP_{max} values are as high or higher than those measured with sheep for tropical grasses, as well as forage legumes, by Zemmelink (1986) (see also Zemmelink and 't Mannetje, 2000), Bosman et al. (1995) and (Mero and Udén, 1998a, b). The IDOM levels associated with VAP_{max} indicate that these feeds, when fed alone, can support animal production systems with relatively high levels of production per animal (twice the maintenance). Such systems can, however, not utilise the large amounts of lower quality crop residues, such as sorghum stover, produced in the same areas. Experiments in which varying levels of feeding cowpea and groundnut haulms are combined with diverse amounts of sorghum stover can be used to determine optimum combinations of the two classes of feeds.

Acknowledgements

This work was part of the Wageningen University Sahel Project (Antenne Sahélienne) in Burkina Faso. Thanks are due to Teunis van Rheenen (scientific co-ordinator of the project) and Maja Slingerland (co-ordinator of the Land Use Work Group) for support during all phases of this study.

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