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Cereal crop residues as feed for goats and sheep

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Summary

The smaller size of goats and sheep compared to cattle and buffalo is an apparent disadvantage because maintenance-energy requirement relative to live weight, is higher for small compared to large ruminants, yet intake-capacity for roughage feeds is not. Under conditions of grazing/browsing, this size-linked disadvantage of goats and sheep is alleviated by their ability to select a more nutritious diet than cattle and buffalo.

The extent to which this phenomenon can be used when feeding cereal crop residues to goats and sheep has been investigated at Reading University. The results of experiments in the UK, using barley straw, and in Ethiopia using sorghum stover, are presented.

The experiments show that with both barley straw and sorghum stover, goats and sheep, when given the opportunity, are able to select for the more nutritious leaf and leaf-sheath components and against the less nutritious stem; in both crop residues, leaf and leaf sheath may account for up to half the weight. With unprocessed barley straw and chopped stover, offering goats and sheep 50 g dry matter (DM) per kg live weight daily, instead of 25 g DM/kg liveweight/day increased intake by about 30%, but the amount of uneaten residue increased from ca. 150 g/kg offered to ca. 500 g/kg offered. The extent to which the intake response to increasing the amount of crop residue offered, can be modified by physical and chemical processing, and concentrate supplementation, is considered.

Strategies for applying this approach, including using the uneaten residue (eg: refeeding after chemical treatment), are discussed in the context of sustainable crop-animal agriculture. Whether the response to increasing the offer rate occurs with rice straw requires researching.

KEY WORDS: Crop residues, straw, goats, sheep, size, selection, high-offer feeding

Introduction

Crop residues as a feed

It is well recognised that cereal crop residues are of low nutritive value (Sundstol and Owen 1984). This is because of their relatively low digestibility (<500 g digestible organic matter [DOM] per kg dry matter [DM], low crude protein content (<50 g/kg DM) and low content of available minerals and vitamins. These deficiencies combine to make crop residues unpalatable, thus their consumption is also low (usually less than 15 g DM/kg live weight daily.

Since the mid 1970's there has been much research and development into finding ways of alleviating these deficiencies (eg: Sundstol and Owen 1984; Doyle *et al* 1986). Much emphasis has been put on straw upgrading techniques using treatment with chemicals (Owen and Jayasuriya 1989a), sodium hydroxide or ammonia in temperate countries and urea-ammonia in tropical countries. Treatment with these chemicals increases digestibility by 100 to 150 g DOM/kg DM and increases intake by about 4 g DM/kg liveweight/day (25%). Use of cereal crop residues for goats and sheep was reviewed by Owen (1981) and Owen and Katelgile (1984).

Although these methods are now being applied, the extent of their application is not as widespread as one would expect, in view of the large research and development effort which has been put into the subject. There are several reasons for this, particularly in developing, tropical countries (Owen and Jayasuriya, 1989b). One reason is the fact that the technologies are often too "high tech." for application by smallholder, subsistence farmers who do not have the resources to purchase and apply the chemicals to crop residues. Another reason, perceived by smallholders, is that the increase in ruminant production, typically improved growth rate, following the feeding of treated crop residues, does not justify the cost and effort of treatment. Another criticism of urea-ammonia treatment of crop residues is that only about 30% of the nitrogen of the urea applied, is recovered in the treated forage; 70% of the nitrogen applied is polluting the atmosphere as ammonia gas. It is argued that farmers would benefit more if the urea was used as a fertiliser to increase crop yield, instead of using it to upgrade the crop residue.

Background to studies at reading university with goats and sheep

In view of the above, our research at Reading University with barley straw, and at the International Livestock Centre for Africa, Ethiopia, with sorghum stover, has aimed at developing methods of feeding crop residues to small ruminants which do not involve chemical treatment, but which do lead to improved intake of straw, comparable to that achieved with chemical treatment. The underlying theme of our work has been to adopt a "grazing" approach to feeding crop residues such as straw. This means offering crop residues in large excesses so as to provide the opportunity for animals, particularly small ruminants, to select out the most nutritious components and to reject the less nutritious components.

As indicated earlier, the low nutritive value of straws is well recognised. Much less recognised is the fact that the botanical fractions of straws differ considerably in nutritive value. Thus leaf (500 - 600 g DOM/kg DM) and to a lesser extent leaf sheath, are much more digestible than stem (c 300 g DOM/kg DM) (Ramazin *et al* 1986). Leaf and leaf sheath also contain more nitrogen than stem. In most straws, leaf and leaf sheath constitute up to half the weight of the straw, but there is much variation in this. The differing digestibilities of straw components holds for both temperate (wheat, barley, oats) and tropical straws (maize, sorghum, millet) except for rice; stem and leaf in rice straw are of similar value.

The conventional approach to feeding straw is to feed to appetite. This means offering sufficient straw such that only a small proportion (10 to 20%) of the amount offered is refused. This convention is normally used in experiments which measure intake of forages by ruminants under ad libitum stall-feeding conditions. This definition of *ad libitum* is based on the classical studies of voluntary intake in sheep by Blaxter *et al* (1961). *Ad libitum* defined in this way ensured that measurements of intake were made under standard conditions whilst also ensuring minimum wastage of feed and minimum selection of feed.

At the outset of our experiments we were conscious of the Van Soest school (Van Soest 1982) arguments concerning species size and ability to eat selectively. The smaller size of goats and sheep compared to cattle and buffalo gives them an apparent disadvantage because maintenance-energy requirement relative to live weight is higher for small compared to large ruminants, yet intake capacity for roughage feeds is not. Under conditions of grazing/browsing, this size-linked disadvantage of goats and sheep is alleviated by their ability to select a more nutritious diet than cattle and buffalo. At Reading University we therefore began to question the validity of the conventional *ad libitum* approach (ie: allowing refusal rates of only 100-200 g/kg offered) to feeding crop residues to goats and sheep, in view of the fact that we wished to develop feeding methods where selective feeding might be advantageous. Evidence from grazing studies with sheep also encouraged us to question the conventional approach to *ad libitum* feeding of straw under stall-feeding conditions. Gibb and Treacher (1976) had shown that DM intake of grazing sheep increased as the amount offered increased, and intake was maximised only when allowance was approximately 4.0 times that consumed.

In the case of stall-fed straws and other low quality forages, we therefore hypothesised that the quantity and quality of straw consumed would increase if the amount offered was increased to allow animals to refuse more than the rate of 10 to 20% of amount offered, normally adopted in *ad libitum* feeding trials. Our research has aimed to define how much straw needs to be offered to ruminants, especially goats and sheep, to enable them to select the more nutritious components of straw and also to eat more. We have worked with barley straw in Reading University and with sorghum stover in Ethiopia. The results of some of our experiments will be presented to illustrate the extent to which intake of crop residue can be manipulated by the amount offered and by other factors eg, physical processing and amount of supplement.

The general approach

The general approach has been similar. The trials have generally involved individually-fed animals given small quantities of high- protein supplement (20-30% of total diet) and offered straw *ad libitum*. The supplement has been formulated to supply sufficient rumen-degradable nitrogen and minerals (ARC 1980, 1984). Measurements have been made of the quantity and quality of the straw offered and refused in order to assess the amount and composition of that consumed. Quality assessment has involved chemical analysis and *in vitro* digestibility assay (Tilley and Terry 1963). More recently, botanical fractionation of crop residue offered and crop residue refused has also been undertaken.

Table 1: Intake and selection of barley straw by castrated goats allowed to refuse 20 or 50 % of the amount offered (Wahed et al 1990)*

	Straw refusal-rate allowed (g DM/kg straw offered)	
	200	500
Initial weight (kg)	32.6	32.7
Supplement intake (g DM/d)	205	205
Straw offered (g DM/d)	550	1122
Straw refused (g DM/kg DM offered)	205	483
Straw intake (g DM/d)	437	580
Straw intake (g DM/kg LW/d)	14.4	18.9
Digestible** straw intake (g DOM/kg L/d)	5.9	8.3

	Straw offered	Straw refused	
Nitrogen (g/kg DM)	5.1	4.5	4.6
Digestibility in vitro (g DOM/kg DM)	412	320	347

* 18 goats/treatment; measurements over 21 days following a 14-d preliminary period.
** Based on *in vitro* digestible organic matter [OM] of offered and refused straw.

Barley straw: effect of refusal-rate in goats

Allowing goats to refuse 500 g/kg of the quantity of straw offered instead of the more conventional 200 g/kg rate, resulted in a 31% increase in straw DM intake. Digestible straw intake was estimated to increase even more, by 41%. Table 1 also shows that the straw refused was of lower nitrogen and DOM content than straw offered, presumably because goats had selected out the more nutritious leaf and sheath components.

Barley straw: effect of amount offered in goats

Increasing the quantity of straw offered from 18 to 54 and to 90 g DM/kg liveweight/day resulted in increasing intakes of straw DM and DOM (Table 2). The largest response occurred to the first increment of offer and was associated with 566 g/kg of the straw offered, being refused. Increasing intakes were also associated with higher live-weight gains. Straw refusals were of lower quality than straw offered, and refusal qualities were lower, the lower the amount of straw offered.

Table 2: Intake and selection of barley straw by castrated goats offered increasing ad libitum amounts of straw (Wahed et al 1990)

	Straw offered (g DM/kg LW/d)		
	18	54	90
Initial weight (kg)	30.2	30.6	30.4
Final weight (kg)	30.1	33.1	34.0
Supplement intake (g DM/d)	194	194	194
Straw offered (g DM/d)	542	1740	2931
Straw refused (g DM/kg DM offered)	125	566	703
Straw intake (g DM/d)	474	755	871
Straw intake (g DM/kg LW/d)	15.5	22.8	26.2
Digestible2** straw intake (g DOM/kg LW/d)	7.2	12.8	14.5

	Straw offered	Straw refused		
Nitrogen (g/kg DM)	7.4	5.5	5.7	6.1
Digestibility *in vitro* (g DOM/kg DM)	443	354	370	403

* 12 goats/treatment; measurements over 42 days following a 35-d preliminary period.
** Based on in vitro digestible organic matter [OM] of offered and refused straw.

Barley straw: effect of amount offered in sheep

Table 3 shows the results of an experiment with sheep. Again straw intakes increased with increasing amounts offered and there was clear evidence of selection occurring in that refused straw was of lower quality than that offered. As in Table 2, Table 3 shows that increasing the amount of straw offered was associated with increasing proportions being refused.

Table 3: Intake of barley straw by castate sheep offered increasing *ad libitum* ammounts of straw (Wahed *et al*, 1990)

[redacted]			
	Straw offered (g DM/kg LW/d)		
[redacted]			
	18	54	90
Initial weight (kg)	53.3	52.4	52.8
Supplement intake (g DM/d)	293	293	293
Straw offered (g DM/d)	957	2787	4702
Straw refused (g DM/kg DM offered)	208	647	751
Straw intake (g DM/d)	758	984	1117
Straw intake (g DM/kg LW/d)	11.1	19.0	22.2
Digestible straw intake (g DOM/kg LW/d)	6.6	10.5	12.7

[redacted]				
	Straw offered		Straw refused	
[redacted]				
Nitrogen (g/kg DM)	6.4	4.5	5.1	5.5
Digestibility** *in vitro* (g DOM/kg DM)	432	294	361	374
[redacted]				

* 10 sheep/treatment; measurements over 21 days following a 35-d preliminary period.
** Based on *in vitro* digestible organic matter [OM] of offered and refused straw.

Table 4: Effect of amount offered on intake of chopped sorghum stover by goats and sheep in Ethiopia (Aboud et al 1991)*

[redacted]		
	Goat	Sheep
	Amount of stover offered (g/kg LW/d)	

[redacted]						
	25	50	75	25	50	75
Number/treatment	7	7	7	8	8	7
Initial weight (kg)	15.4	16.3	16.3	14.7	16.3	16.5
Stover refused (g/kg offered)	152	427	571	51	318	526
Stover intake (g DM/kg LW/d)	19.9	26.3	29.1	22.1	31.1	32.5
Growth rate (g/d)	9.4	23.4	31.6	28.2	54.1	62.2
[redacted]						

*Measurements over 75 days following a 21-d preliminary period.

Sorghum stover: effect of amount offered in goats and sheep

Table 4 shows the results of an experiment undertaken in Ethiopia with goats and sheep offered chopped sorghum stover and cottonseed cake supplement. The stover was coarsely chopped. Both goats and sheep increased their intake of stover with increasing amounts of stover offered, and this was reflected in increasing rates of live- weight gain. Growth rates of sheep were higher than for goats; intakes were also higher in sheep than goats. The species differences were probably a reflection of the greater growth potential of sheep compared to goats due to the higher mature weight of the sheep genotype used.

Sorghum stover: effect of chopping and amount offered in sheep and cattle

Chopping stover increased intake in sheep, but decreased intake in cattle (Table 5). Both sheep and cattle showed greater intakes when the amount of stover offered was increased. In other experiments at Reading with barley straw (Velasquez 1992), cattle did not show an intake response when offered more straw and sheep did not show a significant increase in intake of barley straw with chopping (Wahed 1987). This illustrates that intake responses to both chopping and the amount of crop residue offered depends on the animal species and the type of residue.

Table 5: Effect of amount offered and chopping on intake of sorghum stover by sheep and cattle in Ethiopia (Osafo *et al* 1993a)

[redacted]				
	Chopped		Unchopped	
[redacted]				
Amount of stover offered (g DM/kg LW/d)	25	50	25	50

Per group of 3 sheep*				
Stover refused				
(g DM/kg DM offered)	115	383	215	518
Stover intake (kg DM/d)	1.08	1.60	0.98	1.24
Live-weight gain (g/d)	45.8	70.5	30.5	55.9
Per bull**				
Stover refused				
(g DM/kg DM offered)	287	597	240	486
Stover intake (kg DM/d)	3.59	3.94	3.74	4.85

* 13 groups/treatment; measurement over 56 days; cottonseed cake at 339 g DM/group.d
** 8 bulls/treatment; measurement over 49 days; cottonseed cake at 790 g DM/bull/d

Sorghum stover: effect of variety

The experiment in Table 6 was designed to test the hypothesis that stover from bird-resistant sorghum is less nutritious than stover from none-bird-resistant sorghum on account of the greater content of polyphenolic, anti-nutritive factors in bird-resistant varieties. Although DM digestibility was lower in the bird- resistant stover, intake was unaffected. This was probably due to the higher leaf-plus-sheath:stem ratio in bird-resistant stover. Another experiment in this study (Osafo *et al* 1993c) has shown large variation in the leaf-plus-sheath:stem ratios between varieties of both bird-resistant and none bird-resistant cultivars.

Table 6 also illustrates the contrasting effects on intakes of leaf-plus-sheath and stem of increasing the amount of stover offered.

Table 6: Effects of sorghum stover variety and amount offered on growth, intake and digestibility in Ethiopian sheep (Osafo *et al* 1993b)

	Bird-resistant		Non-bird-resistant	
	Amount of stover offered (g DM/kg LW/d)			
	25	50	25	50
Growth rate (g/d)	16.1	-4.0	25.3	+3.5
Stover refused (g DM/				
kg DM offered)	110	379	135	379
Stover intake (g DM/d)	478	628	474	633
Leaf# intake (g DM/d)	287	464	242	394
Stem intake (g DM/d)	187	165	234	239
Stover DM				
digestibility## (g/kg)	496	512	549	533

* Leaf-plus-sheath:stem ratio, 1.25.
** Leaf-plus-sheath:stem ratio, 0.82.
*** 12 rams, of initial weight 20 kg, per treatment; intake & growth measurement over 42 days; no supplement except minerals.
# Leaf=Leaf-plus-sheath.
Total collection of faeces.

Barley straw: effect of amount of concentrate supplement

In the experiment shown in Table 7, doubling the amount of straw offered increased the amount consumed whereas increasing the amount of supplement the amount of straw consumed. Intake of straw at the low-offer-rate of straw plus low-supplement, was the same as the intake of straw at the high-offer-rate of straw plus high- supplement. The results demonstrate that straw intake may be manipulated by both amount of residue offered and amount of supplement.

Barley straw: effect of treatment and amount offered in goats

The experiment summarised in Table 8 showed that the intake response to increasing the amount of straw offered was least with NaOH-treated straw; this was attributed to the wet and sticky nature of the straw hindering the selection of leaf by the goats. Table 8 also shows that the largest response to increasing the straw offer-rate was with NH_3-treated straw.

Table 7: Effect of amount of barley straw offered and amount of concentrate fed on intake of straw by goats (Hossain and Owen 1992)

	Straw offered (g DM/kg LW/d)			
	25		50	
Supplement fed (g DM/d)	118	577	116	573
Straw refused				
(g DM/kg DM offered)	381	451	601	677
Straw intake (g DM/kg LW/d)	15.3	13.3	19.3	15.4

* 16 goats/treatment; initial weight 41.5 kg; measurement over 28 days.

Table 8: Effect of amount offered and chemical treatment on intake of barley straw by goats (Alimon et al 1989)***

Offer-rate	Straw [S]		NH_3-S*		NaOH-S**	
(g DM/kg LW/d)	203	503	203	503	203	503
Straw refused (g DM/ kg DM offered)	284	616	266	550	205	640
Intake (g DM/kg LW/d)						
Straw	14.3	19.2	14.5	22.3	16.3	18.2
Leaf	6.2	8.6	6.7	11.0	7.1	8.5
Stem	7.5	8.8	7.6	10.5	9.1	9.5

* 35g NH_3/kg straw DM, using aqueous ammonia.
** Method of Wrathall et al (1989).
*** 6 goats/treatment; initial weight 46 kg; fed supplement at 18 g DM/kg LW^0.75/d.

Effect of previous experience of straw

Table 9 illustrates that readiness to adapt to eating barley straw by lambs was influenced by whether or not they had previous experience of straw as a feed. Whether this is the case with other cereal crop residues and with goats (and large ruminants) remains to be investigated.

Hypothesis confirmed

Tables 1-8 demonstrate that the intakes of barley straw and sorghum stover by goats and sheep are markedly increased when the amount offered is increased so as to allow animals to refuse around 50% of the amount offered, instead of the conventional 10-20% normally allowed. The experiments undertaken confirm the hypothesis that the greater intakes are achieved through animals selecting for the more nutritious leaf and sheath and against the less nutritious stem. The experiments further demonstrate that the intake response to increasing the offer-rate of crop residue can be modified by physical form and chemical treatment of the residue, and by the quantity of concentrate supplement.

Table 9: Effect of offering barley straw to lambs near weaning on their subsequent intake of straw at housing (Odoi and Owen, 1992)

Period (after housing)	Exposed to straw for 28 days* (July 1992)	Not exposed to straw
	Straw intake at housing **(October 1992)	
	(g DM/kg LW/d)	
Days 1-3	7.4	3.9
Week 1	9.2	6.5
Week 2	12.6	11.0
Week 3	13.3	11.6

* 10 lambs/treatment; lambs suckled their dams from birth to weaning at week 14; lambs were 9 weeks of age at beginning of July; ewes and lambs grazed pasture when not offered straw.
** Straw offered at 25 g DM/kg LW/d; supplement fed at 15 g DM/kg $LW^{0.75}$/d.; lambs were of 37 kg LW at housing.

Strategies for using feed refusals

Table 10 shows the result of an experiment with young goat kids to test a strategy of treating refused-straw with NaOH, and refeeding. Unfortunately the experiment had to be stopped after 28 days due to coccidiosis infection in kids fed treated refused straw. The infection was considered to be associated with dirty bedding conditions caused by kids' increased urine output as a result of consuming NaOH-treated straw. Treatment of refusals with ammonia would have been preferable. Coccidiosis apart, the preliminary results indicate that feeding treated refusals is feasible, but more research is needed as well as investigations into offering straw generously to small ruminants followed by feeding the refusals to other species (eg cattle, buffalo or donkeys).

The experiment summarised in Table 11, was undertaken with stall- fed sheep offered indigenous grass in a simulated stall-feeding system in West Java. Increasing the amount of grass offered not only improved intake and growth rate, but also markedly increased the output of compost made from grass refusals, urine and faeces. Though undertaken with grass, the results in Table 11 suggest that a similar approach should be investigated with crop residues.

Table 10: Growth and intake of goat kids offered increasing amounts of barley straw or refused straw treated with NaOH (Hossain *et al* 1993)

Amount of straw offered** (g DM/kg LW/d)	25	50	25

Growth rate (21 d#)(g/d)	2.2	48.2	40.8
Straw refused (g DM/kg DM offered)	355	586	383
Intake straw (g DM/d)	227	309	228
Intake of straw fractions (g DM/kg LW/d)			
Leaf & sheath	9.0	14.8	
Stem	7.4	5.8	

* Straw refused by kids, treated with NaOH and urea (Wrathall *et al* 1989).
** 7 kids/treatment; initial weight 14.3 kg; initial age, 2.5 months
# Trial terminated after 28 days due to coccidiosis infection in kids offered NaOH-treated refused straw.

Practical application and further research

Practical application

The practical application of the results shown in Tables 1-8, requires consideration in the context of sustainable crop-animal agriculture.

The most likely method of application in tropical developing countries is to allow small ruminants to graze crop residues in situ, following grain harvest. Residues rejected by small ruminants could then be collected and stall-fed to large ruminants, possibly after urea-ammonia treatment. Any refusals would be available, along with urine and faeces, for composting or biogas production.

In situ stubble grazing following cereal harvesting is already widely practised in many tropical and sub-tropical countries. Alternatively, rejected residues could be left in the field to act as a mulch; again this is already practised in many situations. Rejected residues following in situ grazing or stall-feeding could be used as fuel; once again this is already practised, eg, in Ethiopia.

Table 11: Effect of amount of cut-and-carried grass offered, on intake by sheep and on output of compost in Indonesia (Tanner *et al* 1993)

	Amount of indigenous grass offfered (g DM/kg LW /d)		
	25*	50*	75*
Growth rate (g/d)	-16.5	25.8	28.5

Grass refused			
(g DM/kg DM offered)	109	359	526
Intake of grass			
(g DM/kg LW/d)	22.1	31.7	34.9
Intake of digestible**			
grass (g DOM/kg LW/d)	11.8	19.0	21.7
Compost#			
Yield (kg)	81	243	348
Yield (kg DM)	27	71	144
N (g/kg DM)	17.6	18.2	19.4
P (g/kg DM)	6.2	6.7	7.4
K (g/kg DM)	32.4	36.8	42.3

* 10 sheep/treatment; initial weight 29 kg; intake and growth measured over 70 d.
** Digestibility measured by total collection of faeces.
# Made from grass refusals and output of faeces and urine from 3 sheep/treatment over 50 d and composting for a further 50 d.

Further research

Rice straw is a major cereal crop residue in China. Whether the responses shown in Tables 1-8 and 10-11 would occur with rice straw is not known.

The fact that rice straw leaf is less digestible than stem would lead us to hypothesise that intake responses to allowing goats and sheep to refuse 50% of the amount offered, instead of the conventional 10-20%, would not occur. On the other hand, Phang and Vadiveloo (1992) recently reported the intake by goats of rice straw leaves to be 11.8 g DM/kg LW/d whereas that of stem was only 5.8 g DM/kg LW/d. Leaves and stem were fed separately. However the DM digestibility of leaf diets was lower than stem diets (562 vs 685 g/kg). Clearly investigations such as those in Tables 1-8 need to be undertaken with rice straws using varieties differing in their leaf:stem ratios.

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