Anim. Prod. 1992, 55: 407-412

0003-3561/92/29930407$02·00

Chemical composition, intake, apparent digestibility and nylon-bag disappearance of leaf and stem fractions from straw of four barley genotypes

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Abstract

Four experiments examined the chemical composition, intake, dry matter (DDM) and organic matter (DOM) apparent digestibilities and rates of disappearance from nylon bags of hand-separated leaf and stem fractions of straw from four genotypes of barley: Arabi Abiad, Beecher, C63 and ER/Apam. In experiment 1, 900 g leaf from each genotype was offered to three or four wethers together with 200 g soya-bean meal (SBM), and in experiment 2 the leaf from the same four genotypes was offered ad libitum *with 200 g SBM. In experiment 3, 500 g stem from Arabi Abiad and Beecher was offered with 100 g SBM to six wethers in two groups. Experiment 4 measured the rate and extent of disappearance of the leaf and stem fractions from nylon bags incubated in the rumen of wethers.*
The genotypes had widely contrasting morphological characteristics. Stems contained about half as much ash and crude protein as leaves and differences within fractions were small. The leaf and stem fractions of the two-rowed barleys Abiad and Apam contained less modified acid-detergent fibre than the six-rowed Beecher and C63 genotypes.
When leaf was offered with SBM, both restrictedly and ad libitum, *the DDM and DOM of this fraction were similar between genotypes (P > 0·05) and in experiment 2 the intake of leaf was also similar between genotypes (P > 0·05). The apparent digestibility of stem differed significantly between Arabi Abiad and Beecher in experiment 3 (P < 0·05). Significant differences were apparent between genotypes in the extent and rate of disappearance of leaf and stem from nylon bags after 48 h incubation in the rumen.*

Keywords: *barley straw, digestibility, nutritive value.*

Introduction

Screening cereal crop germplasm for lines with straw of high feeding value has received increasing attention during the past decade (Reid, Capper and Neate, 1988; Galletti, 1991). Feeding trials indicate that genetic variability in straw quality is undoubtedly present and lines with tall plants generally have a lower leaf proportion and lower feeding value than lines with short plants (Capper, Thomson, Rihawi, Termanini and Macrae, 1986; Capper, Thomson and Rihawi, 1989; International Center for Agricultural Research in the Dry Areas, 1988 and 1989). It remains to be shown in feeding trials that there is genetic variability within the leaf and stem fractions of straw from different lines of cereal. Laredo and Minson (1973) and Poppi, Minson and Ternouth (1981) showed that the apparent digestibility of leaf and stem fractions from tropical grasses were similar even though the intakes of leaf were higher than stem fractions. More recently, Ramanzin, Ørskov and Tuah (1986) showed variability in the nylon-bag disappearance of leaf and stem fractions from different cereal species.

This paper reports four experiments which determined the intake, apparent digestibility and nylon-bag disappearance of hand-separated leaf and stem fractions of straw from four genotypes of barley with known contrasts in feeding value of the whole straw (Capper *et al.*, 1986 and 1989). Experiments 1 and 2 aimed to measure the feeding value of leaf fractions offered either restrictedly or *ad libitum*, respectively, and experiment 3 studied the feeding value of the stem fraction offered restrictedly. Soya-

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bean meal was offered with straw fractions to eliminate any limitations on intake that protein deficiencies might induce. The aim of experiment 4 was to measure the nylon-bag disappearance of leaf and stem fractions of straw from the four genotypes.

Material and methods

Four experiments were conducted using hand-separated leaf and stem fractions of barley straw from Arabi Abiad, a Syrian landrace, and three improved genotypes, Beecher, ER/Apam and C63. These genotypes, referred to as Abiad, Beecher, Apam and C63, were selected because of their range of morphological characteristics (Table 1) and feeding value. Abiad and Apam are two-rowed genotypes and Beecher and C63 six-rowed genotypes. The studies were conducted at Tel Hayda, ICARDA's research station 30 km south of Aleppo (36°01'N, 36°56'E, 284 m altitude) where the mean annual rainfall is about 350 mm and in the 1986/87 growing season it was 360 mm.

Crop management

The four barley genotypes were each machine sown in two 180 × 17 m plots of uniformly deep soil (vertisol). The date of sowing was 10 November 1986, the seed rate was 100 kg/ha, and 60 kg P_2O_5 per ha as triple superphosphate and 30 kg N per ha as ammonium sulphate were applied at sowing. A further 30 kg N per ha was applied in the spring. Crops were harvested at the same time in June 1987 when completely dry.

Crop sampling

Mature standing plants were hand clipped at 2 to 3 cm above ground level at 10 1-m^2 sites chosen at random in each plot. Each hand-clipped sample was weighed, threshed and the straw and grain weighed. Thirty intact plants were hand pulled from another 10 sites in each plot and 15 of these were chosen at random and separated into stem, leaf blade, leaf sheath, chaff, rachis and grain and weighed without further drying. Stem height, which excludes the rachis, was measured to the nearest 1 mm. Leaf proportion is the proportion of leaf blade and sheath in the sum of the stem, leaf sheath and leaf blade fractions.

Crop harvesting and straw preparation

Barley plants were harvested by hand pulling and after removing the heads and roots by clipping, the straw was hand separated into leaf and straw fractions. These fractions were machine chopped to 2 to 3 cm lengths prior to feeding.

Animals

Mature Awassi wethers were used; they initially weighed 47 to 63 kg and had been drenched with an anthelmintic before the experiments started.

Treatments

The same four barley genotypes were used in three experiments and were supplemented with soya-bean meal (SBM, containing 510 g crude protein per kg dry matter (DM)). The amounts of SBM were estimated to exceed the needs for rumen degradable protein (Agricultural Research Council, 1984). Attempts to feed stem *ad libitum* failed because of inappetance and diarrhoea. The fourth experiment is described below.

Experiment 1: feeding value of leaf at restricted level. Chopped leaf was offered restrictedly (900 g air DM) with 200 g SBM per day.

Experiment 2: feeding value of leaf at ad libitum *level.* Chopped leaf was offered *ad libitum* with 200 g SBM per day.

Experiment 3: feeding value of stem at restricted level. Chopped stem was offered restrictedly (500 g air DM) with 100 g SBM per day. A preliminary experiment had shown that this amount of straw was probably close to *ad libitum*.

Feeding procedures

Because of a shortage of straw fractions, feeding periods were short. Preliminary periods were 13 days in experiments 1 and 2, and 6 days in experiment 3. Seven-day collection periods were used in each experiment. Foods were offered at 08.00 h after removing refusals and at 14.00 h. In experiment 2 *ad libitum* feeding was achieved by adjusting food refusals daily to proportionately 0·10 to 0·20 of intake. Wethers were weighed at the start and the end of each feeding period after an overnight fast. They received 10 g salt and 10 g dibasic calcium phosphate daily and water was available at all times except for the 1st h after food was offered.

Chemical analyses

Samples of leaf and stem, and subsamples of food offered, food refused and faeces were analysed for concentrations of DM, ash and crude protein (Ministry of Agriculture, Fisheries and Food (MAFF), 1981) and modified acid-detergent fibre (MAFF, 1973).

Nylon-bag disappearance

Experiment 4: nylon-bag disappearance of leaf and stem. Experiment 4 measured the disappearance of chopped (2-mm sieve) leaf and stem fractions from porous nylon bags (40 μm mesh size) using procedures described by Ørskov, Hovell and Mould (1980). Measurements of disappearance of leaf were made in duplicate at 6, 12, 24, 48 and 72 h, and of stem in duplicate at 6, 12, 24, 48, 72 and 96 h using three rumen-cannulated wethers offered a good quality vetch hay and a mineral supplement. Solubility (washing losses) of leaf and stem fractions was determined in triplicate by placing nylon bags containing 2 g samples in water at 20°C for 1 h and then rinsing the bags in cold water. Bags were then dried at 70°C for 22 h.

Statistical design and data analysis

Experiments 1 and 2. Fourteen wethers were blocked into four groups balanced for live weight and then wethers from each group were allocated at random to the four treatments (genotypes). There were four wethers allocated to Abiad and Apam but only three to Beecher and C63 because of a shortage of food. Experiment 2 immediately followed experiment 1 and the same 14 wethers were used in each experiment.

Experiment 3. Another sixteen wethers were used in an experiment with the same design as experiment 1. Because of high levels of refusals of stem from Apam and C63, only data from three wethers offered Abiad and three wethers offered Beecher were included in the statistical analysis. Results were analysed by one-way analysis of variance. Apparent digestibilities of leaf and stem fractions were estimated by difference, assuming SBM had a coefficient of DM apparent digestibility of 0·795 (MAFF, Department of Agriculture and Fisheries for Scotland and Department of Agriculture for Northern Ireland, 1984).

Experiment 4. Nylon-bag disappearance was measured using three wethers. The parameters of the equation Y (disappearance) $= a + b(1 - c^{-kt})$ were estimated using least-squares procedures.

Table 1 *Yields (kg/ha, air dried) of grain and straw and morphological characteristics of four barley genotypes*

	Abiad	Beecher	C63	Apam	s.e.d.
Yield components					
Grain	3590	3510	3810	4870	
Straw + chaff	5370	5030	7070	7010	
Morphological characteristics					
Row type					
Whole plant mass (g)	2·05	4·74	3·89	2·20	0·191
Stem height (cm)	49	84	85	53	2·1
Leaf proportion	0·44	0·30	0·41	0·43	0·015

Results

The grain yields were high, with Apam yielding more than the other three genotypes which were similar (Table 1). C63 and Apam had the highest straw yields. The two-rowed Abiad and Apam had a lower plant mass ($P < 0·001$) and shorter stems ($P < 0·001$) than the six-rowed Beecher and C63, and Beecher had the lowest leaf proportion ($P < 0·001$). C63 had a high leaf proportion, even though it had tall stems.

Stems contained about half as much ash and crude protein as leaves and differences between genotypes were small (Table 2). The crude protein concentration in the total diet was about 118 g/kg DM ($P < 0·001$) and 79 to 96 g/kg DM ($P > 0·05$) in experiments 1 and 2, respectively, and about 100 g crude protein per kg DM in experiment 3. The leaf and stem fractions of the two-rowed barleys contained less modified acid-detergent fibre than the six-rowed genotypes.

The dry and organic matter apparent digestibilities of the leaves offered at either the restricted (experiment 1) or *ad libitum* (experiment 2) level were similar ($P > 0·05$) between genotypes, as were the intakes (Table 3). However, in experiment 3, Abiad stems were more digestible than Beecher stems at a similar intake ($P < 0·01$; Table 4).

Small genotypic differences in the losses of water-soluble material within leaf and stem fractions were apparent but the differences between leaf and stem were large (Table 5). However, 48-h losses of C63 leaf from nylon bags were lower than for Abiad and Beecher ($P < 0·001$), and 48-h losses of Abiad stem were higher than those of Beecher and C63 ($P < 0·01$). Large differences were seen between the disappearance of leaf and stem fractions. The extent (b) of leaf disappearance was highest ($P < 0·001$) in the case of Abiad and lowest for C63 leaf. A similar

Table 2 *Composition of leaf and stem fractions of straw from four barley genotypes and crude protein content in total diet (g/kg DM)*

		Abiad	Beecher	C63	Apam
Ash	Leaf	130	130	148	131
	Stem	57	51	51	62
Crude protein	Leaf	30	26	30	30
	Stem	14	17	13	15
Crude protein in total diet	Leaf†	119	113	116	116
	Leaf‡	96	79	88	87
	Stem	97	103		
Modified acid-detergent fibre	Leaf	402	442	418	408
	Stem	448	468	484	464

† Restricted level (experiment 1).
‡ *Ad libitum* (experiment 2).

Table 3 *Experiments 1 and 2: apparent digestibility coefficients of leaf fractions from straw of four barley varieties and daily intakes when offered to sheep at a restricted level (experiment 1) and* ad libitum *(experiment 2)*

	Experiment no.	Abiad (no. = 4)	Beecher (no. = 3)	C63 (no. = 3)	Apam (no. = 4)	s.d.†
Apparent digestibility coefficients of leaf						
Dry matter	1	0·56	0·59	0·51	0·55	0·055
	2	0·55	0·57	0·55	0·52	0·035
Organic matter	1	0·62	0·64	0·57	0·62	0·056
	2	0·61	0·62	0·60	0·59	0·037
D value‡	1	0·54	0·56	0·49	0·54	0·048
	2	0·53	0·53	0·51	0·51	0·033
Leaf intakes						
Dry matter (g)	1	824	827	835	832	19·0
	2	1151	1511	1346	1348	253·2
Dry matter (g/M$^{0·75}$)	1	44·2	39·9	44·1	43·0	3·20
	2	58·6	69·0	64·5	65·3	9·36
Organic matter (g)	1	718	725	715	727	20·5
	2	999	1313	1142	1163	221·5
Crude protein (g)	1	26·7	21·2	25·3	25·0	
	2	31·6	37·0	40·0	38·8	5·54

† Square root of error mean square.
‡ Proportion of digestible organic matter in the dry matter.

result was seen for stem although the values were substantially lower than for leaf ($P < 0·001$).

Discussion

The barley genotypes used in these experiments were chosen because of their differences in plant morphology and previous studies had shown that they differed widely in nutritive value (Capper *et al.*, 1986 and 1989), despite their relatively similar grain and straw yields. However, the genotypic differences in the chemical composition within fractions were small and similar to those found in other studies (Åman and Nordkvist, 1983; Capper *et al.*, 1986; Ramanzin *et al.*, 1986).

Table 4 *Experiment 3: apparent digestibility coefficients of stem fraction of two barley straws and daily intakes when offered at a restricted level*

	Abiad	Beecher	s.e.d.
Apparent digestibility coefficients of stem			
Dry matter	0·52	0·44	0·011
Organic matter	0·56	0·48	0·014
D value†	0·53	0·45	0·014
Stem intakes (g)			
Dry matter	458	438	35·4
(g DM/M$^{0·75}$)	22·6	22·9	2·88
Organic matter	432	416	33·9
Crude protein intakes (g)			
Stem	6·6	7·2	0·77
Stem + SBM	53·1	53·7	0·77

† Proportion of digestible organic matter in the dry matter.

The apparent digestibilities of the two fractions showed how genotypic differences between leaf fractions could be small, whereas large differences were seen between the stems of Abiad and Beecher. Even though the comparison of leaf and stem apparent digestibility is confounded by level of feeding and sheep and assumes a constant value for the apparent digestibility of the SBM, it is evident that the difference between the apparent digestibilities of Abiad leaf and stem was small, but for Beecher the difference was large. These results, and the higher proportion of leaf in Abiad, would result in the higher apparent digestibility of whole Abiad straw as compared with whole Beecher straw and confirms other studies conducted at ICARDA (Capper *et al.*, 1986 and 1989; ICARDA, 1988).

Differences in leaf intake due to genotype were not detected even though variation in the extent and rate of disappearance of leaf between genotypes were seen in experiment 4. There was reasonable agreement between the *in vivo* and nylon-bag results regarding the lower apparent digestibility for C63 leaf and Beecher stem. The intake of stems of C63 and Apam could not be measured because of inappetance and diarrhoea in the wethers.

The higher extent (*b*) and rate (*c*) of disappearance of leaf compared with stem agree with the results of Ramanzin *et al.* (1986). This would partially explain why the restricted level of feeding chosen was higher for leaf compared with stem in experiments 1 and 3, respectively. However this comparison is somewhat biased by differences in sheep and experimental design. A second factor contributing to this intake difference could have been a shorter rumen mean retention time (MRT) of leaf compared with stem as found in tropical grasses by Laredo and Minson (1973) and Poppi *et al.* (1981). A longer MRT of stem would be related to the higher concentration of lignocellulosics in stem than in leaf of these genotypes (Capper *et al.*, 1986 and 1989). The negative intercepts (*a*) are considered to be an artifact of the nylon-bag method and differ from the solubility values.

The results of these experiments suggest that the apparent digestibility and intake of the leaf fractions from the four genotypes were similar in mature sheep, whereas genotypic differences in the apparent digestibility of the stem fraction were present between Abiad and Beecher. This indicates how the stem fraction is largely responsible for the difference in the nutritive value of whole straw from Arabi Abiad and Beecher reported in the two earlier studies at ICARDA.

An alternative approach to breeding for improved nutritive value that merits more attention is the mechanical separation of the more nutritious leaf from the poorly digested and protein-deficient stem. Leaves could be given to ruminants and the stems could either be used for industrial purposes or returned to the soils which are generally severely deficient in organic matter in arid and semi-arid regions.

Table 5 *Experiment 4: solubility (washing losses) and 48-h losses of dry matter (DM), and constants of the equation describing DM disappearance from nylon bags over time of leaf and stem fractions from four barley genotypes*†

	Abiad	Beecher	C63	Apam‡	s.e.d.
Leaf					
Solubility	194	189	221		
48-h losses	757	737	699		3·0
Constants					
a	−65	−52	45		19·1
b	851	821	678		14·1
c	0·078	0·074	0·069		0·0040
Residual s.d.	1·3	1·0	1·0		
Stem					
Solubility	100	141	100	110	
48-h losses	434	372	350	407	12·4
Constants					
a	−58	20	−19	−35	10·3
b	523	401	406	476	9·8
c	0·059	0·057	0·059	0·061	0·0032
Residual s.d.	1·5	0·9	1·2	0·7	

† Solubility, 48-h losses, *a* and *b* expressed as g/kg DM, and *c* expressed as fraction per h.
‡ Insufficient leaf sample.

Acknowledgements

This paper is written in memory of the late Frances Herbert who died in a car accident in 1988 shortly after completing experiment 2. She was the recipient of ODA/TDRI (now NRI) studentship EMCX139 at Wye College (University of London). Dr R. C. Campling made valuable comments on an early draft of the paper. The technical help of Adnan Termanini, Safouh Rihawi and the staff in the ICARDA Forage Quality Laboratory is much appreciated.

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(*Received* 26 *February* 1992—*Accepted* 8 *June* 1992)