Comparative effects of wheat bran and barley husk on nutrient utilization in rats

1. Protein and energy

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1. The present work with growing rats was undertaken to compare the effect of wheat bran and barley husk on nutrient bioavailability. The experiment involved a total of nine dietary treatments consisting of a control group, without wheat bran or barley husk, and two series of four groups with increasing amounts of fibre from 50 to 117 g/kg dry matter (DM) from the two fibre sources. Dietary nitrogen concentration was kept constant at 15 g N/kg DM by adjusting the diets with an N-free mixture. Protein sources were casein, fortified with methionine and white wheat flour. True protein digestibility (TD), biological value (BV), net protein utilization (NPU) and digestible energy (DE) were estimated.

2. TD decreased when total dietary fibre (TDF) increased, the effect being greater in the case of wheat bran. The difference in response can be explained by the larger N contribution from bran than from barley husk. N from barley husk was actually digested less than N from wheat bran.

3. Changes in TD due to fibre were small, both for wheat and barley husk. It was concluded that decreased TD with fibre at moderate levels was due to poor digestibility of the N associated with the fibre source rather than decreased digestibility of N from other dietary components.

4. BV was only marginally affected by the fibre levels, indicating that the relatively high lysine content in both wheat bran and barley husk had a low availability.

5. Wheat bran and barley husk showed almost the same negative effect on DE and DM digestibility (DMD). DMD correlated significantly with DE, demonstrating that DMD is a simple and convenient means of monitoring DE.

Interest in the effect of fibre-rich cereal products on nutrient bioavailability has increased both because of the awareness of the importance of consuming more fibre in the human diet (Trowell, 1976) and also to achieve a more efficient utilization of cereal products in animal feeding (Munck, 1981). Although a high-fibre intake appears to decrease energy, nitrogen and mineral absorption (Kelsay, 1978), generalizations can be misleading. The type and complexity of the fibre source, either purified or in natural products, and the level in the diet, can influence the results obtained both in animal and human studies (Sauer *et al.* 1979; Beames & Eggum, 1981; Frølich, 1984).

The purpose of the present studies was to compare the effects of wheat bran and barley husk on nutrient bioavailability in rats. These two fibre-rich cereal fractions have a different botanical origin and quite different chemical composition. Wheat bran is composed of the pericarp and testa and also carries the aleurone cell layer that contains nearly 15% of the protein and between 50 and 80% of the minerals in the kernel (O'Dell *et al.* 1972). Barley husk comprises the outer parts of the kernel (palea and lemma), usually separated during threshing, and contains about 5% of the protein but more than 30% of the minerals of the kernel (Bach Knudsen, 1982).

The fibre level is considerably higher in barley husk and the composition of the fibre differs from that of wheat bran, being particularly richer in lignin (Nyman *et al.* 1984).

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Various other components with nutritional implications, such as phytate and tannins, also differ in these two products (O'Dell *et al.* 1972; Eggum & Christensen, 1975).

In order to compare specifically the nutritional effects of the fibre of these products, the experiment was designed to compare the influence of the fibre source (either wheat bran or barley husk) and the fibre level (measured as total dietary fibre) on the protein, energy and mineral utilization in the rat. The present paper reports results on protein and energy utilization.

EXPERIMENTAL

Diets

A basal diet, with no wheat bran or barley husk added, served as control. This diet was composed of casein supplemented with 10 g DL-methionine/kg dry matter (DM) and wheat flour (80% extraction rate) as protein sources, each providing half the total dietary protein set at 98 g/kg DM; a N-free mixture consisting of (g/kg DM) autoclaved potato starch 806·0, sucrose 90·0, cellulose powder 52·0, soya-bean oil 52·0; a mineral mixture (see Table 1); a vitamin mixture as described by Eggum (1973).

In the test diets, wheat bran (bran series, diet nos. 1, 2, 3, 4) or barley husk (husk series, diet nos. 1, 2, 3, 4) were added at increasing levels so that diets with corresponding numbers in the two series contained the same level of total dietary fibre (TDF). The addition of wheat bran or barley husk was done at the expense of the wheat flour, keeping the total dietary protein constant. Adjustments for TDF also involved alterations in the proportion of the N-free mixture in the diets. The composition of the experimental diets is given in Table 1 (see also Table 2).

Animals and feeding

The experimental procedure has been described by Eggum (1973). Groups of five male Wistar rats weighing approximately 70 g were assigned to each dietary treatment. The control diet was included in both series, therefore it was given to a total of ten animals. Mean weights of the groups at the beginning of the experiment differed by no more than 0·5 g. The rats were housed individually in Plexiglass metabolism cages in a controlled environment. The diets were given for 9 d and the balance measurements were done during the last 5 d. Each animal received 10 g dietary DM and 150 mg N, daily throughout the experiment.

Table 1. *Composition of experimental diets* (*g/kg dry matter* (*DM*))

Dietary treatment...	Control	Bran series				Husk series			
		1	2	3	4	1	2	3	4
Casein + 10 g DL-methionine/kg DM	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0
Wheat flour	394·0	358·0	322·0	250·0	106·0	385·0	374·0	355·0	317·0
Wheat bran	—	25·0	50·0	100·0	200·0	—	—	—	—
Barley husk	—	—	—	—	—	13·5	27·0	54·0	108·0
Nitrogen-free mixture*	500·0	511·0	522·0	544·0	588·0	496·0	493·0	485·0	470·0
Mineral mixture†	40·0	40·0	40·0	40·0	40·0	40·0	40·0	40·0	40·0
Vitamin mixture	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·0

* For details of composition, see above.

† Providing (g/kg mixture): $CaCO_3$ 68·6, $C_{12}H_{10}Ca_3$. $4H_2O$ 308·3, $CaHPO_4$. $2H_2O$ 112·8, K_2HPO_4 . $3H_2O$ 218·8, KCl 124·7, NaCl 77·1, $MgSO_4$ 38·3, $MgCO_3$ 35·2, ferric citrate 7·65, $MnSO_4$. H_2O 0·201, $CuSO_4$. $5H_2O$ 1·00, KI 0·041, NaF 0·507, $AlNH_4(SO_4)_2$. $12H_2O$ 0·090, $ZnSO_4$. $7H_2O$ 11·00.

True protein digestibility (TD), biological value (BV), DM digestibility (DMD) and energy digestibility (DE) were measured. Net protein utilization (NPU; TD × BV) was calculated. Metabolic and endogenous N were determined by adding 4% ether-extracted, freeze-dried egg protein to the N-free mixture (Eggum, 1973).

Analytical methods

N and ash analyses were performed following standard methods (Association of Official Analytical Chemists, 1975). Starch and sugar were measured according to MacRae & Armstrong (1968) and fat as described by Stoldt (1952). Total, soluble and insoluble fibre were analysed by a gravimetric method based on the digestion of the sample by a heat-resistant α-amylase followed by pepsin and pancreatin, as described by Asp *et al.* (1983).

Amino acid analyses were carried out according to Mason *et al.* (1980). Energy in diets and faeces was determined by the method of Weidner & Jakobsen (1962).

Statistical analysis

The results were subjected to two-way analysis of variance (ANOVA). Pooled standard errors were determined after testing for variance homogeneity. Differences between groups were identified by the honestly significant difference (HSD; Tukey's test) (Gill, 1978). Regression analyses were performed on treatment means.

RESULTS
Chemical composition

The chemical composition and amino acid content of the main variable components of the diets, wheat flour, wheat bran and barley husk, are given in Table 2. As expected, wheat bran contained about twice as much protein (171·3 g/kg DM) as barley husk (85·6 g/kg DM) but much less TDF (399·1 g/kg DM) compared with that in barley husk (737·8 g/kg DM). Lysine and threonine content were higher for wheat bran and barley husk as compared with wheat flour. The values for chemical and amino acid composition of the wheat flour were within the normal range expected for the corresponding extraction rate (Pedersen & Eggum, 1983*a*).

The chemical and amino acid compositions of the diets are given in Table 3. The diets were approximately isonitrogenous and isoenergetic. The source of N in the bran and husk series was different, wheat bran contributing proportionally more N. The dietary proportions of bran N to total N were 0·04, 0·09, 0·18 and 0·36 for diet nos. 1, 2, 3, 4 of the bran series respectively, while the proportions of husk N to total N for corresponding diets of the husk series were 0·01, 0·02, 0·05 and 0·10.

The fibre content of the basal diet was derived from the wheat flour, which contributed about one-third of total dietary fibre, and the cellulose component of the N-free mixture. In the test diets, as wheat bran or barley husk were proportionally increased, the total, as well as insoluble fibre in diet no. 4 in both series, increased up to 2·7 times the level in the basal diet. Diets of both series with the same number contained close to the same level of total as well as insoluble and soluble dietary fibre. The bran fibre ratios (bran fibre : total fibre) in diet nos. 1, 2, 3, 4 of the bran series were 0·19, 0·33, 0·50 and 0·69 respectively, while the husk fibre ratios (husk fibre : total fibre) for the respective diets were 0·20, 0·33, 0·51 and 0·68.

The amino acid content of the diets reflected the partial substitution of wheat flour by wheat bran or barley husk, with lysine and threonine showing a slight increase particularly for the bran series as the substitution was proportionally higher, while other amino acids only changed to a small extent.

Table 2. *Chemical and amino acid composition of wheat flour, wheat bran and barley husk*

	Wheat flour	Wheat bran	Barley husk
Chemical composition (g/kg DM)			
Ash	9·3	50·5	77·7
Crude protein (nitrogen × 6·25)	118·8	171·3	85·6
Fat	22·2	63·6	42·1
Starch + sugars	784·5	336·9	84·1
Dietary fibre:			
Total	40·3	399·1	737·8
Insoluble	27·6	370·1	717·4
Soluble	12·7	29·0	20·4
Amino acid composition (g/kg crude protein)			
Lysine	24·3	39·4	38·1
Threonine	26·8	31·2	32·7
Cystine	24·0	20·0	16·9
Methionine	15·3	14·1	15·2
Histidine	22·5	25·9	18·3
Leucine	72·5	61·3	55·5
Isoleucine	38·6	33·6	30·6
Valine	46·0	47·3	45·8
Phenylalanine	48·2	37·7	35·0
Aspartic acid	44·6	66·0	66·2
Glutamic acid	340·4	200·0	137·2
Proline	116·1	65·0	59·2
Alanine	32·9	45·6	45·8
Arginine	41·5	65·4	47·6
Glycine	37·8	50·2	45·6
Serine	49·9	44·1	38·3
Tyrosine	30·5	26·6	20·9

DM, dry matter.

Animal experiments

The results for protein utilization and energy and DM digestibilities are given in Table 4. An F test showed no significant differences in the indices measured for the control diets fed either with the bran or husk series. Therefore, both experimental treatments were considered as one and combined mean (with SEM) values are given.

TD

Increasing TDF from either wheat bran or barley husk decreased TD of protein and although the changes were of small magnitude, and no bigger than five percentage units, they were significant both for the level and the type of fibre, being more pronounced with the addition of wheat bran (Fig. 1(a)).

The relation between the dietary N ratio from bran or husk and faecal N excretion corrected for metabolic losses, is given in Fig. 2. We observed that for the same N contribution in the diet, barley husk produced a higher faecal N excretion than wheat bran.

BV

The BV showed no significant change as the barley husk was increased in the diet, but a significant increase from 0·84 to 0·90 was observed when wheat bran was proportionally increased (Fig. 1(b)). This index varied more significantly due to the fibre type than to the dietary fibre level.

Table 3. *Chemical and amino acid composition of the experimental diets*

Dietary treatment...	Control	Bran series				Husk series			
		1	2	3	4	1	2	3	4
Chemical composition (g/kg DM)									
Crude protein (nitrogen × 6·25)	98·3	98·0	98·0	98·0	100·0	97·0	97·2	97·6	97·9
Dietary fibre:									
Total	43·0	52·0	61·0	79·0	116·0	51·0	60·0	79·0	117·0
Insoluble	38·0	47·0	56·0	73·0	109·0	46·0	55·0	74·0	110·0
Soluble	5·0	5·0	5·0	6·0	7·0	5·0	5·0	5·0	7·0
Energy (kJ/g)	18·1	18·4	18·2	18·5	18·1	17·7	17·8	17·8	17·9
Amino acid composition (g/kg crude protein)									
Lysine	48·8	53·2	54·8	53·1	57·2	50·7	48·7	51·1	53·5
Threonine	31·7	34·7	35·7	34·3	36·1	33·4	31·9	33·4	34·4
Cystine	12·5	12·7	12·7	12·2	11·9	12·8	12·3	12·5	12·7
Methionine	25·0	25·6	26·8	27·3	26·5	25·7	25·3	26·1	25·1
Histidine	23·8	25·8	26·7	25·7	27·5	25·2	24·1	25·1	25·5
Leucine	78·0	83·4	85·2	80·6	82·1	81·3	78·2	80·7	81·6
Isoleucine	43·2	46·4	46·8	44·3	45·6	44·6	43·0	45·0	45·7
Valine	53·2	57·3	59·2	56·3	59·2	55·8	53·6	56·1	57·4
Phenylalanine	45·8	48·6	49·4	46·3	46·2	48·1	46·3	48·0	48·1
Aspartic acid	53·3	58·5	61·0	60·3	65·5	56·2	54·1	57·2	59·4
Glutamic acid	263·8	264·4	263·6	242·9	228·9	273·1	273·0	281·3	272·4
Proline	107·5	107·8	108·0	99·8	95·6	107·3	114·8	114·9	113·4
Alanine	29·0	31·3	32·9	32·3	35·8	30·8	29·8	31·3	32·5
Arginine	35·9	39·4	41·7	42·0	47·6	37·8	36·4	38·1	39·2
Glycine	26·0	28·0	29·5	29·3	32·8	27·5	26·7	27·9	28·7
Serine	51·1	54·7	56·6	53·6	53·8	53·9	51·3	52·7	53·0
Tyrosine	36·7	39·8	40·2	38·4	38·9	38·2	36·7	37·9	37·9

DM, dry matter.

NPU

The values obtained reflected the tendencies observed for TD and BV, remaining fairly constant for increasing wheat bran and decreasing slightly with increasing barley husk concentrations (Fig. 1(c)).

DE

DE was affected very similarly by increasing TDF either as wheat bran or barley husk and, although a significant influence due to fibre type was noted, the effect had a very small absolute value. The increase in TDF from about 40 g/kg DM in the basal diet to about 120 g/kg DM from either of the fibre-rich products, produced a decrease in DE of about eight percentage units (Fig. 3(a)).

DMD and faecal dry weight

DMD followed very closely the response observed for DE with no significant effect due to fibre type but only to fibre level (Fig. 3(b)). DMD correlated significantly with DE

$$DMD = -2·99 + 1·03 \, DE; \, R^2 \, 0·992, \, P < 0·001.$$

Faecal dry weight correlated significantly with TDF irrespective of the fibre source (Fig. 3(c)).

Table 4. *Effect of increasing dietary fibre from wheat bran or barley husk on protein utilization and energy and dry matter digestibility*

Dietary treatment...	Control		Bran series					Husk series				
	Mean	SEM	1	2	3	4	SEM	1	2	3	4	SEM
True protein digestibility	0·979[a]	0·003	0·972[a]	0·963[ab]	0·952[b]	0·926[d]	0·005	0·984[a]	0·967[ab]	0·961[bc]	0·949[c]	0·004
Biological value	0·843[a]	0·007	0·858[a]	0·865[a]	0·883[b]	0·901[b]	0·008	0·850[a]	0·835[a]	0·834[a]	0·837[a]	0·008
Net protein utilization	0·826[a]	0·005	0·833[a]	0·833[a]	0·834[a]	0·833[a]	0·009	0·837[a]	0·807[ab]	0·801[b]	0·795[b]	0·008
Apparent energy digestibility	0·938[a]	0·003	0·925[a]	0·908[b]	0·890[c]	0·856[d]	0·004	0·934[a]	0·916[b]	0·899[c]	0·862[d]	0·004
Dry matter digestibility	0·932[a]	0·003	0·921[a]	0·903[b]	0·884[c]	0·852[d]	0·011	0·927[a]	0·907[b]	0·889[c]	0·850[d]	0·009

[a, b, c, d] Mean values in the same row with different superscript letters were significantly different ($P < 0.05$) using Tukey's test.
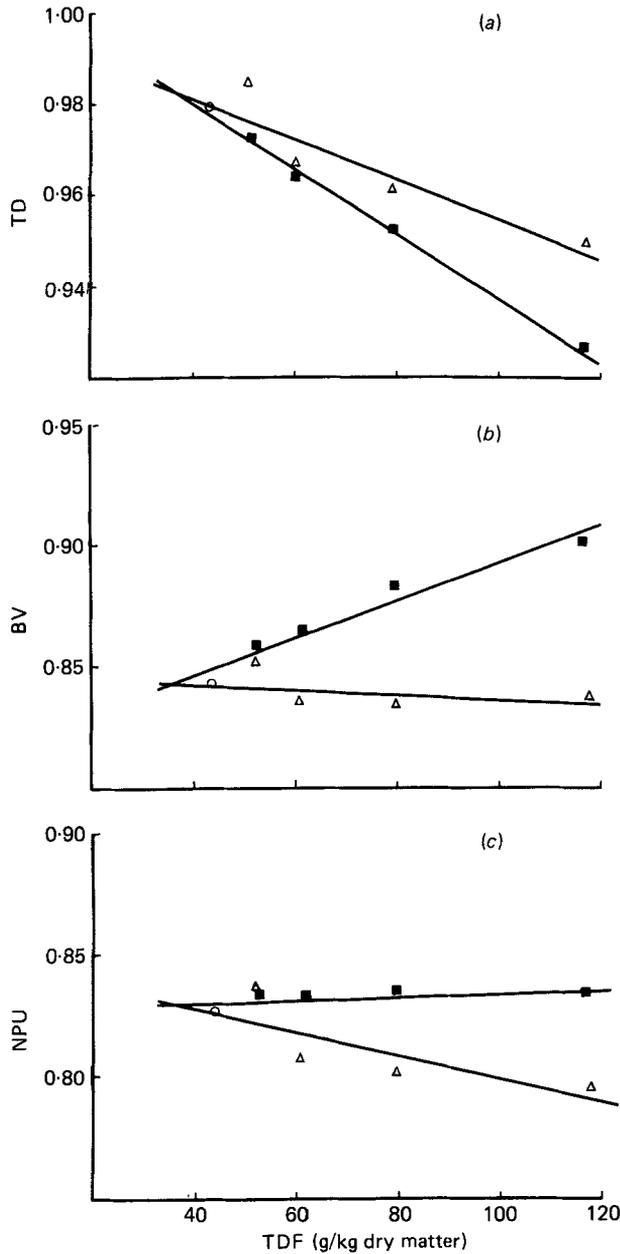
Fig. 1. Relation between total dietary fibre (TDF) and (a) true protein digestibility (TD), (b) biological value (BV) and (c) net protein utilization (NPU).

(○) Basal diet; (■), bran series:

$$TD = 1 \cdot 009 - 0 \cdot 7 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 997, \quad P < 0 \cdot 001;$$
$$BV = 0 \cdot 817 + 0 \cdot 8 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 950, \quad P < 0 \cdot 01;$$
$$NPU = 0 \cdot 828 + 0 \cdot 1 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 279, \quad P < 0 \cdot 05.$$

(△), Husk series:

$$TD = 0 \cdot 999 - 0 \cdot 4 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 873, \quad P < 0 \cdot 02;$$
$$BV = 0 \cdot 848 - 0 \cdot 1 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 278, \quad P > 0 \cdot 05;$$
$$NPU = 0 \cdot 847 - 0 \cdot 5 \times 10^{-3} \ TDF, \quad R^2 \ 0 \cdot 666, \quad P > 0 \cdot 05.$$
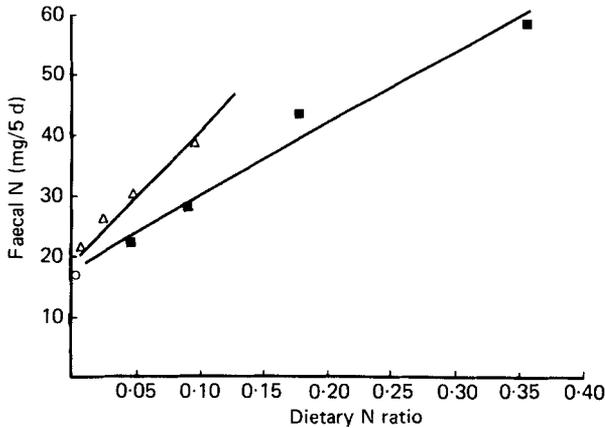
Fig. 2. Relation between dietary nitrogen contribution from wheat bran or barley husk (as dietary ratio) and faecal N excretion during the balance period corrected for metabolic losses.
(○), Basal diet; (■), bran series:

$$\text{faecal N} = 17\cdot80 + 118\cdot2 \times \text{N ratio}, \quad R^2\ 0\cdot978, \quad P < 0\cdot01.$$

(△), Husk series:

$$\text{faecal N} = 18\cdot87 + 215\cdot5 \times \text{N ratio}, \quad R^2\ 0\cdot961, \quad P < 0\cdot05.$$

DISCUSSION

TD of protein decreased when TDF was increased, the effect being more marked in the case of wheat bran. The difference in response between bran and husk can be explained by the larger N contribution from bran, digested less than N from wheat flour, in diets with the same fibre content. Several studies indicate a lower N digestibility of wheat bran compared with other wheat products, although differences in the composition of products tested and experimental conditions may explain discrepancies in the absolute values obtained. TD of N in wheat bran in rats was found to be 0·820, considerably lower than in whole wheat (0·935) (Eggum *et al.* 1985). Pedersen & Eggum (1983*a*) found that TD of protein in wheat flours decreased as the extraction rate increases, from 0·96 for 0·66 extraction rate flour to 0·92 for the whole-grain flour. Betschart *et al.* (1982) reported that TD of N of wheat bran, also measured in rats, was about 0·70 while that of white wheat bread was (on average) 0·91 and of whole-wheat bread 0·87.

When diets with the same N contribution from bran or husk were compared in terms of TD of N, a larger faecal N excretion was obtained when barley husk was used. This suggests that in spite of a more pronounced effect of wheat bran on TD in our test diets, N from barley husk is actually digested less than N from wheat bran. This is in agreement with the findings of Eggum *et al.* (1985) and with Bach Knudsen (1982) who measured TD of protein in barley husk from two varieties of barley, with normal and high lysine content, and found a very low value of 0·50 with no difference with respect to the source used.

In general, the changes in TD of protein observed between the basal and the test diets containing up to about three times as much fibre, were of small magnitude both for wheat bran and barley husk. Therefore these results do not favour the hypothesis of a strong negative effect of added fibre on digestibility of N from the other dietary components, at least at moderate levels of inclusion. It seems that it is rather the protein-N associated with the fibre source that is poorly digested. Several previous studies support this view. When casein was used as the only protein source, no effect on TD of protein was observed when
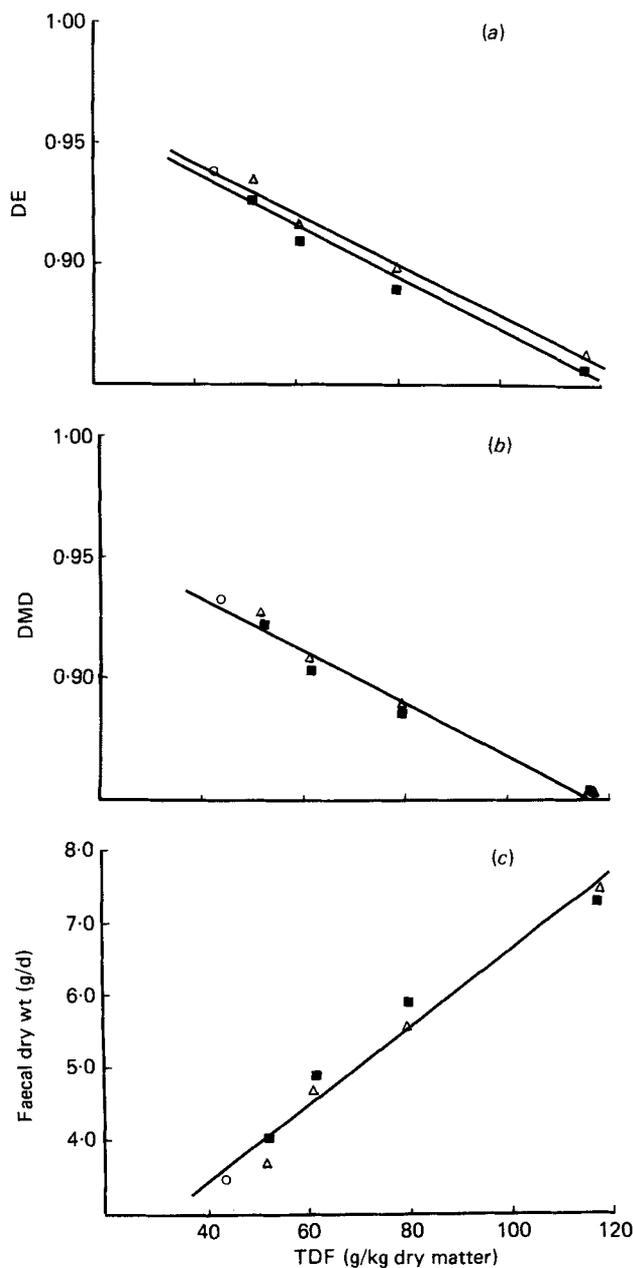
Fig. 3. Relation between total dietary fibre (TDF) and (*a*) energy digestibility (DE), (*b*) dry matter digestibility (DMD) and (*c*) faecal dry weight.

(○), Basal diet; (■), bran series:
$$DE = 0.981 - 1.1 \times 10^{-3}\ TDF, \quad R^2\ 0.982, \quad P < 0.01.$$
(△) Husk series:
$$DE = 0.983 - 1.0 \times 10^{-3}\ TDF, \quad R^2\ 0.990, \quad P < 0.001.$$
Combined series:
$$DMD = 0.976 - 1.1 \times 10^{-3}\ TDF, \quad R^2\ 0.978, \quad P < 0.001.$$

$$Faecal\ dry\ weight = 1.32 + 0.05\ TDF, \quad R^2\ 0.974, \quad P < 0.01.$$

the level of fibre provided as cellulose was increased up to 300 g/kg diet (Eggum, 1973). When fibre was included at up to 150 g/kg from natural sources (barley straw or oat hulls) in a casein-based diet, Sauer *et al.* (1979) did not observe a decrease in TD of protein when comparing different levels of the same fibre source and only minor differences were observed between fibre sources. In contrast to these findings, Shah *et al.* (1982) demonstrated increased excretion of faecal N with increasing amounts of dietary N-free fibre. The same authors also observed a stronger negative influence of wheat bran on TD than in the present study.

The increase in BV observed for the wheat bran is compatible with the higher level of lysine in diets of the bran series compared with the basal diet, although no significant correlation could be established between dietary lysine and BV. Pedersen & Eggum (1983a) also noted a small increase in BV of wheat flours of increasing extraction rates, but also no significant correlation was found between BV and lysine content of the evaluated flours. In the husk series, BV remained essentially unchanged suggesting that the increased lysine derived from the barley husk was poorly available, but also that the fibre in the husk did not adversely affect the availability of amino acids from other dietary components. Bach Knudsen (1982) and Bach Knudsen *et al.* (1983), studying diets in which barley endosperm was increasingly substituted by barley husk, found a pronounced decrease in BV only when the dietary husk ratio was over 0·20 for dietary DM or 0·10 for dietary N, the value remaining fairly constant at lower levels of substitution. These authors explained their results by the very low energy digestibilities of diets with a large contribution of barley husk, resulting in the use of dietary protein as an energy source rather than for tissue synthesis. In the present study, although DE decreased with increasing fibre, it appears that enough energy was absorbed preventing a negative effect on protein quality. Although weight gain was not used as a criteria for nutrient utilization, we observed no significant difference in weight gain for all diets tested indicating that for all treatments the energy absorbed was sufficient to support growth.

NPU reflected, obviously, the trends observed for TD and BV and although significant differences were observed with respect to the type of fibre, in practical terms, increasing fibre from bran or husk within the levels of the present study did not interfere with overall dietary protein utilization.

Wheat bran and barley husk showed almost the same effect on DE, DMD and faecal dry weight, with increasing TDF. The trends observed are in good agreement with previous observations. DE increased with decreasing extraction rates both in wheat flours (Pedersen & Eggum, 1983a) and barley flours (Pedersen & Eggum, 1983b). Energy digestibility of wheat bran was found to be 0·726 compared with 0·892 for whole wheat (Eggum *et al.* 1985) and extremely low values have been estimated for barley husk (Bach Knudsen, 1982). In the present study, for the same DM contribution in the diet a significantly lower DE was found when TDF was increased as barley husk compared with wheat bran. The good correlation between DMD and DE has interesting practical implications since DMD is a simple and convenient means of monitoring DE.

The increased faecal dry weight with total dietary fibre could be due to the undigested components of wheat bran and barley husk, mainly the fibre. Nyman & Asp (1982) found that dietary fibre in wheat bran was rather resistant to fermentation in the rat intestinal tract. More than 60% of wheat bran fibre components were recovered in faeces while guar gum, pectin and sugar-beet produced, in general, much lower recoveries. A low intestinal fermentation of barley husk is suggested by the results of Eggum *et al.* (1984) which showed that hind-gut microbial activity in rats did not increase by supplementation of a barley or soya-bean meal diet with barley husk.

The present study demonstrates that increasing dietary fibre, either as wheat bran or

barley husk at levels that might be found in normal diets, produces minor changes in TD and BV; these might be explained by the availability of the protein-N associated with the fibre-rich product, rather than by adverse effects on the utilization of protein from the remainder of the diet. Increasing the dietary contribution of wheat bran or barley husk brings about a more pronounced effect on dietary energy digestibility than on protein digestibility.

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