AGRICULTURAL AND FOOD SCIENCE IN FINLAND

Vol. 6 (1997): 295–303.

Effects of variety, soil type and nitrogen fertilizer supply on the nutritive value of barley for growing pigs

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The effects of variety, soil type and nitrogen (N) fertilizer supply on the nutritive value of barley were studied with chemical analysis, *in vitro* digestibility and a growth experiment on 240 growing/finishing pigs (live-weight 25–95 kg). Twelve barley batches were formed from three varieties (two-rowed Kustaa and six-rowed Arra and Pokko) grown on mould or clay soil and fertilized with either a low or normal level of N (43 or 71 kg N/ha to mould soil and 76.5 or 110 kg N/ha to clay soil). In the growth experiment all the diets contained similar amounts of barley and soya bean meal (845/120 g/kg).

Variety Arra contained 21 g/kg more CP than did Pokko or Kustaa. The N fertilizer supply slightly increased the CP content of the barley samples (133 vs. 141 g/kg) but decreased the amount of lysine in the protein (31 vs. 29 g/160g N). Regression equation showed that CP and β-glucan were positively and neutral detergen fibre content negatively related to the *in vitro* digestibility of N in barley samples. The content of CP and the *in vitro* digestibilities of dry matter and N were highest in var. Arra. The daily gain and feed conversion ratio (FCR) of the pigs on Arra-based diets was better than that of those on Kustaa or Pokko ($P<0.05$). A higher N fertilizer supply increased slightly the CP content of barley and improved the FCR and carcass quality of the pigs ($P<0.05$). Soil type had only minor effects on the nutritive value of barley. It is concluded that, of the factors studied, variety has the greatest effect on the nutritive value of barley.

Key words: daily weight gain, dry matter, feed conversion ratio, fibre, *in vitro* digestibility, protein

Manuscript received January 1997

Introduction

Barley is the most commonly grown cereal crop in Finland and is mainly used as pig feed. It provides most of the energy and also about half of the protein in pig diets. However, the quality of barley protein is not optimal for pigs since the content of essential amino acids, lysine and threonine in particular, is very low. The main component affecting the utilization of the nutrients in barley is fibre (Taverner and Farrell 1981, Jacyno 1995). An increased fibre content lowers the energy content and can also impair the digestibility of protein and amino acids (Taverner and Farrell 1981, Bach Knudsen and Eggum 1984).

Many factors, most notably climate, soil, variety and fertilizer, can influence the grain yield, composition and nutritive value of barley. Earlier experiments revealed differences between barley varieties in digestibility and utilization by pigs (Just et al. 1983a, b). Fuller et al. (1989) found higher apparent ileal amino acid digestibilities in high protein than in low protein barley varieties. Nitrogen (N) fertilizer has increased the crude protein content of grain but lowered the lysine content in the protein (Thomke 1970, 1976). In some experiments soil type and cultivation location have also caused variations in the nutritive value of barley (Just et al. 1983b, Thomke 1972). The effects of all three factors on the nutritive value have, however, only rarely been studied in the same experiment (Just et al. 1983a, b). Knowledge of differences in the protein and energy value of barley may improve the accuracy of diet formulation and possibly also affect the amount of supplementary protein concentrates needed in pig diets.

The objective of the present experiment was to investigate the effects of variety, N fertilizer supply and soil type on the nutritive value of barley for growing pigs. The nutritive value of barley samples was assessed by their *in vitro* digestibility and the growth performance of the pigs. Some observations of the utilization of the protein by pigs related to N intake were also made.

Material and methods

Barley batches

Three barley varieties, the two-rowed variety Kustaa and the six-rowed varieties Arra and Pokko, were chosen for the experiment. They were grown on either mould or clay soil. N fertilizer was applied at two levels to both soil types: 43 or 71 kg N/ha to mould soil and 76.5 or 110 kg N/ha to clay soil, to represent a low or normal level of N supply for each soil type. Twelve barley batches were produced at the Institute of Crop and Soil Science of the Agricultural Research Centre in Jokioinen, southern Finland (60°49'N and 23°30'E), in growing season 1990.

Animals, diets and experimental procedure

A performance trial was conducted on 240 Yorkshire and Landrace pigs. The pigs, with an average weight of 25.0 kg (SE 0.33), were assigned by sex, weight and litter origin to one of 12 treatments based on the 12 barley batches. Two pigs were placed in each pen, gilts and castrates being kept apart. Each diet was tested on five pens of gilts and five pens of castrates. The treatments were arranged 3 × 2 × 2 factorially to test the effects of variety, N fertilizer supply and soil type.

Each barley (845 g/kg) was supplemented with a constant level of soya bean meal (120 g/kg) and mineral and vitamin mixture (35 g/kg). The barleys were ground in a hammer mill to pass a 3.5- mm mesh. The protein and amino acid supply of the pigs varied owing to the variation in the protein and amino acid content of the barley batches. The digestible crude protein (CP) and lysine contents in the diets

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ranged from 121 to 144 g/kg and from 5.2 to 5.5 g/kg, respectively. The protein and lysine contents in the diets were kept below the level recommended in the nutritional requirements (Salo et al. 1990) in order to maximize the amount of barley in the diets and to reveal differences in the quality of protein in barley for pigs.

The pigs were housed in partially slatted, concrete-floored pens providing free access to water. They were weighed at 2-week intervals, and their feed consumption was determined daily pen by pen. The pigs were fed twice a day on a restricted scale in relation to age (1.4 to 2.9 kg/pig/day); the daily allowance was increased by 0.2 kg/week at the beginning, and by 0.1 kg/week after the eighth experimental week. Before feeding the diets were mixed with water. The pigs were slaughtered when they reached a weight of 95 kg, and their carcass weight was recorded 24 h after slaughter. The carcass quality of the pigs was determined as described by Valaja et al. (1993).

Chemical analyses

A standard feed analysis was conducted on the barley samples and soya bean meal (AOAC 1984). The dry matter (DM) of the feeds and *in vitro* residues was determined after 24 h at 105°C. The DM content of the diets was determined at 2-week intervals. The CP content of the feeds and *in vitro* residues were analysed as 6.25 * Kjeldahl N. Ether extract (EE) was analysed after acid hydrolysis. The amino acids of the barley samples and soya bean meal were determined by gas chromatography after hydrolysis with 6 N HCl at 110°C for 20 h (Näsi and Huida 1982). The barley samples were also analysed for neutral detergent fibre (NDF) content by the method of Robertson and Van Soest (1981), for total dietary fibre content by the method of Asp et al. (1983) and for β-glucans content by the method of McClear and Glennie-Holmes (1985). *In vitro* assay was performed on the barley samples by the method of Boisen and Fernandez (1991), a two-step procedure comprising a 6-hour incubation in pepsine solution followed by an 18-hour incubation in pancreatin solution. Instead of continuous magnetic stirring, handmixing every half-hour was used during the first incubation step.

Calculations and statistical analysis

The net energy content and feed unit values of the barley samples were calculated with the Finnish energy evaluation system for pigs (Tuori et al. 1995) using constant digestibility coefficients. The data were analysed by the GLM procedure of SAS (1985). The four-way analysis of variance model used to analyse the data was:

$$Y_{ijklmn} = \mu + V_j + S_k + N_l + SE_m + VS_{jk} + VN_{jl} + SN_{kl} + e,$$

where Y_{ijklmn} is the dependent variable, μ is the overall mean, V_i is the effect of variety, S_j is the effect of soil type and N_k is the effect of N fertilizer; VS_{jk}, VN_{jl} and SN_{kl} are the interactions between the factors; and SE_m is the effect of sex. e is a normal distributed random variable. The N fertilizer supply was pooled to two levels, low and normal, for the statistical analysis as it was assumed that the total available N from soil and fertilizer was approximately the same in both soils. The difference between variety means was tested with Tukey's test. The relations between *in vitro* digestibilities and chemical constituents were calculated by linear regression equations. In all analyses the data on one pen were treated as an experimental unit.

Results

Chemical composition and *in vitro* digestibility

The CP and lysine contents of the barley batches ranged from 120 to 161 g/kg DM and from 27 to

35 g/160 g N, respectively (Table 1). Arra contained, on average, 21 g/kg more CP than did Pokko or Kustaa. The lysine content in the protein was fairly similar in all varieties, whereas the lysine content in DM was highest in Arra (4.0, 4.3 and 4.0 g/kg DM in Kustaa, Arra and Pokko, respectively). Pokko contained slightly less β-glucans than did Kustaa or Arra. The N fertilizer supply slightly increased the CP content of the barley samples (133 vs. 141 g/kg) but concomitantly decreased the amount of lysine in the protein (31 vs. 29 g/160g N).

The *in vitro* digestibility of DM and N in barley batches ranged from 65.9% to 71.9% and from 85.1% to 88.6%, respectively, the variation being higher in DM digestibility. The mean digestibility of DM in Kustaa, Arra and Pokko was 67.3%, 71.0% and 69.8%, respectively, being highest in Arra. The mean digestibility of N in Kustaa, Arra and Pokko was 87.3%, 88.1% and 85.9%, being also highest in Arra (Table 1). The following regression equation was calculated for the *in vitro* digestibility of N (Y) as dependent and the CP, NDF and β-glucan contents as independent variables:

$$Y = 86.38\ (SE\ 3.784) + 0.49\ (SE\ 0.093) \times CP - 0.40\ (SE\ 0.117) \times NDF + 0.76\ (SE\ 0.332) \times \beta\text{-glucan}\ (P<0.001;\ r^2=0.91).$$

No such equation could be calculated for the *in vitro* digestibility of DM.

Performance and carcass quality of the pigs

The performance results are presented as the main factors in Tables 2 and 3 since the interac-

Table 1. Chemical composition of barley batches (g/kg DM).

Variety	Kustaa				Arra				Pokko			
Soil type	Mould		Clay		Mould		Clay		Mould		Clay	
N supply, kg/ha	43	71	76.5	110	43	71	76.5	110	43	71	76.5	110
Dry matter, g/kg	881	884	903	858	882	886	883	885	883	885	906	894
Crude protein	134	137	122	127	148	149	147	161	127	140	120	132
Ether extract	13	18	17	18	22	18	23	25	21	22	21	22
Crude fibre	55	54	54	53	58	51	49	51	53	58	53	52
Nitrogen free extract	777	769	782	777	749	759	753	737	776	757	782	769
Ash	22	21	25	24	23	23	27	26	22	23	24	25
NDF	212	220	225	235	237	217	207	227	237	241	233	231
Total dietary fibre	212	225	234	235	244	233	226	209	226	221	224	224
β-glucans	42	43	48	43	42	44	42	43	35	38	36	37
Amino acids, g/160 g N												
Lysine	32	28	31	32	31	29	29	27	35	28	31	31
Threonine	27	28	31	31	28	30	31	29	33	33	33	32
Methionine	12	11	14	14	13	14	12	12	12	15	13	13
Histidine	19	21	31	24	20	18	22	25	24	20	27	30
Leucine	53	53	53	55	54	54	55	54	55	55	57	57
Isoleucine	25	25	28	27	25	26	26	25	25	26	27	27
Phenylalanine	41	40	41	42	37	39	40	41	40	40	39	40
Arginine	40	41	44	43	41	44	43	41	46	45	44	45
Valine	37	37	38	39	37	37	38	36	37	38	40	39
In vitro digestibility, %												
DM	68.1	68.8	65.9	66.6	70.4	70.8	71.9	71.1	69.1	70.6	68.9	70.8
N	87.7	87.9	86.7	86.8	87.6	88.1	88.6	88.0	85.7	86.5	85.1	86.5

NDF=neutral detergent fibre. V=variety, S=soil type, N=nitrogen supply.

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tions were insignificant. The pigs on diets composed of Arra grew faster than did those on diets composed of Kustaa (P<0.05); the growth rate of pigs on diets composed of Pokko was intermediate. The pigs on Arra-based diets consumed less feed as DM than did the pigs on Kustaa-based diets (P<0.05). However, the N intake of the pigs on Arra-based diets was the highest among the varieties (P<0.05). The feed conversion ratio (FCR) of the pigs on diets composed of Arra was better than that of the pigs on diets composed of Kustaa or Pokko (P<0.05). A higher N fertilizer supply of barley improved the FCR of the pigs (P<0.01), but also increased their N intake (P<0.01). The pigs fed barley grown on mould had a better FCR than did those fed barley grown on clay soil (P<0.05).

The carcass lean content of the pigs on Arra-based diets was higher than that of the pigs on Kustaa-based diets (P<0.05) and intermediate for the pigs on Pokko-based diets. The N fertilizer supply of barley increased the content of carcass lean (P<0.05) and lean in valuable parts (P<0.05).

The castrated male pigs gained weight faster (P<0.001) and had a better FCR (P<0.001) than did the gilts. In contrast, the gilts produced leaner carcasses than did the castrated males. The differences were highly significant in all carcass quality measurements.

Discussion

Chemical composition

N fertilizer supply increased the CP content of the barley samples and decreased the content of lysine in the protein. A similar trend in CP and lysine contents was observed in the experiments

Table 2. Effect of barley variety and sex on pig performance. LS means of factors are presented.

	Variety Kustaa	Arra	Pokko	SEM n=40	Signif.	Sex Gilts	Castr. males	SEM n=60	Signif.
Initial weight, kg	25.0	25.0	25.0	0.17	NS	25.0	25.1	0.13	NS
Final weight, kg	96.7	96.6	96.4	0.23	NS	96.7	96.4	0.19	NS
Final weight, corr.kg	96.7	96.6	96.4	0.10	NS	97.0	96.1	0.33	o
Carcass weight, kg	71.0	70.9	70.7	0.30	NS	71.2	70.5	0.24	o
Loss at slaughter, %	26.6	26.6	26.6	0.20	NS	26.4	26.8	0.17	*
Daily gain, g/day	820^{a}	841^{b}	827^{ab}	6.14	*	812	846	5.0	***
Days in exp.	88.1	85.8	86.8	0.76	o	89.6	84.3	0.62	***
Feed consumption,									
kg DM/animal	185.7^{a}	178.2^{b}	182.2^{ab}	1.50	**	186.0	178.0	1.22	***
Nitrogen kg/animal	5.09^{a}	5.39^{b}	4.99^{a}	0.042	***	5.28	5.04	0.034	***
FCR,									
kg DM/kg gain	2.59^{a}	2.49^{b}	2.56^{a}	0.019	***	2.58	2.51	0.015	***
FU/kg gain	2.84^{a}	2.72^{b}	2.82^{a}	0.021	***	2.84	2.75	0.017	***
MJ NE/kg gain	26.4^{a}	25.3^{b}	26.2^{a}	0.19	***	26.4	25.6	0.16	***
Back fat thickness, mm	24.5	24.0	23.9	0.34	NS	23.1	25.6	0.28	***
Lean in valuable cuts, %	79.7	80.4	80.2	0.24	o	81.1	79.1	0.20	***
Carcass lean, %	53.0^{a}	53.7^{b}	53.5^{ab}	0.20	*	54.2	52.7	0.16	***

Significance:NS=non-significant, o=P<0.10, *=P<0.05, **=P<0.01, ***=P<0.001.
SEM=standard error of means. LS=least square. FCR=feed conversion ratio. FU=feed unit. NE=net energy. MJ=mega joule.

Table 3. Effect of soil type and nitrogen fertilizer level on pig performance. LS means of factors are presented.

	Soil type		N-supply		SEM	Significance	
	Mould	Clay	Low	Normal	n=60	S	N
Initial weight,kg	25.1	25.0	25.1	25.0	0.13	NS	NS
Final weight,kg	96.7	96.3	96.2	96.9	0.19	NS	*
Final weight,corr.kg	96.8	96.3	96.3	96.8	0.33	NS	NS
Carcass weight, kg	71.0	70.7	70.6	71.1	0.24	NS	NS
Loss at slaughter, %	26.6	26.6	26.6	26.6	0.16	NS	NS
Daily gain, g/day	834	824	824	834	5.01	NS	NS
Days in exp.	86.7	87.1	86.9	87.0	0.62	NS	NS
Feed consumption,							
kg DM/animal	181.3	182.7	182.7	181.4	1.23	NS	NS
Nitrogen kg/animal	5.18	5.13	5.08	5.24	0.034	NS	**
FCR,							
kg DM/kg gain	2.53	2.56	2.57	2.52	0.015	NS	*
FU/kg gain	2.77	2.82	2.82	2.76	0.017	*	**
MJ NE/kg gain	25.7	26.2	26.3	25.7	0.16	*	**
Back fat thickness, mm	24.0	24.3	24.4	23.8	0.28	NS	NS
Lean in valuable cuts, %	80.12	80.11	79.77	80.46	0.20	NS	*
Carcass lean, %	53.33	53.51	53.13	53.71	0.16	NS	*

Significance:NS=non-significant, *=P<0.05, **=P<0.01.
S=soil type. N=nitrogen supply. SEM=standard error of means. LS=least square. FCR=feed conversion ratio. FU=feed unit. NE=net energy. MJ=mega joule.

of Bengtsson and Eggum (1969), Just et al. (1983b), Truelsen and Sorensen (1986) and Fuller et al. (1989). N fertilizer increases mainly the amount of storage proteins, hordeins, which are low in lysine, whereas the amount of albumins and globulins remains rather constant (Kirkman et al. 1982). Usually, however, the relative decline in lysine has been so slight that the total content of lysine in grain has increased (Jones et al. 1968, Thomke 1970). Arra clearly had the highest CP content of all the varieties studied. It has the highest CP content of the varieties commonly grown in Finland and is mostly used as animal feed. Kustaa and Pokko, with their lower protein contents, are also used for distilling and malting.

In vitro digestibility

The variation in the *in vitro* digestibility of DM among barley samples indicated that there may have been differences in the energy value of the barley batches. DM digestibility was highest in variety Arra. Similarly, Just et al. (1983a) found differences in *in vivo* energy and organic matter digestibility between barley varieties. Thomke and Frölich (1968), however, found no differences in energy digestibility between high- and low-protein barley varieties. The energy digestibility and energy value of barley are usually negatively related to the fibre content (Bell et al. 1983, Jacyno 1995, Darrouch et al. 1996, Beames et al. 1996) but no such relationship was established in our experiment. We did, however, find a very narrow variation in the fibre content between our barley samples.

The high *in vitro* digestibility of N in Arra also indicated its higher feeding value. The high CP content of Arra explained some of the better *in vitro* digestibility of N, a positive relationship having been found between the protein content of the grain and *in vivo* digestibility in many other studies, too (Eggum 1970, Eggum and Chris-

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tensen 1975, Taverner and Farrel 1981, Just et al. 1983b, Jacyno 1995). Fuller et al. (1989) showed that the apparent ileal digestibility of CP and most of the essential amino acids was higher in high-protein than in low-protein varieties of barley. In the experiment of Thomke and Frölich (1968), the differences in the feeding value of barley varieties were related to the CP content, a conclusion that is also in agreement with our results because Arra contained more CP than did Kustaa or Pokko.

The regression equation showed that CP, NDF and β-glucan contents explained the variation in *in vitro* digestibility of N reasonably well. The relationship between CP and β-glucan contents and protein digestibility was positive but NDF impaired protein digestibility. A similar relationship between protein digestibility and β-glucan content was found in the study of Bach Knudsen and Eggum (1984), because β-glucans are mostly located in the cell walls of the endosperm, which also has the highest protein digestibility. Likewise in the experiments of Taverner and Farrell (1981) and Hall et al. (1987), hemicellulose and NDF, of which hemicellulose is the major component, were the most closely negatively related to protein digestibility and amino acid availability.

Pig performance

Barley variety had a greater effect on the performance of the pigs than did soil type or N fertilizer. The feeding value of variety Arra, measured by *in vitro* digestibility or pig performance, was slightly better than that of the other two varieties, Kustaa and Pokko. The diets composed of Arra contained slightly more lysine than did those composed of Kustaa or Pokko (5.5 vs. 5.3 g/kg). The daily lysine intake of the pigs on Arra diets was therefore higher than that of the pigs on Kustaa or Pokko diets. The combined effects of both increased lysine intake and higher digestibility resulted in the performance responses of the pigs on Arra-based diets.

The amount of soya bean meal in our diets was higher than that used elsewhere (Thomke and Frölich 1968, Thomke 1972) and may have masked some of the difference in the protein value of the barley samples. The DM intake and FCR of the pigs fed different barley varieties followed the same pattern as *in vitro* DM and N digestibility. The feed energy values of the barley samples were calculated with the constant digestibility coefficients from feed tables (Tuori et al. 1995) and did not take into account the differences, if any, in the digestibility values. The actual differences in FCR calculated as feed units may therefore have been less than was reported.

N fertilizer supply improved the FCR and carcass quality of the pigs in our experiment. Similarly, the higher N fertilizer supply of barley has had a positive effect on the daily N retention (Just et al. 1983a, b) and performance of pigs (Thomke 1976). Thomke (1970), however, concluded that the protein quality of barley declined with higher CP content since the relative content of most of the essential amino acids decreased in the protein. This finding is in agreement with our results, which suggest that extra N is mainly excreted in urine. Soil type did not have a marked effect on the nutritive value of barley. In other experiments, in contrast, soil type or growth locality has affected the chemical compostion and nutritive value of barley (Thomke 1972, Just et al. 1983a). In the study of Thomke (1972) growth locality affected both the content and digestibility of CP in barley samples. Similarly, Just et al. (1983a) found a difference in the digestibility of CP and energy between barley samples grown on different soil types. However, the differences were not very consistent because soil type and barley variety strongly interacted in both digestibilities.

Conclusions

Variety affected the feeding value of barley more than did soil type or level of N fertilizer. The *in vitro* digestibility of DM and N and the performance of pigs were higher in variety Arra than in Kustaa or Pokko. N fertilizer increased the CP content of barley and slightly improved the FCR and carcass quality of the pigs. Soil type had only minor effects on the nutritive value of the barley studied. The *in vitro* digestibility of N was positively related to the CP and β-glucan contents, and negatively to the NDF content of barley samples. The results indicated that *in vitro* assay could be used as a preliminary tool to detect differences in the feeding value of barley samples.

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SELOSTUS

Lajikkeen, typpilannoitustason ja maalajin vaikutus ohran ruokinnalliseen arvoon lihasioilla

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Maatalouden tutkimuskeskus

Tutkimuksessa selvitettiin lajikkeen, typpilannoitustason ja maalajin vaikutuksia ohran kemialliseen koostumukseen, *in vitro* -sulavuuteen sekä ruokinnalliseen arvoon lihasioilla. Tutkimuksessa käytetyt 12 ohraerää muodostuivat kolmen ohralajikkeen (Arra, Kustaa ja Hankkijan Pokko), kahden maalajityypin (multamaa ja savi) ja typpilannoitustason (matala ja normaali molemmilla maalajeilla) yhdistelmistä. Kasvatuskokeessa oli mukana 240 lihasikaa (painoväli 25–95 kg). Jokaista ohraerää kohti oli 20 pariruokittua sikaa, jotka kasvatettiin sukupuolet erillään. Kaikki rehuseokset sisälsivät saman määrän ohraa (84,5 %) ja valkuaisrehuna soijarouhetta (12 %).

Raakavalkuais- ja β-glukaanipitoisuuden kasvu paransi ohran valkuaisen *in vitro* -sulavuutta. NDF kuitupitoisuus sen sijaan huononsi valkuaisen *in vitro* -sulavuutta. Ohran raakavalkuais-, β-glukaani- ja NDF-pitoisuudet selittivät 91 % valkuaisen *in vitro* -sulavuudessa esiintyvästä vaihtelusta.

Ohralajikkeista Arran raakavalkuaispitoisuus sekä valkuaisen ja kuiva-aineen *in vitro* -sulavuudet olivat hiukan parempia kuin Kustaan tai Hankkijan Pokon. Arra menestyi parhaiten myös kasvatuskokeessa. Arra-ohralla ruokittujen sikojen päiväkasvu ja rehuhyötysuhde olivat parempia kuin Kustaa tai Pokko lajikkeita syöneiden sikojen. Typpilannoitus nosti ohraerien raakavalkuaispitoisuutta ja paransi sikojen rehuhyötysuhdetta. Myös runsaasti typpilannoitettua ohraa syöneiden sikojen lihaprosentti oli hiukan suurempi. Maalajityypillä ei ollut suurta vaikutusta sikojen kasvutuloksiin.