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Apparent ileal amino acid digestibility and the nutritive value of the triticale cultivars Moreno and Ulrika for growing-finishing pigs

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Both digestibility and performance experiments were carried out to evaluate the nutritive value of triticale for growing-finishing pigs. In experiment 1, the apparent ileal and faecal digestibility of nutrients in barley (*Hordeum vulgare* cv. Viivi) and two triticale (*Tritico secale*) cultivars, Moreno and Ulrika, were measured using six cannulated barrows with a body weight (BW) of 82–107 kg. In experiment 2, 132 pigs were used over 25–100 kg BW to study the effects of replacing barley in a barley-soyabean meal-based diet with graded amounts of triticale cv. Moreno (25, 50, 75, or 100%) and cv. Ulrika (50 or 100%). The apparent ileal and faecal digestibilities of dry matter and organic matter were higher for both triticale cultivars than for barley ($P < 0.05$). The apparent ileal digestibilities of protein and amino acids were similar for barley and the triticales ($P > 0.05$). The apparent ileal digestibility of lysine averaged 65.6, 70.8, and 70.5% for barley and triticale cv. Moreno and Ulrika, respectively. The net energy content of triticales (11.5 MJ kg^{-1} DM) was 0.4 MJ kg^{-1} DM higher than that of barley. The replacement of barley with the triticale cultivars Moreno and Ulrika exerted a positive quadratic effect on daily weight gain and the feed conversion ratio of pigs from 50 to 100 kg and from 25 to 100 kg BW ($P < 0.01$). The best performance of the pigs was observed when 50–75% of the barley was replaced with cv. Moreno or 50% with cv. Ulrika. Carcass lean percentage decreased linearly with increasing amounts of cv. Moreno ($P < 0.01$) and decreased quadratically with increasing amounts of cv. Ulrika in the diet ($P < 0.05$). Therefore, we concluded that 50–75% of barley can be replaced by triticale in diets for growing-finishing pigs.

Key words: pigs, amino acids, cereals, triticale, digestibility, performance

Introduction

Triticale is an intergenic hybrid of wheat (*Triticum* spp.) and rye (*Secale* spp.). Selections of triticale have been found to surpass parental values for protein and lysine contents (Erickson et al. 1978). In pig feeding, replacement of barley with triticale is attractive because crops of triticale in good growing conditions can be bigger

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than those of wheat and barley (Bruckner et al. 1998, Kangas et al. 2001). In addition, the net energy content of triticale is greater than that of barley (Tuori et al. 1996).

The nutritive value of older triticale cultivars varies markedly. In addition, their effects on pig performance have been inconsistent (Farrell et al. 1983, Coffey and Gerrits 1988, Andersson and Simonsson 1992). Replacement of 50 to 100% of barley or wheat with older selections of triticale has reduced pig performance, presumably due to anti-nutritional factors and poor palatability of triticale (Farrell et al. 1983) and (or) due to unbalanced amino acid composition of the triticale-based diets (Hale et al. 1985, Coffey and Gerrits 1988). It remains unknown if new selections of triticale are improved not only in terms of disease resistance or agronomic desirability but also in terms of their nutritional value for pigs. Therefore, the objectives of this study were to evaluate the nutritive value of two new triticale cultivars in terms of the apparent ileal and faecal digestibility of nutrients (Experiment 1) and the performance of growing-finishing pigs (Experiment 2).

Material and methods

Animals and experimental procedures

Both digestibility and performance experiments were carried out to determine the nutritive value of triticale for growing-finishing pigs. The experimental procedures in both experiments were evaluated and approved by the Animal Care Committee of MTT Agrifood Research Finland.

Experiment 1 was carried out to determine the apparent ileal and faecal digestibility of nutrients in two new triticale (*Tritico secale*) cultivars, Moreno and Ulrika, and to compare it to that of barley (*Hordeum vulgare*) cultivar Viivi (Table 1). Six cannulated barrows (5 Finnish Landrace and 1 Finnish Landrace × Yorkshire) were randomly allotted to three treatments according to a balanced two-period change-over design (Gill and Magee 1976) to obtain four replicates per treatment. The pigs were cannulated at 39 kg body weight (BW) according to the steered ileo-caecal valve method (Mroz et al. 1996), and after accomplishing another digestibility trial (Partanen et al. 2001), they had reached 82 kg BW at the beginning of this experiment. Pigs were housed in 1.43 × 1.23 m metabolic pens with a slatted plastic floor and transparent plastic walls at an ambient temperature of 20–23°C. After two 14-day periods, their final BW was 107 kg.

The barley and the triticales used were harvested in 1996 and ground in a hammer mill with a 4-mm sieve (Automatic Roller Mill, Automatic ABC 900 11, Automatic Equipment MFG, Pender Nebraska, USA). The experimental diets contained barley or triticales (972.6 g kg^{-1}), a vitamin and mineral premix (16.0 g kg^{-1}), limestone (7.0 g kg^{-1}), and monocalcium phosphate (4.4 g kg^{-1}). Per kilogram of feed, the premix supplied: 2.8 g Ca, 1.0 g P, 0.6 g Mg, 4.0 g NaCl, 127 mg Fe, 28 mg Cu, 112 mg Zn, 29 mg Mn, 0.34 mg Se, 0.27 mg I, 6368 IU vitamin A, 637 IU vitamin D_3, 61 mg vitamin E, 2 mg thiamin, 6 mg riboflavin, 3 mg pyridoxine, 24 μg vitamin B_{12}, 0.2 mg biotin, 17 mg pantothenic acid, 24 mg niacin, 2 mg folic acid, and 2 mg vitamin K. Chromium mordanted straw (1.6 g kg^{-1} of feed) prepared according to Udèn et al. (1980) was used as an indigestible marker. It provided 200 mg Cr kg^{-1} of feed. Pigs were fed twice daily (0600 and 1800) a total of 80 g dry matter per kg $BW^{0.75}$ per day. Meals were offered after mixing with water (2 l kg^{-1} of feed). Pigs had *ad libitum* access to water.

There were two 14-day experimental periods. After 6 days of adaptation, faeces were collected quantitatively for 3 days following the procedure of van Kleef et al. (1994). Thereafter, ileal digesta were collected twice for 12 h (from 0600 to 1800) with three adaptation days between these collections. Digesta were collected directly into a plastic bag fixed to the cannula. The plastic bags were removed every 15 min, weighed, and frozen immediately at –20°C.

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Table 1. Chemical composition of barley and triticales investigated in Experiment 1.

Nutrient	Barley cv. Viivi	Triticale cv. Moreno	Triticale cv. Ulrika
Dry matter, g kg^{-1} feed	883	888	888
In g kg^{-1} dry matter:			
Ash	28	19	19
Crude protein	125	119	102
Ether extract	35	26	22
Crude fibre	47	23	24
Starch	557	655	673
Amino acids, g per 16 g nitrogen:			
Lysine	3.42	3.38	3.83
Methionine	1.73	1.76	1.70
Cystine	3.01	2.72	3.12
Threonine	3.42	3.17	3.29
Isoleucine	3.34	3.27	3.23
Leucine	6.93	6.58	6.75
Valine	5.46	5.10	4.97
Phenylalanine	4.78	4.80	4.69
Tyrosine	3.37	3.02	3.22
Arginine	5.14	4.99	5.28
Histidine	2.51	2.61	2.77
Proline	10.0	8.94	8.36
Glycine	4.13	4.04	4.29
Serine	3.93	4.55	4.56
Alanine	3.95	3.92	4.29
Aspartic acid	5.67	5.95	6.28
Glutamic acid	26.09	28.03	24.10
Gross energy, MJ kg^{-1} dry matter	18.4	18.1	18.3

Experiment 2 was carried out with 132 growing-finishing pigs (36 Yorkshire, 83 Finnish Landrace, and 13 crosses of these) of 25 kg initial BW. The animals were housed in 66 solid, concrete floor pens of 1.0 × 2.5 m, two gilts or two barrows per pen. Each pen was an experimental unit. Pens were randomly allotted to seven dietary treatments differing in the proportions of triticale cultivars and barley. There were 10 replicates in treatments 1 to 5 and 8 replicates in treatments 6 and 7. Treatment 1 (control) was a barley-soyabean meal-based diet. In treatments 2 to 5, barley percentages of 25, 50, 75, or 100, respectively, were replaced with triticale cv. Moreno. In treatments 6 and 7, barley percentages of 50 and 100, respectively, were replaced with triticale cv. Ulrika. The triticales were from the same batches as in Experiment 1 (Table 1), whereas the barley was not: it contained 119 g crude protein and 64 g crude fibre kg^{-1} DM. These ingredients were used after grinding in a hammer mill with a 3.5-mm sieve and were mixed with all supplements in a Gehl Mix-All 170 Equipment mixer (Gehl Company, West Bend, Wisconsin, USA). Two-phase feeding was applied, and the composition of grower and finisher diets is shown in Table 2. The grower phase was during the initial 5 weeks of the trial (to about 50 kg BW), whereas the finisher phase lasted until 100 kg BW was reached before slaughtering. Daily rations were adjusted weekly to an age-based, restricted feeding scale (in the growing phase from 1.2 to 2.0 kg feed per day and in the finishing phase from 2.2 to 3.0 kg feed per day) and given in slurry form (2 l water per kg of feed). Water was available *ad libitum* from drinking nipples. Carcass lean percentage was determined with a Hennessy grading probe GP4 (Hennessy Grading Systems, Ltd., Auckland, New Zealand). Carcass fatness was measured in terms of back and side fat thickness. The thickness of back fat was calculated as the mean of five measurements that were taken at the shoulder, in the middle, and at three locations of ham. The thickness of side fat was determined at the end of the *longissimus dorsi*. Ham was dissected into fat and meat with bones to determine the ham lean percentage.

Chemical analyses

Feed samples, freeze-dried digesta, and faecal samples were ground to pass through a 1-mm sieve. Dry matter content was determined by drying at 103°C for 16 h. The contents of ash and ether extract (after 4 M HCl hydrolysis) were determined by standard methods (AOAC 1990), crude fibre content using the method of Hirsjärvi and Andersen (1954). Starch concentration was determined after ethanol extraction according to Bach Knudsen et al. (1987). The triticales were analysed for β-glucans according to McClearly and Codd (1991) and for total, soluble, and insoluble dietary fibre as neutral sugar residues, uronic acid residues, and Klason lignin according to Theander et al. (1995). Nitrogen content was determined by the Dumas method using a Leco FP 428 nitrogen analyser (Leco Corp., St Joseph, USA). Concentrations of amino acids were assayed using a Biochrom 20 Amino acid analyser (Pharmacia Biotech, Cambridge, England) according to the official EC method (Commission Directive 98/64/EC) after acid hydrolysis (6 M HCl, 110°C, 24 h). For methionine and cystine assays, samples were oxidized with performic acid (0°C, 16 h) before acid hydrolysis. Chromium was determined by atomic absorption spectrophotometry (Williams et al. 1962). Gross energy of feeds was determined with an IKA C 400 calorimeter (Janke & Kunkel GmbH, Staufen, Germany) using benzoic acid (BCS-CRM 190, Bureau of Analysed Samples Ltd., Newham, England) as a calibration standard.

Calculations and statistical methods

Apparent ileal and faecal digestibilities were calculated from nutrient to chromium rations as follows:

Apparent ileal or faecal digestibility = $[(N/Cr)_d - (N/Cr)_f] / (N/Cr)_d$

where $(N/Cr)_d$ is the dietary ratio of nutrient to chromium and $(N/Cr)_f$ is the ratio of nutrient to chromium in ileal digesta or faeces. The net energy content of the triticale cultivars and barley was calculated from their chemical composition and the faecal digestibility coefficients according to Schiemann et al. (1972).

Statistical analyses were carried out using the GLM procedure of SAS (SAS 1998). The digestibility data were analysed using the following model (Snedecor and Cochran 1989): $Y_{ijk} = \mu + A_i + P_j + D_k + e_{ijk}$, where μ is the overall mean, A, P, and D are the effects of the i^{th} animal (i = 1,…,6), j^{th} period (j = 1, 2), and k^{th} dietary treatment (k = 1, 2, 3), respectively, and e is the error distribution with a mean of 0 and the variance σ^2. Differences between treatments were tested with the following orthogonal contrasts: 1) barley vs. triticale cultivars Moreno and Ulrika and 2) cv. Moreno vs. cv. Ulrika.

Performance data were analysed using the following model (Snedecor and Cochran 1989): $Y_{ij} = \mu + S_i + T_j + (S \times T)_{ij} + e_{ij}$, where μ is the overall mean, S, T, and S × T are the effects of the i^{th} sex (i = 1, 2), j^{th} treatment (j = 1, …,7), and their interaction, respectively, and e is the error distribution with a mean of 0 and the variance σ^2. No significant interactions between sex and treatments were found, and therefore the data were pooled over the sex in this paper. The statistical effect of replacing barley with triticale in diets was evaluated for both triticale cultivars using polynomial contrasts (linear and quadratic). The non-orthogonal contrasts were used to

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Table 2. Ingredients and calculated composition of grower and finisher diets fed to pigs in experiment 2.

	Treatment						
	1	2	3	4	5	6	7
Grower diets(1)							
Ingredients, g kg^{-1}							
Triticale Moreno	–	193.0	384.8	577.2	768.7	–	–
Triticale Ulrika	–	–	–	–	–	384.8	768.7
Barley	770.6	577.2	384.9	192.0	–	384.8	–
Soyabean meal (486 g CP kg^{-1})	200.0	200.0	200.0	200.0	200.0	200.0	200.0
Limestone	9.1	9.2	9.3	9.5	9.6	9.3	9.6
Monocalcium phosphate	4.6	4.8	5.1	5.3	5.6	5.1	5.6
Vitamin and mineral premix(2)	12.4	12.5	12.6	12.7	12.8	12.6	12.8
L-Lysine- HCl	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Calculated composition, g kg^{-1} (3)							
Crude protein	175	175	175	175	176	169	164
Ileal digestible lysine	9.2	9.2	9.2	9.3	9.3	9.2	9.2
Ileal digestible methionine + cystine	5.3	5.2	5.2	5.2	5.2	5.1	4.9
Ileal digestible threonine	4.8	4.7	4.7	4.7	4.6	4.6	4.3
Calcium	7.4	7.4	7.5	7.6	7.7	7.5	7.7
Digestible phosphorus	2.6	2.6	2.7	2.7	2.7	2.7	2.7
NE MJ kg^{-1}	9.2	9.3	9.4	9.5	9.6	9.4	9.5
Finisher diets							
Ingredients, g kg^{-1}							
Triticale Moreno	–	205.5	410.7	616.0	820.3	–	–
Triticale Ulrika	–	–	–	–	–	410.7	820.3
Barley	822.2	616.3	410.6	204.8	–	410.6	–
Soyabean meal (486 g CP kg^{-1})	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Limestone	8.5	8.6	8.7	8.8	8.9	8.7	8.9
Monocalcium phosphate	3.9	4.2	4.5	4.7	5.0	4.5	5.0
Vitamin and mineral premix(2)	12.6	12.7	12.8	13.0	13.1	12.8	13.1
L-Lysine- HCl	2.8	2.7	2.7	2.7	2.7	2.7	2.7
Calculated composition, g kg^{-1} (3)							
Crude protein	157	157	157	157	158	151	145
Ileal digestible lysine	7.7	7.7	7.7	7.7	7.8	7.7	7.7
Ileal digestible methionine + cystine	4.9	4.9	4.9	4.8	4.8	4.7	4.5
Ileal digestible threonine	4.2	4.1	4.1	4.1	4.0	3.9	3.7
Calcium	6.9	7.0	7.1	7.2	7.2	7.1	7.2
Digestible phosphorus	2.4	2.5	2.5	2.5	2.6	2.5	2.6
NE MJ kg^{-1} (3)	9.3	9.4	9.5	9.6	9.7	9.5	9.6

(1) Fed for 5 weeks from 25 kg to about 50 kg body weight.

(2) The premix contained per 10 g the following minerals and vitamins: 1.8 g Ca, 0.6 g P, 0.4 g Mg, 2.5 g NaCl, 79 mg Fe, 17 mg Cu, 70 mg Zn, 18 mg Mn, 0.21 mg Se, 0.17 mg I, 3980 IU vitamin A, 398 IU vitamin D3, 38 mg vitamin E, 1.5 mg thiamin, 3.6 mg riboflavin, 2.1 mg pyridoxine, 15 µg vitamin B12, 0.15 mg biotin, 11 mg pantothenic acid, 15 mg niacin, 1.5 mg folic acid, and 1.5 mg vitamin K.

(3) Based on chemical analysis and digestibility coefficient determination for cereals and on tabulated values for other ingredients (Tuori et al. 1996).

compare the inclusion levels of the triticale cultivars (dietary treatments 3 and 5 vs. dietary treatments 6 and 7). Residuals were checked for normality and plotted against fitted values.

Results and discussion

Chemical composition of the triticales

The triticale cultivars Moreno and Ulrika used in our study were harvested in Finland in 1996. From practice, it is known that they are suitable for cultivation and animal feeding. They are tolerant of soil acidity and extreme climates. In addition, they are relatively resistant to many of the foliar diseases of winter cereals (Bruckner et al. 1998, Kangas et al. 2001). Furthermore, triticale is sowed in autumn and keeps the soil surface covered in winter with its vegetation, thus decreasing nitrogen flow to the environment.

Both triticale cultivars had similar DM and ash contents (Table 1). The crude protein content was 119 and 102 g kg^{-1} DM for Moreno and Ulrika cultivars, respectively, and was slightly lower than that of barley. In Canadian experiments, the crude protein content of triticale cultivars varied between 100 and 155 g kg^{-1} DM (Balogun et al. 1988), whereas in Australian experiments, from 83 to 172 g kg^{-1} DM (Farrell et al. 1983). In Experiment 1, the amount of amino acids in triticale protein (g per 16 g N) was nearly the same as in barley protein, except for the contents of valine and proline, which were lower, and for aspartic acid, whose content was a little higher in the triticales than in barley. In the cultivar Ulrika, the lysine content was higher and the proline and glutamic acid contents lower than in cv. Moreno. According to Coffey and Gerrits (1988), triticale has a good balance of amino acids for pigs. However, its nutritive value may vary depending on the cultivar and soil fertility, growing location, agronomic practice, and climatic conditions (Farrell et al. 1983, Bruckner et al. 1998). The amino acid contents of cv. Moreno in our study were similar to the respective values reported by Farrell et al. (1983), Adeola et al. (1987), and Coffey and Gerrits (1988) for different cultivars. However, in the cv. Ulrika, the arginine, isoleucine, leucine, lysine, methionine, threonine, and phenylalanine contents were lower than the respective values presented by Farrell et al. (1983).

The crude fibre contents of the triticale cultivars Moreno and Ulrika were 119 and 146 g kg^{-1} DM, respectively, and those of β-glucans 2.7 and 2.5 g kg^{-1} DM, respectively. The insoluble sugar contents (g kg^{-1} DM) were similar in the cultivars Moreno and Ulrika, i.e. arabinose 23 and 23, xylose 27 and 30, mannose 9 and 9, galactose 6 and 8, and glucose 29 and 28, as well as those of soluble arabinose and xylose, i.e. 8 and 8 g kg^{-1} DM, respectively. The insoluble uronic acid content of both cultivars was 3 g kg^{-1} DM. The cultivars contained no soluble mannose, galactose, glucose, or uronic acids. However, the greatest differences between the triticale cultivars were in the contents of total dietary fibre and Klason lignin, which amounted to 119 and 146 g kg^{-1} DM and 8 and 29 g kg^{-1} DM for cv. Moreno and Ulrika, respectively. In addition, cv. Ulrika contained more insoluble dietary fibre than cv. Moreno. Crude fibre content in the triticales was half of that in barley, whereas the starch content was higher in the former. This is in agreement with the results of Batterham et al. (1989). The values for the total dietary fibre content of the triticales were closer to those for wheat (119 and 146 vs. 138 g kg^{-1} DM) than to those for rye (174 g kg^{-1} DM) or for barley (221 g kg^{-1} DM). The contents of insoluble dietary fibre components in the triticales used corresponded more to the respective values for the rye than for the wheat used by Bach Knudsen and Johansen (1995).

Digestibility of nutrients

Overall, no treatment-related health problems of the cannulated pigs were observed in Experiment

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1, except in the case of one pig, which was discarded after the first period due to reduced appetite. The remaining pigs consumed their feed allowances normally, and their weight increased 720 g per day on average.

Comparing the triticales to barley (Table 3), the apparent faecal digestibility (AFD) was higher for dry matter (P = 0.02), organic matter (P = 0.02), and gross energy (P = 0.02) in the former, whereas it was lower for ether extract (P = 0.02). Comparing cv. Moreno to cv. Ulrika, the AFD of ether extract was higher (P = 0.03) in the former. The AFD of dry matter in both cultivars was similar to the results of Balogun et al. (1988) and of Farrell et al. (1983) and somewhat lower than the values reported by Haydon and Hobs (1991). The AFD of gross energy corresponded well with the results of Leterme et al. (1991), whereas the AFD of organic matter was higher in our experiment. We found that the AFD of crude protein tended to be higher (P = 0.07) in the triticales than in barley. The AFD of crude protein in both cultivars was comparable with the results of Farrell et al. (1983), Balogun et al. (1988), and Leterme et al. (1991), whereas Haydon and Hobs (1991) reported clearly lower values.

The apparent ileal digestibility (AID) of dry matter for the triticales was approximately 10 percentage points higher than for barley (P = 0.05) (Table 3). Furthermore, the AID of organic matter was higher (P = 0.03) for the triticales than for barley. The AID of crude protein was similar (P = 0.42) for barley and the triticales (Table 3). The values for both cultivars corresponded well with the data of Balogun et al. (1988), whereas Rakowska et al. (1990) and Haydon and Hobs (1991) reported greater values. Also, the AID of amino acids in our study was not different from the results of Rakowska et al. (1990), except for lysine, arginine, and histidine. In contrast to our results, Rakowska et al. (1990) found that the AID and AFD of crude protein and amino acids were greater in triticale than in barley or rye. Haydon and Hobbs (1991) found that the AID and AFD of crude protein and amino acids in triticale and wheat were similar. The AID of amino acids in triticale tested by the latter authors was higher than in our study.

The calculated net energy values for barley, triticale cultivar Moreno, and triticale cultivar Ulrika were 11.1, 11.5, and 11.5 MJ kg^{-1} DM, respectively (Table 3). Barley contained more indispensable digestible amino acids per energy unit than the triticales. In the experiments of Andersson and Simonsson (1992), the metabolisable energy content of triticale was between that of barley and wheat (12.9 MJ ME kg^{-1} DM). The energy value of grain for pigs is most dependent on the fibre content. Poorly digestible non-starch polysaccharides comprise mainly the cell wall of cereals and lower the digestibility and the availability of nutrients. In our experiment, the crude fibre content was lower and the starch content higher in the triticales than in barley. In addition, nutrient digestibilities (AID and AFD) of the triticales were higher than those of barley. Therefore, the calculated net energy value for the triticales was 0.4 MJ kg^{-1} DM higher than for barley.

Pig performance

In Experiment 2, the pigs' weight gain ranged from 837 to 894 g per day and no feed refusals were noted, irrespective of the treatment. Incidentally, one pig was removed from treatment 4 because of unusually low weight increase. Replacement of barley with either of the triticale cultivars resulted in a positive quadratic effect (P = 0.01) on daily weight gain and feed conversion ratio during the finishing period (P = 0.01) and whole fattening (Table 4). Pigs receiving diets in which 25-100% of barley was replaced with triticale cv. Moreno and 50% with cv. Ulrika performed better than those fed no triticale (only barley). However, when barley was completely replaced with cv. Ulrika , the daily weight gain and feed conversion ratio worsened. Comparing cultivars, pigs fed cv. Moreno grew faster (P = 0.02) and consumed less feed (P = 0.05) than pigs fed cv. Ulrika.

Table 3. Apparent ileal and faecal digestibility (%) of nutrients in barley and in triticale cultivars Moreno and Ulrika fed to pigs in Experiment 1.

	Barley cv. Viivi	Triticale cv. Moreno	Triticale cv. Ulrika	SEM(1)	Probability-value: Barley vs. triticales	Probability-value: Moreno vs. Ulrika
Replicates	3	4	4			
Ileal digestibility:						
Dry matter	66.5	75.4	76.4	1.44	0.05	0.68
Ash	18.3	15.3	20.3	8.50	0.98	0.74
Organic matter	69.2	78.1	79.0	1.09	0.03	0.66
Crude protein	70.1	75.1	71.4	2.10	0.42	0.37
Ether extract	54.7	51.4	36.5	4.82	0.28	0.18
Amino acids:						
Lysine	65.6	70.8	70.5	1.58	0.17	0.92
Methionine	77.3	80.9	77.8	1.14	0.35	0.21
Cystine	79.3	80.2	79.8	1.72	0.81	0.90
Threonine	66.9	66.3	61.6	3.35	0.61	0.46
Isoleucine	72.4	76.4	72.7	1.79	0.51	0.31
Leucine	77.0	79.5	77.2	1.64	0.64	0.45
Valine	75.1	78.2	75.6	1.59	0.52	0.40
Phenylalanine	75.2	82.3	79.3	1.49	0.13	0.32
Tyrosine	72.7	72.7	69.3	2.30	0.68	0.43
Arginine	77.6	77.3	78.4	1.61	0.93	0.70
Histidine	73.9	77.7	77.0	1.39	0.23	0.77
Proline	80.7	88.1	86.5	1.44	0.09	0.53
Glycine	63.6	66.6	58.8	3.96	0.89	0.32
Serine	71.8	77.4	74.3	2.14	0.34	0.45
Alanine	65.4	69.7	68.7	1.94	0.32	0.76
Aspartic acid	64.2	70.3	67.7	2.14	0.28	0.51
Glutamic acid	85.4	90.8	88.9	0.74	0.06	0.25
Faecal digestibility:						
Dry matter	81.8	87.2	87.5	0.50	0.02	0.67
Ash	43.6	42.4	44.5	1.65	0.96	0.50
Organic matter	83.9	89.2	89.5	0.45	0.02	0.70
Crude protein	78.7	84.3	81.6	0.79	0.07	0.16
Ether extract	53.9	44.5	33.4	1.33	0.02	0.03
Crude fibre	4.2	6.0	12.0	2.45	0.32	0.25
Nitrogen free extract	96.1	97.2	97.4	0.18	0.05	0.45
Gross energy	81.0	86.6	87.0	0.56	0.02	0.73
Calculated						
Net energy, MJ kg^{-1} DM(2)	11.1	11.5	11.5			
Feed units, FU kg^{-1} DM(2)	1.19	1.24	1.23			

(1) SEM for barley is 1.29 times the value given in the table.
(2) Net energy content was calculated according to Schiemann et al. (1972). Feed unit = 9.3 MJ NE.

In the study of Andersson and Simonsson (1992), the growth of pigs fed triticale was slightly slower than pigs receiving barley. Furthermore, Adeola et al. (1987) found that daily weight gain, feed consumption, and feed efficiency declined with increasing levels of triticale in a maize-soyabean meal-based diet. Also, Farrel et al. (1983) did not recommend triticale

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Table 4. Performance of growing-finishing pigs fed graded amounts of triticale cultivars Moreno and Ulrika in substitution for barley in experiment 2.

Triticale cultivars	Moreno					Ulrika			Probability (P-value)				
									Moreno		Ulrika		Moreno vs
Substitution % for barley	0	25	50	75	100	50	100						
Treatment	1	2	3	4	5	6	7	SEM[3]	Linear	Quadratic	Linear	Quadratic	Ulrika[4]
N	10	10	10	10[1]	10	8	8						
Fattening days over from 25- to 100 kg BW	89.0	87.2	86.1	86.9	87.2	88.1	91.6	0.99	0.24	0.11	0.08	0.11	0.01
Daily weight gain, g[2]													
25–50 kg BW	730	763	766	753	760	761	724	14.4	0.28	0.22	0.77	0.09	0.18
51–100 kg BW	912	964	974	970	942	953	901	12.2	0.10	0.01	0.54	0.01	0.02
25–100 kg BW	844	888	894	887	871	880	837	9.4	0.09	0.01	0.60	0.01	0.02
Feed consumption, kg DM per pig													
25–50 kg BW	46.8	47.1	47.2	47.4	48.9	47.1	47.1	0.15	0.01	0.01	0.25	0.56	0.01
51–100 kg BW	134.0	128.3	125.3	127.8	129.2	131.0	137.4	2.85	0.26	0.07	0.44	0.22	0.02
25–100 kg BW	180.9	175.4	172.4	175.1	178.0	178.1	184.5	2.85	0.51	0.04	0.40	0.23	0.05
Feed conversion ratio, kg DM kg^{-1} gain													
25–50 kg BW	1.95	1.87	1.87	1.91	1.95	1.88	1.99	0.041	0.83	0.07	0.54	0.09	0.58
51–100 kg BW	2.64	2.48	2.43	2.45	2.56	2.51	2.63	0.040	0.11	0.01	0.83	0.02	0.08
25–100 kg BW	2.42	2.28	2.24	2.28	2.35	2.30	2.42	0.035	0.22	0.01	0.92	0.01	0.09

(1) One pig was removed from the experiment.
(2) Final weight corrected by 25% loss at slaughter.
(3) SEM in treatment 4 is 1.06 times and SEM in treatments 6 and 7 is 1.12 times the SEM presented in the table.
(4) Treatments 3 and 5 vs. treatments 6 and 7.

Table 5. Carcass characteristics of pigs fed graded amounts of triticale cultivars Moreno and Ulrika in substitution for barley in Experiment 2.

Triticale cultivars	Moreno					Ulrika			Probability (P-value)				
									Moreno		Ulrika		Moreno vs
Substitution % for barley	0	25	50	75	100	50	100						
Treatment	1	2	3	4	5	6	7	SEM[2]	Linear	Quadratic	Linear	Quadratic	Ulrika[3]
N	10	10	10	10[1]	10	8	8						
Slaughter loss, %	25.2	25.3	25.5	24.7	25.1	26.3	25.5	0.28	0.46	0.82	0.39	0.01	0.04
Cold carcass weight, kg	75.3	76.5	75.9	77.2	76.3	75.6	76.0	0.51	0.04	0.08	0.27	0.85	0.33
Back fat thickness, mm	19.4	19.5	20.4	20.7	20.8	20.4	21.0	0.77	0.11	0.85	0.16	0.84	0.87
Side fat thickness, mm	14.5	14.1	14.3	15.9	15.7	15.4	15.5	0.62	0.04	0.42	0.29	0.61	0.48
Lean in ham, %	86.5	86.6	86.3	85.9	84.8	85.5	85.1	0.45	0.01	0.16	0.05	0.57	0.59
Lean in carcass, %	59.1	59.3	58.5	58.7	58.1	57.8	58.4	0.33	0.01	0.60	0.19	0.04	0.67

[1] One pig removed from experiment.
[2] SEM in treatment 4 is 1.06 times and SEM in treatments 6 and 7 is 1.12 times the SEM presented in the table.
[3] Treatments 3 and 5 vs. treatments 6 and 7.

as the sole cereal grain in feeds for growing-finishing pigs. The authors found that an optimum growth rate could be obtained when triticale replaced 50% of wheat in the diet. The negative effect of triticale on the performance of pigs has been attributed to its anti-nutritional compounds such as β-glucan and alkyl resorcinols, to trypsin inhibitor activity, and to fungal diseases (ergot) (Farrell et al. 1983). However, the content of anti-nutritional factors in triticales seems to vary in different cultivars (Batterham et al. 1989, Rakowska et al. 1990). In our triticale cultivars Moreno and Ulrika, the content of pentosans as well as of arabinose and xylose was similar to that of wheat, and β-glucan content was lower than reported for barley by Bach Knudsen and Johansen (1995).

In our experiment, slaughter loss percentages (Table 5) were higher in pigs fed cv. Ulrika than pigs fed cv. Moreno ($P = 0.04$). The proportion of lean in ham decreased linearly ($P < 0.05$) when barley was replaced with triticales. Also, the proportion of lean in carcass decreased linearly ($P = 0.01$) when barley was replaced by cv. Moreno, and it increased quadratically ($P = 0.04$) when triticale cv. Ulrika was used. Triticale addition did not affect the thickness of back fat of pigs ($P > 0.05$). The thickness of side fat increased ($P = 0.04$) linearly in pigs receiving triticale cultivar Moreno. However, the effects of triticale cultivars on cold carcass weight, side fat thickness, back fat thickness, and lean in ham and in carcass percentages were negligible ($P > 0.05$). Brand et al. (1995) reported no differences in dressing percentage and eye muscle area as a result of replacing maize with triticale. Triticale supplementation did not affect back fat thickness and carcass lean meat content in the studies of Brendemuhl et al. (1996) and Myer et al. (1996). The authors found that higher back fat thickness in pigs fed maize instead of triticale was proportionally related to the higher energy intake. In our experiment, the differences in chemical composition between triticale and barley and between triticale cultivars may explain the effects of barley replacement on slaughter performance and carcass traits.

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In both triticales, starch content was higher and ether extract and crude fibre contents were lower than in barley. Furthermore, the amino acid content of the triticales was in general lower than that of barley. This may imply that the decrease in carcass leanness of pigs fed triticale may be attributed to a lower ratio of amino acids to net energy in triticale than in barley. A similar conclusion is presented by Hale et al. (1985) and Coffey and Gerrits (1988): lower protein and lysine and higher energy contents of triticale compared to barley increase requirement for amino acid balancing with protein concentrates or synthetic amino acids when triticale is incorporated into pig diets.

Conclusions

The chemical composition of the triticale cultivars Moreno and Ulrika and of the barley cultivar Viivi were different. In particular, the protein content of triticales was lower compared to barley. Furthermore, the apparent faecal digestibility of organic matter and the net energy content of the triticales was higher compared to barley. The nutritive value of the triticale cultivars was not identical, implying that a cultivar's nutritive value should be known before it is incorporated in pig diets. A replacement of barley with both triticales had a quadratic effect on pig performance. Pigs receiving diets in which 25–100% of barley was replaced with triticale cv. Moreno and 50% with cv. Ulrika performed better than those fed no triticale. However, when barley was completely replaced with cv. Ulrika, the performance worsened. In addition, a replacement of barley with both triticales decreased carcass quality. Therefore, we recommend that 50-75% of barley can be replaced by triticale in diets for growing-finishing pigs without negative effects. Although the apparent ileal digestibilities of amino acids were similar for barley and the triticales, the protein and amino acid contents of the triticales were lower than those of barley. Therefore, when barley is replaced with high-energy, low-protein triticale, it is desirable to balance amino acids with supplemental protein concentrates or essential amino acids.

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SELOSTUS

Ruisvehnälajikkeiden Ulrika ja Moreno rehuarvo lihasikojen ruokinnassa

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Ruisvehnälajikkeiden Ulrika ja Moreno sekä ohralajikkeen Viivi ravintoaineiden ohutsuoli- ja kokonaissulavuudet selvitettiin kuudella ohutsuolikanyloidulla leikkosialla 82–107 kg elopainoisina. Lisäksi kasvatuskokeessa 25, 50, 75 tai 100 % ohrasta korvattiin Morenolla tai 50 tai 100 % Ulrikalla. Kasvatuskokeessa oli 132 lihasikaa, joiden aloituspaino oli 25 kg. Ruisvehnien kuiva-aineen ja orgaanisen aineen näennäiset ohutsuoli- ja kokonaissulavuudet olivat parempia kuin ohran. Ohran ja ruisvehnien valkuaisen ja aminohappojen sulavuuksissa ei sen sijaan ollut eroja. Ruisvehnien kuiva-aineen nettoenergia-arvo oli 0,4 MJ/kg suurempi kuin ohran, mutta aminohappopitoisuuden suhde energiapitoisuuteen pienempi kuin ohran. Sikojen päiväkasvu ja rehuhyötysuhde paranivat loppukasvatuskaudella korvattaessa ohraa ruisvehnällä. Korvattaessa ohraa yli 75 % Morenolla tai yli 50 % Ulrikalla, kasvu ja rehuhyötysuhde alkoivat kuitenkin huonontua. Ruhon lihaprosentti laski korvattaessa ohraa Morenolla ja Ulrikalla. Tämän vuoksi ruisvehnää voidaan käyttää 50–75 % lihasikojen rehun ohrasta.