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Tolerance of broiler chickens to dietary rye soluble arabinoxylans

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ABSTRACT

Four growth experiments were conducted on 304 one-week old broiler cockerels to determine the response of chickens to the increasing levels of rye and its soluble arabinoxylans (SAX) in the diet. Substituting more than 10% of maize with rye depressed body weight gain and substituting more than 20% decreased the feed conversion ratio in chickens. However, if the lower AME value of rye was compensated for by sunflower oil supplementation the tolerated level of rye in a maize diet increased about threefold, corresponding to about 0.9% of dietary rye SAX. Similar results were obtained when rye SAX preparation was added to a wheat diet. Reducing the dietary SAX content to about 1.4% in the diets with rye hybrids, which were selected for better feeding quality, resulted in a noticeable improvement of chick performance. The nutrition parameters obtained in chickens fed the diets based on these hybrids were not significantly different as compared with wheat diet and significantly better as compared with population rye diet containing about 2.07% dietary SAX.

KEY WORDS: dietary soluble arabinoxylans, rye, tolerance, broiler chickens

INTRODUCTION

Rye is a cereal of light sandy soils which prevail in Poland and about 3.2 million tons of this grain is used annually for feeding purposes. However, it is well known that despite the better amino acid composition of protein the feeding value of rye is inferior as compared to other cereals, especially when fed to young chickens. Soluble arabinoxylans have been recognised as the main causative factor respon-

sible for the negative effects of rye on chicken performance (Antoniou et al., 1981; Fengler and Marquardt, 1988). These negative effects of SAX on chick performance is mostly related to the viscous properties of rye arabinoxylans. Therefore, estimation of an acceptable proportion of rye and corresponding rye SAX content in chicken diets is important.

The aim of the present study was to determine the tolerated level of rye in the diet for broiler chickens both without (Experiment 1) and with additional plant oil supplement compensating for the lower AME value of rye (Experiment 2), the effect of level of SAX preparation isolated from rye milling fraction (Experiment 3) and the nutritional value of rye hybrids selected for low viscosity and SAX content (Experiment 4).

MATERIAL AND METHODS

Diets

The composition of diets used in Experiments 1, 2 and 3 is presented in Table 1. In the diets used in Experiment 1 and 2 maize (blend sample) was replaced by the rye var. Motto in 10% increments but the diets used in Experiment 2 were supplemented with additional amounts of sunflower oil to compensate for the lower AME value of rye. The diets used in Experiment 3 contained the wheat var. Almari (diets 1-8) or the rye var. Motto (diet 9) and diet 1 was supplemented with an enzyme preparation (Bio-feed Plus). Increasing amounts of rye SAX preparation were added to wheat diets 3-8. The rye SAX preparation was obtained from the fine fraction of rye bran by large-scale extraction of water soluble arabinoxylans carried out in a fermentation chamber with partial enzymatic hydrolysis of starch and protein according to Annison et al. (1992).

In Experiment 4, designed for evaluation of the nutritive value of rye hybrids selected for low water extract viscosity and low SAX content, the diets consisted of 75% (series I) or 70% (series II) of tested grain, soyabean protein concentrate (up to 21.0 % of protein in the diet), soyabean oil (3%), and were supplemented with vitamins, minerals and methionine. Wheat based diet was used as a control. All cereal grains were grown in Radzików in 1995 and 1996 harvest seasons.

The diets were formulated to meet the requirements of broiler chickens and were prepared in a mash form.

Experimental

The growth experiments were performed on 304 one week-old male broiler chickens kept in individual cages in a room with constant lighting. The design of

TABLE 1

Composition of the diets in Experiments 1-3

Ingredient	Diets, %								
	1	2	3	4	5	6	7	8	9
Experiment 1									
Maize	70	60	50	40	30	20	10	0	
Rye	0	10	20	30	40	50	60	70	
Other ingredients[1]	30	30	30	30	30	30	30	30	
Calculated values									
Protein, %	20.99	21.01	20.99	21.01	20.99	20.99	21.03	21.02	
ME, kcal/kg	3346	3274	3202	3126	3054	2982	2909	2837	
Experiment 2									
Maize	70	60	50	40	30	20		0	
Rye	0	10	20	30	40	50		70	
Sunflower oil	1	2	3	4	4	4		4	
Other ingredients[1]	29	28	27	26	26	26		26	
Calculated values									
Protein, %	21.01	21.01	21.00	21.00	21.00	20.99		21.00	
ME, kcal/kg	3279	3269	3248	3228	3155	3082		2940	
Experiment 3									
Wheat	702	70	70	70	70	70	70	70	0
Rye	0	0	0	0	0	0	0	0	70
SAX preparation	0	0	0.69	1.38	2.07	2.76	4.14	5.52	0
Other ingredients[1]	30	30	29.31	28.62	27.93	27.24	25.86	24.48	30
Calculated values									
Protein, %	21.02	21.02	21.02	21.02	21.02	21.02	21.02	21.02	21.00
ME, kcal/kg	3210	3210	3205	3201	3196	3191	3181	3171	2926

[1] other ingredients (% of diet) were: soyabean protein concentrate to adjust dietary protein to 21%; and sunflower oil: Exp.1 – 2; Exp. 3 – 2.5; vitamins; minerals; dicalcium phosphate; calcium carbonate; DL-methionine to cover the requirements of the chickens; and maize starch up to 100

[2] containing 0.5 g/kg Bio-feed plus enzyme (Novo Nordisk)

the experiments was factorial (diets) and one bird was treated as a replicate. In Experiment 1 each diet was fed to nine birds and in the other three experiments to eight birds for 7 days. Birds had free access to feed and water. In the 4-7 days of the experiment excreta samples were collected quantitatively over 72 h, lyophilised and analysed for dry matter to calculate dry matter retention (DMR). The following growth performance values were determined: feed intake, body weight gain (BWG) and feed conversion ratio (FCR).

Analytical and statistical methods

Total soluble polysaccharides and their constituent sugars were determined as aldononitrile acetates by gas liquid chromatography according to McGinnis (1982) after hydrolysis with 1 M fluoroacetic acid (TFA) at 125°C for 1 h. Protein (Nx6.25) was determined by the Kjeldahl method using a Tecator semiautoanalyzer, dry matter and ash contents by standard AOAC methods (1990). All analyses were performed either in duplicate or triplicate and expressed on a dry matter basis.

The data were subjected to one-way analysis of variance and Duncan's multiple range test. The minimum level of statistical significance was $P \leq 0.05$.

RESULTS AND DISCUSSION

The contents of SAX, protein and ash in cereal components of the diets and in the SAX preparation are shown in Table 2. Maize contained only trace amounts of soluble arabinoxylans while rye had twice as much as wheat. The rye SAX preparation contained about 6 times more these soluble polysaccharides than rye. The ratios of soluble arabinose to soluble xylose in rye and the SAX preparation were almost the same (0.67 and 0.68, respectively) indicating a similar structure of both arabinoxylans.

TABELA 2

Contents of soluble arabinoxylans and total polysaccharides, protein and ash in cereal components of the diets, % DM

Item	Maize	Rye	Wheat	SAX preparation
Soluble polysaccharides				
arabinoxylans	0.05 ± 0.00	3.10 ± 0.19	1.55 ± 0.01	19.73 ± 0.39
total	0.73 ±0.01	4.51 ± 0.21	2.61 ± 0.09	71.39 ± 1.14[2]
SA/SX ratio	0.75	0.67	0.74	0.68
Protein	10.29/12.45[1]	10.96	16.04	16.09
Ash	1.70	1.72	1.69	7.63
DM	90.39	91.78	88.82	91.69

[1] maize used in Experiments 1 and 2, respectively

[2] glucose constituted 48.3%, mannose 1.28 and galactose 2.09% of total polysaccharide contents. High glucose content in this SAX preparation is probably of dextrin origin, the remains of incomplete hydrolysis of starch by term-stable α-amylase (Termamyl 120 L, Novo Nordisk) applied

The level of rye at a 20% concentration in the maize diet, without compensating for its lower energy value, significantly ($P \leq 0.0001$) depressed growth, while at a 30% concentration worsened both FCR and DMR in broiler chickens (Table 3). Similar depressions in growth performance of chickens fed rye diet have been reported by other authors (Moran et al., 1970; Patel and McGinnis., 1976; Friesen

TABLE 3
The effect of increasing level of rye in maize diet on growth performance of broiler chickens (Experiment 1)

Maize – Rye % in the diet	Diet intake g/7 days	BWG g/7 days	FCR g feed/g BWG	DMR %
70 – 0	223[a]	170.4[a]	1.31[e]	78.29[a]
60 – 10	213[a]	158.9[a]	1.34[e]	77.49[ab]
50 – 20	201[ab]	136.6[b]	1.48[de]	75.48[bc]
40 – 30	184[bc]	118.7[bc]	1.58[cd]	73.42[cd]
30 – 40	170[cd]	100.9[cd]	1.75[bc]	71.99[de]
20 – 50	154[de]	87.0[d]	1.82[b]	70.95[de]
10 – 60	130[e]	65.5[e]	2.10[a]	69.63[ef]
0 – 70	133[e]	60.6[e]	2.25[a]	67.31[f]
Pooled SEM	8.9	7.6	0.06	0.84

means within a column with no common superscripts differ significantly at P≤0.05

et al., 1991). Thus the tolerated proportion of rye in the maize diet amounted to 10%, which corresponded to 0.3% of dietary SAX (Figure 1). Each further 10% increase of rye reduced BWG by about 17.5 g and increased FCR by 0.14. However, when the diets with increasing amounts of rye were additionally supplemented with unsaturated fat, the tolerated dose of dietary SAX was elevated about threefold to 0.9% and corresponded to 30% rye in the diet (Figure 2). The BWG of chickens fed a diet containing 30% rye was found to be 170 g vs 172 g on a maize diet while FCR values were 1.36 and 1.29, respectively (P≥0.05). The results of these two experiments confirmed the major negative effect of SAX on dietary

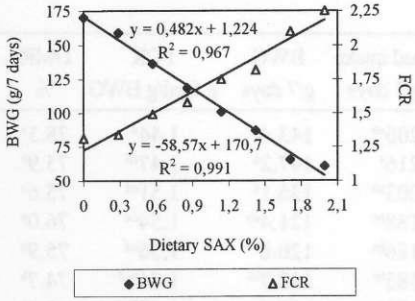

Figure 1. Relationship between dietary soluble arabinoxylan (SAX) content and weight gain (BWG) and feed conversion ratio (FCR) of broiler chickens fed diets containing an increasing level of rye in maize diet (Experiment 1)

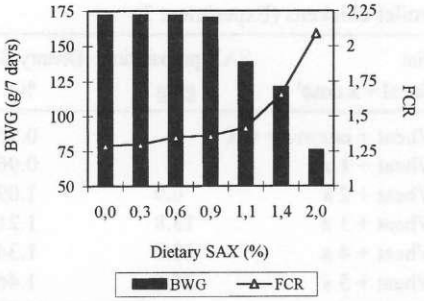

Figure 2. Effect of dietary soluble arabinoxylans (SAX) on weight gain (BWG) and feed conversion ratio (FCR) of broiler chickens fed diets containing an increasing level of rye in maize diet additionally supplemented with oil (LSD values for BWG = 18.4 and for FCR = 0.08 at P≤0.05, Experiment 2)

energy utilization and indicate the possibility of preventing this adverse effect by unsaturated fat supplementation. Earlier it has been shown that the performance of chickens fed a rye diet is markedly affected by the level of dietary fat (Antoniou et al., 1980) and that the fats rich in unsaturated fatty acids are better utilized by chickens than tallow or lard which are rich in saturated fatty acids (Antoniou et al., 1980; Choct et al., 1996; Smulikowska and Mieczkowska, 1996). Digestibility of unsaturated fatty acids was found to be very low (from 38 to 45%) in chickens fed a diet containing an equivalent of 4% soluble wheat pentosans (Choct et al., 1996). Conceivably, in the present study, increasing the amount of added oil improved chicken performance as compared with those fed diets without such supplement (Figures 1 and 2). The beneficial effect of plant oil supplementation in a rye diet on growth performance and metabolizable energy values in broilers was also reported by Rutkowski (1996).

The addition of rye SAX preparation to the wheat diet increased the dietary SAX concentration to a level corresponding with that in the rye diet. Wheat SAX constituted about half of the total dietary SAX in the diet with the highest dose of added rye SAX preparation. As shown in Table 4, neither BWG nor FCR were affected by the supplementation of the wheat diet with a commercial arabinoxylan degrading enzyme in the applied short-term experiment, with some slight improvement of DMR. Therefore, dietary wheat SAX could be considered as "inert" in this short-term experiment and the nutritional effect of dietary SAX on chicken performance could generally be attributed to rye SAX.

TABLE 4

Effect of increasing level of added rye SAX preparation in wheat based diet on performance of broiler chickens (Experiment 3)

Diet	SAX preparation	Dietary SAX	Feed intake	BWG	FCR	DMR
Cereal + x dose[1]	g/kg	%	g/7 days	g/7 days	g feed/g BWG	%
Wheat + enzyme + OX	0	0.96	206^{ab}	143.4^{a}	1.44^{d}	78.3^{a}
Wheat + 1 x	0	0.96	216^{a}	147.2^{a}	1.47^{cd}	75.9^{b}
Wheat + 2 x	6.9	1.09	203^{ab}	135.1^{a}	1.51^{cd}	75.6^{b}
Wheat + 3 x	13.8	1.21	188^{bc}	121.4^{ab}	1.54^{cd}	76.0^{b}
Wheat + 4 x	20.7	1.34	186^{bc}	120.6^{bc}	1.56^{cd}	75.9^{b}
Wheat + 5 x	27.6	1.46	185^{bc}	112.7^{bc}	1.64^{bcd}	74.7^{b}
Wheat + 6 x	41.4	1.71	172^{c}	105.4^{c}	1.68^{bc}	75.4^{b}
Wheat + 8 x	55.2	1.96	174^{c}	100.8^{c}	1.77^{b}	74.1^{b}
Rye	0	2.00	145^{d}	75.70^{d}	2.09^{a}	69.4^{c}
Pooled SEM			9.02	7.21	0.069	0.75

[1] one dose of rye SAX preparation equals 6.9 g/kg of the diet, equivalent of 0.125% of SAX (for details see Table 1)

means within a column with no common superscripts differ significantly at $P \leq 0.05$

The addition of increasing amounts of rye SAX to the wheat-based diet significantly ($P \leq 0.0001$) affected growth performance of broiler chickens but not ($P \geq 0.05$) DMR. Both feed intake and weight gain decreased ($P \leq 0.05$) when the equivalent of 0.25% rye SAX was added, which corresponded with the results of Experiment 1, while poorer ($P \leq 0.05$) FCR was attained at a concentration as high as 1% rye SAX in the wheat diet. Although in the diet with the highest dose of added rye SAX the concentration of dietary SAX was the same as in the rye-based diet, all the nutrition parameters were significantly better than in chickens fed with the rye diet. Since the antinutritive properties of wheat SAX have well been established (Choct and Annison, 1990, 1992a,b; Choct et al., 1992), the results of this study may imply that their antinutritive activities are not manifested as severely as those of rye SAX. This may be caused by the differences in chemical structure between wheat and rye SAX (Fincher and Stone, 1986).

TABLE 5

Effect of dietary soluble arabinoxylans (SAX) concentration in the diets containing grain of selected rye hybrids on chicken performance (Experiment 4)

Rye hybrid	Dietary SAX %	Feed intake g/7 days	BWG g/7 days	FCR g feed/gBWG
I serie (1995)[1]				
Wheat – Almari	0.62	182	116.1	1.58
Rye				
(2035x804) x 705	1.28	180*	96.4*	1.96
(2686x2591) x 705	1.51	158*	85.9	1.92*
(1993x2059) x 543	1.52	151	89.4	1.73*
(1993x4475) x 2803	1.53	155*	84.4	1.89*
(2040x4475) x 2803	1.66	160*	88.2	1.91*
Motto	2.04	138	68.7	2.08
LSD, at $P \leq 0.05$		29.7	24.3	0.36
II serie (1996)[2]				
Wheat – Almari	0.96	145.6	95.3	1.54
Rye				
(1993x2680) x 3332 -RAH 596	1.10	127.9*	78.9	1.65*
(1993x51334) x 3332	1.17	142.4*	80.7*	1.79
(1964x2035) x 3332	1.28	140.1*	82.3*	1.73*
(910x5491) x 3332	1.41	143.4*	87.4*	1.64*
(2035x2130) x 3332	1.46	124.9	76.2	1.66*
Motto	2.10	119.0	58.9	2.10
LSD, at $P \leq 0.05$		20.4	16.0	0.22

rye hybrids of low SAX content: [1]out of 24 hybrids; [2]out of 31 hybrids tested biologically on broiler chickens

* values do not differ significantly from that of wheat

The selection of rye hybrids with reduced water extract viscosity and an associated decreased SAX content in grain, which is one of the breeding programs conducted in the Institute of Plant Breeding and Acclimatisation (Madej et al., 1994; Boros et al., 1998), leads to a dietary SAX reduction by 20-48% in comparison with population rye var. Motto (Table 5). Consequently, as expected, a significant improvement of chicken performance was achieved with rye hybrids of lower SAX content. In 10 hybrids out of 55 tested (Boros et al., 1998) obtained nutrition parameters, BWG or FCR, were insignificantly ($P \geq 0.05$) different than those obtained on the control wheat diet. In addition in 6 hybrids the BWG and FCR of chickens fed diets containing these grain did not differ significantly ($P \leq 0.05$) than those obtained in chickens fed diet with population rye. This would point to the possibility of at least doubling the proportion of rye in chicken diet.

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STRESZCZENIE

Tolerancja kurcząt brojlerów na zawartość w diecie rozpuszczalnych arabinoksylanów żyta

Na 304 siedmiodniowych kogutkach brojlerach przeprowadzono 4 doświadczenia, w których określono wpływ poziomu żyta i rozpuszczalnych arabinoksylanów (SAX) na spożycie paszy, przyrosty i wykorzystanie paszy. Kurczęta tolerowały 10% żyta (0,3% SAX) w diecie kukurydzianej nieuzupełnionej tłuszczem, natomiast dodatek do diety oleju słonecznikowego, wyrównujący niższą wartość energetyczną żyta, spowodował trzykrotne zwiększenie tolerowanej ilości SAX. Dodatek wzrastającej ilości preparatu SAX, otrzymanego z otrąb żytnich, powodował proporcjonalne zmniejszenie przyrostów i wykorzystania paszy.

Ocena wartości pokarmowej mieszańców żyta selekcjonowanych w kierunku obniżonej zawartości SAX wykazała, że większość z nich nie wpływa ujemnie na oznaczone wskaźniki w porównaniu z kontrolną dietą.