

# Interactions between dietary fat type and exogenous enzyme supplementation of broiler diets based on maize, wheat, triticale or barley

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## ABSTRACT

Four growth experiments and a balance study were carried out to examine the effects of different fat types (beef tallow or soyabean oil) in broiler diets based on wheat, triticale, maize or barley in response to feed enzyme supplementation. Performance parameters were recorded over 35 days. Viscosity in the ileal digesta, apparent digestibility of fat and protein at the terminal ileum were measured at day 21 of age. In addition, fat digestibility was measured at the faecal level along with apparent metabolizable energy value (AME<sub>N</sub>) and apparent net protein utilization (NPU<sub>N</sub>).

It was found that enzyme addition to all diets improved feed to gain ratio significantly. This was most visible in triticale- and barley-based diets supplemented with tallow than in the soyabean oil-containing counterparts until 21 days of age. Effects became smaller or disappeared when the whole fattening period was considered. Significantly better performance of broilers fed soyabean oil compared with tallow-containing diets was observed over the whole fattening period.

Intestinal viscosity was significantly reduced by enzyme addition to all diets. Furthermore, significantly higher intestinal viscosity was found in tallow-fed birds (triticale-, barley- or maize-based diets). Apparent protein digestibility at the terminal ileum was not affected by fat type but was

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improved by enzyme supplementation in wheat- and barley-based diets. Fat digestibility at both the ileal and faecal levels was significantly higher in birds fed the soyabean oil-containing diets and was significantly improved after enzyme supplementation. The enzyme effect on fat digestibility was more pronounced at the faecal level and was positively correlated to  $AME_N$  and  $NPU_s$ .

**KEY WORDS:** broiler, fat, maize, wheat, triticale, barley, exogenous enzymes

## INTRODUCTION

The supplementation of broiler diets with exogenous enzyme preparations containing hydrolases capable of partial hydrolysis of cereal non-starch-polysaccharides (NSP) is currently a common practice. Enzyme activities of such preparations are matched to the substrate composition of the respective cereals or diets. Diets containing rye, wheat or triticale are supplemented with predominantly xylanase-containing enzyme preparations, whereas predominantly  $\beta$ -glucanase-containing preparations are added to barley-based diets. The mode of action of added enzymes was recently reviewed by Simon (1998).

However, from a practical point of view, it was shown by Jeroch et al. (1995) that enzyme effects might vary considerably among different experiments. Taking FCR as a criterion (unsupplemented control = 100), ranges in enzyme effects from 94 to 100%, 93 to 100%, 92 to 99% and 97.5 to 99% were reported for diets based on wheat, barley, rye, and triticale, respectively.

It was recognized by several investigators that dietary fat type is one factor contributing to the reported variation in enzyme effects (Smulikowska and Mieczkowska, 1996; Dänicke et al., 1997a,b; Langhout et al., 1997). Generally, it is shown that enzyme effects are much greater if rye- or wheat-based diets contained dietary fat of animal origin instead of plant oils. Improvements in performance were explained by marked increases in fat digestibility. The physiological basis of such effects was reviewed by Smulikowska (1998).

The aim of the present study was to examine whether such interactions might occur in broilers fed unsupplemented or enzyme-supplemented diets based on wheat, triticale, barley or even maize and containing either beef tallow or soyabean oil.

## MATERIAL AND METHODS

### *Experimental design*

Each of the four cereals (wheat, triticale, maize, and barley) was combined with either 10% soyabean oil or 10% beef tallow and was prepared either with or without an enzyme preparation. Wheat-, triticale- and maize-based diets were sup-

plemented with Avizyme 1300 and the barley-based diets with Avizyme 1100. The inclusion rate of each enzyme preparation was 1 g/kg.

Avizyme 1300 (Finnfeeds Int., Marlborough, UK) obtained from *Trichoderma longibrachiatum* contained 3000 IU/g xylanase, 40 IU  $\beta$ -glucanase and 14 IU cellulase activity per g, measured at pH 6.0 on the basis of reducing substance formation. Avizyme 1100 (Finnfeeds Int., Marlborough, UK) contained 300 IU  $\beta$ -glucanase (pH 5.3), 250 IU xylanase (pH 5.3) and 800 IU protease (pH 7.0). Furthermore, each diet was supplemented with 0.5% of  $\text{TiO}_2$  as an indigestible marker. A total of 16 diets resulted from this experimental design (Table 1).

### *Digestibility measurements*

Birds used in the experiment were male broilers of the Lohmann meat strain grown on a broiler starter diet (230 g/kg crude protein, 13.2 MJ  $\text{AME}_N/\text{kg}$ ) in a commercial cage battery until day 10 of age. At this age, cockerels were divided into 16 groups of 20 birds, each group having an equal mean body weight. Birds were placed into metabolic cages (four per cage) and given experimental diets containing  $\text{TiO}_2$  as an inert marker. Water and diets were provided *ad libitum*. Excreta samples were taken per cage (5 replications per group) from day 19 to day 21 of age and kept frozen before being further processed. At day 21 of age the broilers were killed by decapitation after cervical dislocation, the intestines were quickly excised and the ileum was ligated and divided into the terminal ileum, corresponding to the length of the caeca, and the proximal ileum, from Meckel's diverticulum to the start of the terminal ileum. Digesta from the proximal and terminal ileum of six or seven birds of each group were pooled separately (3 replications per group) and thoroughly mixed. Pooled samples from the proximal ileum were kept on ice before being centrifuged for viscosity measurements. Digesta from the terminal ileum was frozen immediately in liquid nitrogen and kept frozen before being used for determination of digestibility.

### *Growth experiment*

A total of four growth experiments was carried out. Each of the four experimental diets relating to one cereal type was fed to 90 male broiler chickens of the Lohmann Meat strain starting on day one of age and ending on day 35 of age within each experiment. The birds were randomly allocated to the experimental groups and divided into nine replications per group with 10 chickens in each. Broilers were kept in three-floor battery cages. The lighting and heating program was adjusted according to the recommendations of the breeder. Feed and water were offered *ad libitum*. Diets were provided in a pelleted form. Liveweight and feed consumption were recorded on day 21 of age and at the end of the experiment.

TABLE 1

Composition of the experimental diets, %

Ingredients	Cereal type							
	barley		wheat		maize		triticale	
Barley	62.95	62.95	-	-	-	-	-	-
Wheat	-	-	56.00	56.00	-	-	-	-
Maize	-	-	-	-	50.00	50.00	-	-
Triticale	-	-	-	-	-	-	57.00	57.00
Soya protein isolate	16.44	16.44	17.50	17.50	19.40	19.40	17.40	17.40
DL-methionine	0.46	0.46	0.38	0.38	0.42	0.42	0.40	0.40
L-lysine HCl	0.24	0.24	0.24	0.24	0.18	0.18	0.20	0.20
DL-threonine	0.29	0.29	0.29	0.29	0.27	0.27	0.31	0.31
Soya oil	10.00	-	10.00	-	10.00	-	10.00	-
Cellulose	5.00	-	5.00	5.00	5.00	5.00	5.00	4.89
Tallow	-	10.00	-	10.00	-	10.00	-	10.00
Maize starch	-	5.00	-	5.00	-	5.00	-	5.00
Sand	-	-	5.79	0.79	9.80	4.80	4.89	-
Limestone	0.63	0.63	0.50	0.50	0.38	0.38	0.40	0.40
Dicalcium phosphate	2.71	2.71	2.95	2.95	3.20	3.20	3.05	3.05
NaCl	0.28	0.28	0.35	0.35	0.35	0.35	0.35	0.35
Premix <sup>1</sup>	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enzyme	- <sup>+</sup> 2	- <sup>+</sup> 2	- <sup>+</sup> 3	- <sup>+</sup> 3	- <sup>+</sup> 3	- <sup>+</sup> 3	- <sup>+</sup> 3	- <sup>+</sup> 3
Calculated composition, %								
AME <sub>N</sub> (MJ/kg)					13.30			
Crude protein					23.00			
Lys					1.25			
Met+Cys					0.96			
Thr					1.00			
Trp					0.27			
Ca					0.90			
P					0.70			

<sup>1</sup> vitamin-mineral premix provided per kg of diet:

vitamin A, 12000 IU; vitamin D<sub>3</sub>, 3000 IU; I, 0.6; vitamin E, 42 mg; vitamin B<sub>1</sub>, 2.1 mg; vitamin B<sub>2</sub>, 6.6 mg; vitamin B<sub>6</sub>, 4.1 mg; vitamin B<sub>12</sub>, 20.7 mg; pantothenic acid, 15 mg; nicotinic acid, 36 mg; folic acid, 1 mg; biotin, 102 µg; choline chloride, 700 mg; Fe, 60 mg; Cu, 5 mg; Zn, 51.4 mg; Mn, 60.8 mg; Se, 0.2 mg; ethoxyquin, 120 mg; Zn-bacitracin, 50 mg

<sup>2</sup> Avizyme 1100 (Finnfeeds Int.), 1 g/kg<sup>3</sup> Avizyme 1300 (Finnfeeds Int.), 1 g/kg

### *Carcass characteristics measurements*

One bird of each replication representing the respective mean liveweight was used for determination of the slaughter yields on day 35 of age. Birds were weighed and killed by cutting the jugular vein after electric stunning. Bleeding was fol-

lowed by scalding in a water bath at 57°C for 2 min. Carcasses were then defeathered using a rotary drum picker. The head and feet were removed. Carcasses were cooled for 20 h at 4°C and dissected. Weights of breast skin, total breast meat (without skin), complete right leg, livers and sum of abdominal and visceral fat were individually recorded. The latter parts were excluded in calculation of dressing percentage. All parts were expressed as percentage of liveweight.

#### *Sample preparation*

The pooled and homogenized digesta samples of proximal ileum were centrifuged at 15000 x g for 15 min. The supernatant was then placed on ice until viscosity measurement.

Digesta of terminal ileum and excreta samples were freeze-dried. The samples (including feed samples) were ground in a freezer mill (Model 6700-230, SPEX CertiPrep Inc., NJ, USA) under liquid nitrogen in order to produce a fine powder and to minimize nutrient losses.

#### *Analysis*

Viscosity of digesta supernatant was measured using a Brookfield viscometer (model DV-II+LV) at 40°C. Nutrients of diets, digesta and excreta samples were analyzed according to the methods of VDLUFA (Naumann and Bassler, 1993). Cereal samples were additionally analyzed for starch (polarimetric) and Van Soest-fibre according to the methods of VDLUFA (Naumann and Bassler, 1993). Pentosans of cereals were determined as described by Dusel et al. (1997) and  $\beta$ -glucans were analyzed by the McCleary-method using an analytical kit (Megazyme, Ireland). Gross energy of diets and freeze-dried excreta was measured using an adiabatic bomb calorimeter (model C 4000, Heitersheim, Germany).  $\text{TiO}_2$  in feed, digesta and excreta was analyzed according to Brandt and Allam (1987).

#### *Calculations and statistical analysis*

Apparent digestibility at the terminal ileum and at the faecal level was calculated. Since urinary fat excretion is negligible in broilers, the term digestibility is used for faecal fat as well.

Data were analyzed by two-way ANOVA with fat type and enzyme supplementation as main effects. Significant differences between the means were evaluated by Tukey's HSD test for unequal n. All analyses were carried out using the Statistica program for the Windows™ operating system (StatSoft, Inc., 1994).

## RESULTS

*Chemical composition of cereals*

With respect to cell wall constituents that are the substrates for the added xylanases and  $\beta$ -glucanases, barley contained both the highest total pentosan and  $\beta$ -glucan concentrations (9.4 and 3.9%, respectively). Wheat and triticale were comparable both in pentosan (6.1 and 6.2%, respectively) and in  $\beta$ -glucan concentration (0.6 and 0.7%, respectively) whereas maize contained approximately the half of the concentration of both constituents as that found in wheat and triticale. The share of soluble pentosans amounted approximately to 22% in wheat and triticale and 18% of the total amount in barley and maize. Soluble  $\beta$ -glucans in wheat, triticale and maize were analytically not detectable. Their share in barley was as high as 48% of total amount (Table 2).

TABLE 2

Chemical composition of the cereals, g/kg dry matter

	Barley 'Grete'	Wheat 'Mikon'	Maize 'Mona'	Triticale 'no name'
Starch	500.3	650.8	684.9	655.8
NDF	184.8	109.8	91.2	105.1
ADF	78.2	46.5	29.3	38.5
ADL	12.1	11.0	4.8	10.4
Hemicellulose	106.6	63.3	61.9	66.6
Cellulose	66.1	35.5	24.5	28.1
Total pentosans	93.6	62.0	34.0	61.3
Soluble pentosans	16.9	13.7	6.1	13.6
Total $\beta$ -glucans	39.1	6.1	0.9	7.1
Soluble $\beta$ -glucans	18.9	ND	ND	ND
Crude protein (N* 6.25)	127.9	120.4	107.5	121.1
Ether extract	28.1	14.8	50.6	24.6

*Digestibility measurements*

Apparent digestibility of crude protein (PD), crude fat (FD) and viscosity of the ileal digesta in the proximal ileum is shown in Table 3. Fat in tallow-containing diets was significantly less digestible than fat in soyabean oil-containing diets ( $P < 0.001$ , for all cereals). A significant improvement in FD after enzyme supplementation and significant interactions between fat type and enzyme supplementa-

TABLE 3

Ileal viscosity (Vis, mPas), apparent fat digestibility (FD, %) and apparent protein digestibility (PD, %) at the terminal ileum of male broilers in response to cereal, fat type and enzyme supplementation (day 21 of age)<sup>1</sup>

Fat	Enzyme <sup>2</sup>	Maize			Wheat			Triticale			Barley		
		Vis	FD	PD	Vis	FD	PD	Vis	FD	PD	Vis	FD	PD
Soya oil	-	3.9	92.3	91.3	8.8	87.2	85.2	17.0	91.7	87.8	13.8	86.3	83.0
Soya oil	+	2.9	93.1	90.9	4.7	90.0	88.7	9.3	93.0	87.9	5.0	90.2	88.3
Tallow	-	3.2	65.2	92.0	10.2	67.4	88.3	21.9	45.3	86.2	23.8	51.3	83.8
Tallow	+	2.4	63.4	90.6	4.6	66.7	89.2	12.4	62.8	88.4	7.6	59.4	88.7
Pooled SEM		0.1	2.6	0.7	1.0	1.9	0.9	1.1	2.3	1.7	1.8	3.8	0.9
Effects								P-values					
Fat		0.001	0.000	0.742	0.539	0.000	0.116	0.007	0.000	0.734	0.008	0.000	0.487
Enzyme		0.000	0.835	0.203	0.001	0.624	0.067	0.001	0.003	0.500	0.001	0.146	0.001
Fat x Enzyme		0.369	0.617	0.444	0.461	0.407	0.240	0.428	0.007	0.564	0.072	0.590	0.793

<sup>1</sup> values represent means of 3 pooled samples per group (6 or 7 birds per sample)

<sup>2</sup> 1 g/kg Avizyme 1300 for maize, wheat and triticale based diets, Avizyme 1100 for barley based diet

tion were observed only for triticale-containing diets ( $P < 0.01$ ). PD was not affected by fat type in either diet and was significantly improved after enzyme addition in wheat- and barley-containing diets ( $P < 0.05$  and  $P < 0.001$ , respectively). Ileal viscosity decreased significantly after enzyme supplementation to all diets ( $P < 0.001$ ). Viscosity was significantly higher in diets containing tallow and triticale or barley ( $P < 0.001$ ,  $P < 0.01$ , respectively).

Measurements of fat digestibility at the faecal level (FFD, Table 4) are in general agreement with the digestibility data obtained from the terminal ileum. Enzyme effect in triticale- and barley-based diets on FFD was significant ( $P < 0.05$ ).  $AME_N$  values of the diets as well as metabolizability of energy were closely associated with FFD and were significantly higher in soyabean oil-fed birds ( $P < 0.001$  for all diets). Significant enzyme effects for both measures were detected for birds fed triticale- and barley-based diets ( $P < 0.001$  and  $P < 0.05$ , respectively). Moreover, significant interactions between fat type and enzyme supplementation were detected in triticale-fed birds ( $P < 0.001$ ). Apparent net protein utilization ( $NPU_u$ ) was also significantly influenced by dietary fat type in birds fed triticale ( $P < 0.01$ ), maize ( $P < 0.01$ ), wheat ( $P < 0.001$ ) and barley ( $P < 0.05$ ). Enzyme supplementation significantly improved  $NPU_u$  in triticale- and wheat-fed broilers ( $P < 0.05$ ).

#### *Growth experiment*

Results of the growth experiments are summarized in Table 5 (day 1 to 21 of age – SFP, day 1 to 35 of age – WFP). Body weight gain (BWG) and feed to gain ratios (FCR) were significantly higher in all soyabean oil-containing diets for SFP only and/or for WFP. Enzyme supplementation significantly improved BWG in diets based on wheat ( $P < 0.01$  for SFP), triticale ( $P < 0.05$  for WFP) and barley ( $P < 0.001$  for SFP,  $P < 0.05$  for WFP). FCR was significantly decreased after enzyme addition in diets based on maize ( $P < 0.01$  for SFP,  $P < 0.05$  for WFP), wheat ( $P < 0.05$  for SFP), triticale ( $P < 0.01$  for SFP and WFP), and barley ( $P < 0.001$  for SFP). BWG and FCR were more significantly increased and decreased, respectively, in tallow-containing diets based on triticale (FCR,  $P < 0.01$  for SFP,  $P < 0.05$  for WFP) and barley (BWG,  $P < 0.05$  for SFP, FCR,  $P < 0.01$  for SFP) as indicated by the significant interactions between fat type and enzyme supplementation.

#### *Carcass characteristics*

Selected carcass characteristics are summarized in Table 6. The most apparent effects of dietary treatments were observed in carcass fatness as indicated by the sum of abdominal plus visceral fat. Feeding tallow resulted in fatter birds for all cereal types (maize,  $P < 0.001$ , wheat,  $P < 0.05$ , triticale and barley,  $P < 0.01$ ). In addition, enzyme supplementation increased the fatness of birds fed diets based on



TABLE 4

AME<sub>N</sub> value of the diets, metabolizability of gross energy (AME<sub>N</sub>:GE), apparent net protein utilization (NPU<sub>a</sub>) and faecal fat digestibility (FFD) of broilers in response to cereal, fat type and enzyme supplementation (day 19 to 20 of age)<sup>1</sup>

Cereal	Fat	Enzyme <sup>2</sup>	AME <sub>N</sub>	AME <sub>N</sub> :GE	NPU <sub>a</sub>	FFD	
Maize	Soya oil	-	13.12	71.9	63.9	91.1	
	Soya oil	+	13.55	74.4	67.7	91.8	
	Tallow	-	12.51	68.4	61.7	65.8	
	Tallow	+	12.50	68.6	61.1	65.5	
	Pooled SEM			0.12	0.01	1.6	0.6
	Effects			P-values			
	Fat			0.000	0.000	0.004	0.000
	Enzyme			0.101	0.064	0.258	0.646
	Fat x Enzyme			0.082	0.099	0.122	0.359
	Wheat	Soya oil	-	13.04	72.4	69.8	85.4
Soya oil		+	13.33	74.5	74.1	89.7	
Tallow		-	12.21	68.2	57.8	67.6	
Tallow		+	12.36	68.6	62.1	67.3	
Pooled SEM			0.16	1.0	1.6	1.5	
Effects			P-values				
Fat			0.000	0.000	0.000	0.000	
Enzyme			0.178	0.155	0.017	0.206	
Fat x Enzyme			0.675	0.356	0.970	0.142	
Triticale		Soya oil	-	13.23	73.5	67.4	89.7
	Soya oil	+	13.58	75.1	69.5	91.2	
	Tallow	-	11.05	61.7	59.8	48.8	
	Tallow	+	12.57	69.8	66.4	64.6	
	Pooled SEM			0.11	1.0	1.6	1.8
	Effects			P-values			
	Fat			0.000	0.000	0.003	0.000
	Enzyme			0.000	0.000	0.014	0.001
	Fat x Enzyme			0.001	0.001	0.172	0.001
	Barley	Soya oil	-	12.66	69.9	65.2	83.0
Soya oil		+	12.98	71.4	67.8	88.7	
Tallow		-	10.80	60.0	62.2	48.4	
Tallow		+	11.57	64.7	56.3	60.5	
Pooled SEM			0.22	1.0	2.8	4.3	
Effects			P-values				
Fat			0.000	0.000	0.017	0.000	
Enzyme			0.022	0.022	0.549	0.017	
Fat x Enzyme			0.321	0.202	0.142	0.970	

<sup>1</sup> values represent means of 5 pooled samples per group (4 birds per sample)

<sup>2</sup> 1 g/kg Avizyme 1300 for maize, wheat and triticale based diets, Avizyme 1100 for barley based diet

TABLE 5

Body weight gain (BWG, g) and feed to gain ratio (FCR, g/g) of broilers in response to cereal, fat type and enzyme supplementation<sup>1</sup>

Fat	Enzyme <sup>2</sup>	Maize		Wheat		Triticale		Barley	
		BWG	FCR	BWG	FCR	BWG	FCR	BWG	FCR
Day 1 to 21 of age									
Soya oil	-	748	1.25	826	1.26	749	1.35	760	1.28
Soya oil	+	742	1.24	846	1.24	761	1.35	797	1.26
Tallow	-	685	1.35	778	1.37	673	1.48	641	1.47
Tallow	+	705	1.31	824	1.29	714	1.40	755	1.34
Pooled SEM		12	0.01	15	0.024	15	0.013	14	0.014
Effects									
P-values									
Fat		0.001	0.000	0.007	0.001	0.001	0.000	0.000	0.000
Enzyme		0.568	0.002	0.010	0.019	0.077	0.006	0.000	0.000
Fat x Enzyme		0.259	20.02	0.286	0.184	0.323	0.003	0.010	0.001
Day 1 to 35 of age									
Soya oil	-	1840	1.58	1842	1.61	1758	1.66	1740	1.59
Soya oil	+	1793	1.53	1869	1.59	1820	1.65	1751	1.59
Tallow	-	1653	1.64	1759	1.70	1667	1.76	1528	1.77
Tallow	+	1688	1.62	1835	1.66	1754	1.66	1719	1.69
Pooled SEM		32	0.016	27	0.02	35	0.02	49	0.026
Effects									
P-values									
Fat		0.001	0.001	0.037	0.001	0.035	0.007	0.019	0.000
Enzyme		0.855	0.024	0.063	0.211	0.045	0.009	0.048	0.141
Fat x Enzyme		0.222	0.438	0.361	0.634	0.731	0.052	0.078	0.150

<sup>1</sup> values represent means of 9 replications per group (10 birds per replication)<sup>2</sup> 1 g/kg Avizyme 1300 for maize, wheat and triticale based diets, Avizyme 1100 for barley based diet

triticale or barley ( $P < 0.01$ ). Enzyme supplementation increased breast meat yield and dressing percentage in wheat-fed birds ( $P < 0.05$ ). Moreover, a significant fat effect on liver weight was observed in these birds ( $P < 0.05$ ). Other parameters were not significantly influenced by dietary treatments.

## DISCUSSION

The improvement in performance and nutrient digestibility due to exogenous enzyme addition to broiler diets based on wheat, triticale and barley is in agreement with many literature findings (for review see Jeroch et al., 1995). Similarly, the poorer feeding value of more saturated dietary fats compared with unsaturated fats, for example beef tallow compared with soyabean oil, is also well researched (c.g. Renner and Hill, 1961a, b; Wiseman and Lessire, 1987; Huygebeart et al., 1988; Blanch et al., 1995). In this respect, the presented results are in line with reports on both enzyme and fat effects. Moreover, it was reported by several authors that enzyme supplementation of rye- or wheat-based broiler diets containing animal fats resulted in greater responses than when a plant oil was used (Smulikowska and Mieczkowska, 1996; Dänicke et al., 1997a, b; Langhout et al., 1997). The results of the present study support such findings, although the interactions between fat type and enzyme supplementation were not always significant, it would appear that both performance data and nutrient digestibility in birds fed triticale or barley-based diets were improved to a greater degree if the enzyme preparation was added to the tallow-containing diet. These interactions seemed to be closely associated with the higher intestinal viscosity in birds fed the unsupplemented tallow-containing barley or triticale-based diets. The data suggest that an intestinal viscosity between approximately 2 to 12 mPas (maize- and wheat-based diets, enzyme-supplemented triticale- and barley-based diets) would be of little or negligible consequence, whereas greater than 20 mPas would result in significant deterioration of fat digestibility. However, according to our findings it should be stressed that variation in intestinal and extract viscosity increases progressively when values range between 10 to 20 mPas. This is due to the formation of larger aggregates between polysaccharides and/or nutrients and results in relatively high increases in viscosity corresponding to relatively small increases in the concentration of viscosity-contributing substances (Dänicke et al., 1999a). Such effects could explain, at least in part, the high individual variation of intestinal viscosity within treatments.

The effects of enzyme supplementation of triticale-based diets were shown to be dependent on the pentosan content of triticale. Enzyme effects were smaller when pentosan concentrations in triticale were comparable with wheat and increased with growing pentosan concentrations (Pettersson and Åman, 1988). Flores

TABLE 6

Carcass characteristics (% of live weight, day 35 of age) in response to cereal, fat type and enzyme supplementation<sup>1</sup>

Cereal	Fat	Enzyme <sup>2</sup>	Breast	Thigh and drumstick	Liver	Abdominal and visceral fat	Dressing percentage
Maize	Soya oil	-	12.6	21.0	1.8	1.6	66.5
	Soya oil	+	13.0	20.8	1.7	1.4	65.6
	Tallow	-	13.6	20.8	1.9	2.1	66.1
	Tallow	+	12.6	20.0	1.6	2.2	65.5
	Pooled SEM		0.5	0.5	0.1	0.2	0.5
	Effects						
	Fat		0.740	0.252	0.772	0.001	0.686
	Enzyme		0.615	0.432	0.088	0.752	0.152
	Fat x Enzyme		0.208	0.627	0.243	0.429	0.717
Wheat	Soya oil	-	13.8	20.6	1.6	1.9	68.0
	Soya oil	+	16.0	22.2	1.6	1.9	69.6
	Tallow	-	15.0	21.6	1.9	2.9	68.5
	Tallow	+	15.6	21.4	2.0	2.6	69.3
	Pooled SEM		0.5	0.5	0.1	0.2	0.4
	Effects						
	Fat		0.341	0.789	0.036	0.001	0.817
	Enzyme		0.009	0.180	0.776	0.692	0.007
	Fat x Enzyme		0.102	0.062	0.711	0.558	0.393
Triticale	Soya oil	-	14.6	20.8	2.1	1.1	69.0
	Soya oil	+	14.0	21.2	2.1	1.8	68.8
	Tallow	-	15.4	20.8	2.0	1.9	68.6
	Tallow	+	14.6	21.0	2.0	2.2	69.0
	Pooled SEM		0.6	0.6	0.1	0.2	0.5
	Effects						
	Fat		0.319	0.841	0.700	0.001	0.812
	Enzyme		0.225	0.622	0.898	0.009	0.812
	Fat x Enzyme		0.852	0.869	0.898	0.285	0.435
Barley	Soya oil	-	15.2	21.5	2.1	1.1	70.0
	Soya oil	+	14.6	21.9	2.2	1.8	69.9
	Tallow	-	15.8	21.4	2.1	2.0	69.5
	Tallow	+	15.1	21.8	2.1	2.3	70.5
	Pooled SEM		0.6	0.5	0.1	0.2	0.6
	Effects						
	Fat		0.332	0.805	0.604	0.001	0.943
	Enzyme		0.261	0.542	0.753	0.006	0.476
	Fat x Enzyme		0.958	0.990	0.983	0.291	0.358

<sup>1</sup> values represent means of 9 birds per group<sup>2</sup> 1 g/kg Avizyme 1300 for maize, wheat and triticale based diets, Avizyme 1100 for barley based diet

et al. (1994) reported improvement in performance ranging between 11 and 23% in broilers from day 10 to 24 of age with enzyme supplementation when given diets containing 60% triticale (different varieties) and 3% tallow. The water-soluble pentosan content ranged between 2.4 and 2.7% and did not correlate with triticale feeding value. However, the varieties differed significantly with respect to performance. The authors concluded that factors other than soluble pentosans must be responsible for differences in feeding value of triticale. Scholtyssek and Knorr (1987) measured fat digestibility in broilers fed diets containing either 30% triticale or 30% rye, 5% soyabean oil and a multi-enzyme preparation. The improvement in fat digestibility amounted to 3.2 and 1.1% in triticale- and rye-containing diets, respectively, which supports the findings of the present study where changes in fat digestibility due to enzyme supplementation in soyabean oil-containing diets were only marginal.

In the present experiment, both chemical composition of wheat and triticale and improvement in performance of broilers after enzyme addition were comparable. For both cereals, there was a trend towards greater enzyme effects in groups fed the tallow-containing diets, with this effect on FCR reaching significance in triticale-fed birds. Improvement in BWG and FCR until day 21 of age amounted to 0 to 2% and 5 to 6% in soyabean oil- and tallow-fed birds, respectively. These effects were smaller when the whole fattening period was considered. A direct relationship between fat digestibility and performance was found for triticale- and barley-fed birds. The marked improvement in fat digestibility in tallow-supplemented triticale- or barley-fed birds on enzyme supplementation coincided with an improvement in FCR (day 1 to 21 of age) of 6 and 8%, respectively. The 5% enzyme-related improvement in FCR in tallow- and wheat-fed birds seemed not to be related to fat digestibility but more to precaecal protein digestibility and  $NPU_a$ .

Intestinal viscosity in birds fed the unsupplemented wheat-tallow diet was only half that of their triticale-fed counterparts. Intestinal viscosity is considered to influence fat digestibility markedly, as discussed in more detail by Dänicke et al. (1997b) and Smulikowska (1998). It would appear from the present results that a marked reduction in fat digestibility might be expected at an intestinal viscosity of approximately 20 mPas. This is also supported by the approximately 8 and 12% lower FD and FFD, respectively, in broilers fed the unsupplemented barley-tallow diet compared with their  $\beta$ -glucanase-supplemented counterparts. Rotter et al. (1990) measured the  $AME_N$  of a hull-less barley in the presence of either 4% maize oil or 4% tallow and found an improvement after enzyme supplementation of 20 and 33%, respectively, which supports the existence of interactions between fat type and enzyme supplementation. At the same time, FCR decreased by 9 and 11%, respectively. Hulled barley was used in the present study, therefore, the higher total fibre content might also be involved in modulating its nutritive value. This

is supported by Villamide et al. (1997) who estimates that 55% of the  $AME_N$  value of enzyme-supplemented barley cultivars is accounted for by crude fibre content. Therefore, the feeding value of barley for broilers not only depends on the soluble  $\beta$ -glucan content and intestinal viscosity, but on elimination of this problem through enzyme use; crude fibre or total cell wall content then becomes a very important factor. Enzyme supplementation of maize-based diets did not improve nutrient digestibility,  $AME_N$  or  $NPU_a$ . Despite this, xylanase addition was effective in reducing intestinal viscosity. As discussed above, the low intestinal viscosity in maize-fed birds is accompanied by a relatively small standard error whereby treatment differences became significant. However, the absolute level of viscosity and the enzyme effects seemed to be without physiological significance in terms of examined nutrient digestibility. On the other hand, FCR was significantly reduced due to enzyme supplementation in maize-fed birds irrespective of fat type, which can not be explained by the measured digestibility data. Digestibility of starch as the major energy yielding compound in maize could be improved by enzyme supplementation. It should be noted, however, that the enzyme preparation used for maize diets is matched to wheat- or wheat-and-rye-based diets which contain much higher amounts of pentosans than maize (Table 2). An enzyme preparation which is better matched to maize or maize-soyabean-based diets (amylase, protease and xylanase activities) might produce more consistent effects as shown by Pack et al. (1997) where a 2 to 5% improvement in ileal energy digestibility was reported for different diets based on maize.

The most pronounced effects of the dietary treatments on carcass characteristics were observed for the abdominal plus visceral fat content. Feeding tallow resulted in significantly fatter broilers when compared with soyabean oil. It has been shown by several authors (De Groote et al., 1971; Fuller and Rendon, 1979; Brue and Latshaw, 1985; Dänicke et al., 1999b) that feeding tallow or fats of animal origin containing high ratios of saturated to unsaturated fatty acids results in a higher caloric efficiency, i.e. a higher proportion of net energy to metabolizable energy, than feeding plant oils. In some of these studies, the birds fed the tallow-based diets were in fact fatter (De Groote et al., 1971; Pinchasov and Nir, 1992). It was hypothesized by Pinchasov and Nir (1992) that dietary polyunsaturated fatty acids, which are more abundant in soyabean oil than in tallow, modulate the 9-desaturase complex which causes a reduction in synthesis of oleic acid and a decrease in lipogenesis.

Birds fed the barley or triticale diets were fatter on enzyme supplementation. Fatness increased both in soyabean oil- and in tallow-fed birds, which may be related to improved fat digestibility suggesting a higher energy availability for fat deposition. Similar trends were reported by Dänicke et al. (1999c) who found the degree of fatness of broilers directly related to dietary pentosan concentration and enzyme supplementation.

## CONCLUSIONS

Enzyme supplementation of broiler diets based on wheat, triticale, barley and, to a lesser extent, maize is beneficial in terms of improvement of performance, especially during the first weeks of life, and more pronounced if beef tallow is used instead of soyabean oil at 10% dietary inclusion.

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## STRESZCZENIE

### **Współzależność pomiędzy rodzajem tłuszczu i dodatkiem enzymów egzogennych do diet, zawierających kukurydzę, pszenicę, triticale lub jęczmień, w żywieniu brojlerów**

Przeprowadzono cztery doświadczenia wzrostowe i jedno bilansowe w celu zbadania wpływu różnego rodzaju tłuszczu (tój wołowy lub olej sojowy) oraz dodatku enzymów do diet zawierających pszenicę, triticale, kukurydzę lub jęczmień. Doświadczenia wzrostowe prowadzono przez 35 dni. W doświadczeniu bilansowym u kurcząt w wieku 21 dni oznaczono lepkość treści jelita biodrowego oraz pozorną strawność tłuszczu i białka w końcowej części jelita biodrowego.



Oznaczono także całkowitą strawność tłuszczu, zawartość energii metabolicznej ( $AME_N$ ) oraz pozorne wykorzystanie białka netto ( $NPU_a$ ).

Dodatek enzymów do wszystkich diet poprawiał istotnie wykorzystanie paszy, szczególnie w przypadku diet zawierających triticales i jęczmień i uzupełnionych łożem w porównaniu z dietami uzupełnionymi olejem sojowym. Efekt dodatku enzymów zmniejszał się lub nie występował, gdy uwzględniano cały okres tuczu. Lepsze wyniki produkcyjne w całym okresie tuczu uzyskano u kurcząt otrzymujących diety uzupełnione olejem niż łożem.

Lepkość treści jelitowej istotnie zmniejszała się pod wpływem dodatku enzymów do wszystkich diet; lepkość była istotnie większa u kurcząt otrzymujących diety z łożem (z triticales, jęczmieniem lub kukurydzą). Pozorna strawność oznaczana w jelicie biodrowym nie zależała od rodzaju tłuszczu, natomiast zwiększała się pod wpływem dodatku enzymów do diet z pszenicą i jęczmieniem. Całkowita i jelitowa strawność tłuszczu była istotnie większa u kurcząt otrzymujących dietę z dodatkiem oleju i istotnie wzrastała pod wpływem dodatku enzymów. Wpływ enzymów na całkowitą strawność tłuszczu zaznaczył się wyraźniej niż na jelitową, i był dodatnio skorelowany z  $AME_N$  i  $NPU_a$ .