Improving the Nutritive Value of Full-Fat Rice Bran for Broiler Chickens Using a Lipase-Based Enzyme Preparation

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ABSTRACT : Two experiments were conducted to test the hypothesis that a lipase-based enzyme preparation would increase the AME content of full-fat rice bran (FFRB) by increasing fat digestibility when fed to broiler chickens. Experiment 1 used FFRB from Australia and lasted for 35 days, while Experiment 2 used FFRB from Thailand and lasted for 14 days. Rice bran was substituted in a maize-soybean diet at levels of 90 g/kg (Experiment 1) and at 90 and 180 g/kg in Experiment 2. Total collections of excreta were used for determination of AME content and fat digestibility. In Experiment 1, the enzyme increased the AME content of FFRB between days 4-7, 18-21 and 32-35 by 6.1-16.1% ($p>0.05$), however this was not associated with improved fat digestibility. In Experiment 2, the enzyme enhanced the AME content of FFRB between days 4-7 (10.42 vs. 9.06, $p=0.107$) and 11-14 (11.94 vs. 9.93, $p=0.041$), but again, this was not caused by increased fat digestibility. Inclusion of 180 g/kg depressed the AME content of FFRB by 7.4-11.5% ($p>0.10$) in conjunction with decreased ($p<0.05$) fat digestibility between 0-14 days of age. Improvements in bird growth with the enzyme were seen in Experiment 2 but not in Experiment 1. Increases in AME content of FFRB *per se* were not caused by enhanced fat digestibility, suggesting that the side activities associated with the preparation must have acted singularly or in combination to improve AME content and bird performance. These data show that the response of FFRB to the lipase-based enzyme preparation was dependent upon the geographical origin of the rice bran and the level of FFRB substituted in the basal diet (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 3 : 360-368*)

Key Words : Broiler Chickens, Full-fat Rice Bran, Enzyme, Fat, Digestibility, Apparent Metabolizable Energy

INTRODUCTION

Full-fat rice bran (FFRB) is a by-product of rice milling that is produced in relative abundance in the greater Asian region. Full-fat rice bran is high in gross energy (19-21 MJ/kg) and also crude fat (180-200 g/kg), and hence has potential as a valuable energy ingredient in the broiler industry. However, the widespread use of FFRB is restricted due to concerns with its high NDF fraction (although the soluble non-starch polysaccharide from FFRB has not been shown to possess anti-nutritive properties; Annison et al., 1995), oxidative rancidity of the fats (Farrell, 1994), and its phytate-P content (Farrell and Martin, 1998b).

One aspect of FFRB that has received little attention, and which offers potential for judicious enzyme use and increased nutritive value, is the poor utilisation of fat in rice bran. Warren and Farrell (1990) reported that an inclusion level of 400 g/kg of Australian FFRB caused a 4.6 MJ/kg reduction in ME content for 15-day-old chickens compared to adult cockerels. The lower ME value observed in younger birds was due in part to lower pancreatic lipase secretion, since broilers had a lower fat metabolisability than cockerels (37 vs. 98%) (Warren and Farrell, 1990). Given this, Pluske et al. (1997) reported improved AME content and growth performance between hatch and 14 days of age when birds were fed diets containing 200 g/kg or 400 g/kg Australian FFRB supplemented with a lipase-based enzyme preparation. However, the mechanism whereby an improvement in AME content of the diets containing FFRB occurred was not investigated.

The objective of this study was to investigate the metabolisability of energy and fat and monitor the production response of broiler chickens fed different levels of FFRB (obtained from either Australia or Thailand) in response to supplementation with a lipase-based enzyme preparation. The general hypothesis tested was that provision of a lipase-based enzyme would increase AME content by increasing fat digestibility. Unlike previous experiments (e.g., Warren and Farrell, 1990; Pluske et al., 1997; Martin and Farrell, 1998) where non-commercial levels of FFRB were included in diets, these experiments investigated the utilisation of FFRB included in diets at levels approximating those used commercially.

MATERIALS AND METHODS

Experiment 1

1) Animals, housing, diets and procedures

A total of 288 day-old male broiler chicks of a

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commercial Ross strain was used. On the day of arrival, each bird was weighed and placed into a narrow weight class. Birds of relatively low or high body weight were discarded. Six birds were then assigned to each of 48 pens such that all pens had a similar average weight. The 48 pens were allocated at random to four treatments (B+, B-, 90+ and 90-; see below) so that there were 12 replicates (72 birds) per group.

Two basal diets (B+ and B-) were formulated according to the Standard Ross Poultry Finisher 1 Formulation recommendation. Two treatment diets (90+ and 90-), where the maize-soybean basal diet was substituted with 90 g/kg Australian FFRB, were also prepared. Diet B+ was the basal diet plus 1 g/kg enzyme, whereas Diet B- was the basal diet without enzyme. Diets 90+ and 90- each contained 90 g/kg Australian FFRB and 910 g/kg of the basal diet. Diet 90+ was supplemented with 1 g/kg of the enzyme. Each diet was supplemented with minerals and vitamins, and was mixed thoroughly prior to pelleting through a 2.4 mm dye at 65℃. The chemical composition of the FFRB from Australia is depicted in table 1. The composition of the experimental diets is presented in table 2.

The birds were maintained in electrically-heated, thermostatically-controlled battery brooders with raised

Table 1. Chemical analysis of FFRB obtained from Australia (Experiment 1) and Thailand (Experiment 2) (g/kg air-dry weight)[1]

Item	FFRB from Australia		FFRB from Thailand	
DM	903		906	
GE (MJ/kg)	19.3	(21.4)	19.0	(20.6)
NDF[2]	223	(246)	226	(249)
ADF[2]	83	(92)	98	(108)
Hemicellulose[3]	140	(154)	128	(141)
Crude protein (N×5.95)[4]	136	(151)	125	(138)
Crude fat	171	(189)	182	(201)

[1] Values in parentheses expressed on DM basis.
[2] NDF: neutral detergent fibre; ADF: acid detergent fibre; Determined according to AOAC (1990).
[3] Calculated as NDF minus ADF.
[4] CP: crude protein; determined using Kjeldahl analysis (AOAC, 1990).

Table 2. Composition of diets in Experiment 1 (g/kg air-dry weight)[1]

	B+	B-	90+	90-
Ingredients:				
Maize	587	588	534	535
Soybean meal	230	230	209	209
Soybean oil	20	20	18.3	18.3
Meat and bone meal	150	150	136.7	136.7
Full-fat rice bran	-	-	90	90
L-lysine	2.5	2.5	2.3	2.3
DL-methionine	3.5	3.5	3.2	3.2
Vitamins[2]	0.5	0.5	0.5	0.5
Salt	4	4	3.6	3.6
Minerals[2]	1.5	1.5	1.4	1.4
Enzyme[3]	1	-	1	-
Chemical analysis:				
GE (MJ/kg)	17.10	16.74	16.97	16.98
Fat (g/kg)	53.6	52.7	63.8	63.8
Dry matter (g/kg)	904.9	903.5	890.6	900.1
Calculated analysis:				
AME (Kcal/g)	3,110	3,110	3,095	3,095
Crude protein (g/kg)	230	230	220	220
Crude fat (g/kg)	64	64	71.7	71.7
Lysine (g/kg)	14	14	13.5	13.5
Met.+Cys. (g/kg)	9.7	9.7	9.3	9.3
Total phosphorus (g/kg)	11	11	12	12
Calcium (g/kg)	17	17	16	16

[1] See text for details of experimental diets.
[2] Nutritech starter vitamin and mineral premix (Nutritech International, Auckland, NZ).
[3] Allzyme Lipozyme (Alltech, Inc., Nicholasville, KY USA) containing lipase (900 lipase units/g) and protease (425 HUT/g) derived from *Aspergillus niger*, and cellulase (19 CMCU/g) and xylanase (400 xylanase units/g) derived from *Trichoderma longibrachiatum*.

wire-mesh floors for 14 days. On day 15, all birds were transferred to an electrically-heated grower shed until the completion of the experiment at day 35. In the battery brooder shed, the temperature was kept at 36℃ from day-old to day 4 of age, 34℃ between days 5 and 10, and 30℃ up to day 14 of age. In the grower shed, temperature was gradually reduced by 0.5℃ per day from 27℃ on day 14 down to about 21℃ on day 35. Lighting of 23 hours light and 1 hour dark was provided in both sheds.

All birds were given *ad libitum* access to feed and water. The birds from each cage and the feed were weighed at day 0 (the beginning of the experiment), day 14 (when birds were shifted to grower cages), day 35 (at the end of the experiment), and at the beginning and the end of the three excreta collection periods (days 4-7, days 18-21 and days 32-35).

Experiment 2

1) Animals, housing, diets and procedures

A total of 360 day-old male broiler chickens of a commercial Ross Strain was used. On the day of arrival, each bird was weighed and placed into a narrow weight class. Birds of relatively low or high body weight were discarded. Five birds were assigned to each of 54 pens such that all pens had a similar average weight. The 48 pens were allocated at random to six treatments (B+, B-, 90+, 90-, 180+ and 180-; see below) so that there were 9 replicates (54 birds) per group. Environmental conditions in the battery brooder shed are described previously.

Two basal diets (B+ and B-) were formulated according to the Standard Ross Poultry Finisher 1 Formulation recommendation. Four treatment diets (90+, 90-, 180+ and 180-), where the maize-soybean basal diet was substituted with 90 g/kg or 180 g/kg FFRB obtained from Thailand, were also prepared. Diet B+ was the basal diet plus 1 g/kg enzyme, whereas Diet B- was the basal diet without enzyme. Diets 90+ and 90- each contained 90 g/kg Thai FFRB and 910 g/kg of the basal diet, while diets 180+ and 180- each contained 180 g/kg Thai FFRB and 820 g/kg of the basal diet. Diets 90+ and 180+ were supplemented with 1 g/kg of the enzyme. Each diet was supplemented with minerals and vitamins, and was mixed thoroughly prior to pelleting through a 2.4 mm dye at 65℃. The chemical composition of the FFRB

Table 3. Composition of diets in Experiment 2 (g/kg air-dry weight)

	B+	B-	90+	90-	180+	180-
Ingredients:						
Maize	587	588	533.9	534.9	481.1	4821
Soybean	230	230	209.3	209.3	188.6	188.6
Soybean oil	15	15	13.7	13.7	12.3	12.3
Meat and bone meal	95	95	86.5	86.5	77.9	77.9
Fish meal	60	60	54.6	54.6	49.2	49.2
Rice bran	-	-	90	90	180	180
L-lysine	2.5	2.5	2.3	2.3	2.1	2.1
DL-Methionine	3.5	3.5	3.2	3.2	2.9	2.9
Vitamins[2]	0.5	0.5	0.5	0.5	0.4	0.4
Minerals[2]	1.5	1.5	1.4	1.4	1.2	1.2
Salt	4	4	3.6	3.6	3.3	3.3
Enzyme[3]	1	-	1	-	1	-
Chemical analysis:						
GE (MJ/kg)	17.4	17.3	17.2	17.2	17.5	17.2
Crude fat (g/kg)	49	47.1	60	60	72.1	72.1
Dry matter (g/kg)	886.6	885.3	878	884.4	884.6	880.6
Calculated analysis:						
AME (Kcal/g)	3,105	3,105	3,094	3,094	3,082	3,082
Crude protein (g/kg)	240	240	230	230	220	220
Fat (g/kg)	61	61	69	69	77	77
Lysine (g/kg)	14.9	14.9	14	14	13	13
Met.+Cys. (g/kg)	10.2	10.2	9.7	9.7	9.2	9.2
Total phosphorus (g/kg)	10.5	10.5	11.1	11.1	11.8	11.8
Calcium (g/kg)	15.5	15.5	14	14	13	13

[1] See text for details of experimental diets.

[2] Nutritech starter vitamin and mineral premix (Nutritech International, Auckland, NZ).

[3] Allzyme Lipozyme (Alltech, Inc., Nicholasville, KY USA) containing lipase (900 lipase units/g) and protease (425 HUT/g) derived from *Aspergillus niger*, and cellulase (19 CMCU/g) and xylanase (400 xylanase units/g) derived from *Trichoderma longibrachiatum*.

from Thailand is depicted in table 1. The composition of the experimental diets is presented in table 3.

Since only a limited quantity of FFRB was obtained from Thailand, the experiment lasted for only two weeks. All birds were given *ad libitum* access to feed and water. The birds from each cage and the feed were weighed at the beginning and the end of each excreta collection period (days 4-7 and days 11-14).

Total excreta collection

During the collection periods, total daily excreta were collected on a plastic sheet laid under each cage. The plastic sheets were cut according to the size or area of the cage, weighed, and labelled before placing underneath the cages. The plastic sheets were then collected, weighed, and frozen at -20℃ after each days collection. Upon the completion of each excreta collection period, faeces collected over the four days were pooled and a (proportional) representative sub-sample was taken for each cage. The representative samples of all pens were then freeze-dried, lyophilised to equilibrate with atmospheric conditions, and then ground through a 1mm sieve grinder for laboratory analysis of GE, DM and fat. Samples of each diet were also ground for analysis of GE, DM and fat. From the laboratory analysis and freeze-drying, the amount of DM excreted by each pen on each day could be calculated.

Chemical analysis

Dry matter, GE and crude fat content were determined in duplicate. Dry matter was determined after 1 g samples were dried to a constant weight for 18 hours in a Watvic Oven (Watson Victor Ltd.) at 105℃. Gross energy was determined in a Gallenkamp adiabatic bomb calorimeter. The Soxhlet fat extraction method was used for crude fat determination after samples were washed with petroleum ether (40-60℃) for eight hours.

Determination of AME content and fat digestibility

The AME content of each diet during the collection periods for both experiments was calculated according to procedures outlined by Farrell et al. (1991). To derive the AME content of the test ingredient, the FFRB was added in replacement of a portion of the basal diet. The AME content of the FFRB was then calculated according to the following equation (Miller, 1974):

$$AMEtest=(AME_{basal}*P)+\{AMEI_{ng}*(1-P)\}$$

subsequently,

$$AMEI_{ng}=\frac{AME_{test}-AME_{basal}*P}{1-P}$$

where P=proportion of the basal diet in the test diet, and Ing=test ingredient.

Statistical analysis

In Experiment 1, two one-way analysis of variances were conducted. The first analysis examined the effect of enzyme supplementation in the basal diet, and the second analysis examined the effect of enzyme in the 90 g/kg FFRB-containing diet. In Experiment 2, data were subjected to two analyses. The first analysis examined the differences between the basal diet with and without enzyme supplementation (one-way analysis of variance). The second analysis examined the effect of the enzyme preparation on different levels of FFRB inclusion (2×2 factorial analysis of variance with Bonferroni pairwise comparison, with respective factors being 90 and 180 g/kg FFRB diets with and without enzyme supplementation). All data were analysed according to the generalised linear model (GLM) procedures of SAS (1997).

RESULTS

Experiment 1

1) AME content and fat digestibility

A small but significant (p=0.024) improvement of 1.8% in the AME content of the basal diet was observed between days 18-21 in the presence of enzyme. The AME content in the basal diet was numerically higher between days 4-7 and 32-35 with enzyme addition (p=0.198 and 0.162, respectively). A 2.4% improvement (p=0.008) in AME content due to enzyme in the diet containing 90 g/kg FFRB was seen between days 32-35, and was numerically higher with enzyme supplementation between days 4-7 and 18-21 (p=0.215 and 0.218, respectively). Enzyme addition increased the AME content of FFRB *per se* between days 4-7, 18-21 and 32-35 by between 6.1 and 16.1 %, however, the improvement was not significant (p=0.213, p=0.348, and p=0.065, respectively) (table 4).

Addition of the enzyme preparation did not increase (p>0.05) fat digestibility in either the basal diets or the FFRB-containing diets. A significant increase (p<0.05) in fat digestibility was observed as birds aged in both the basal and test diets (table 4).

2) Bird performance

Throughout the 35-day growth period there was no statistical influence of enzyme supplementation on any production index measured for any of the diets used. However, between days 8-13 and 14-21, there was a trend for an improvement in daily gain in the basal diet supplemented with enzyme (p=0.089 and p=0.061

respectively). For the 35-day period, there was a trend (p=0.066) for increased FCR in birds fed the FFRB-containing diet in the presence of enzyme (1.59 vs. 1.56) (table 5).

Experiment 2

1) AME content and fat digestibility

Inclusion of enzyme in the basal diet increased the

Table 4. Influence of enzyme supplementation on AME content of the whole diet, the AME content of the FFRB, and fat metabolisability determined at different times during growth[1]

	Basal Diet		SE	90 g/kg FFRB		SE
	+Enzyme	-Enzyme		+Enzyme	-Enzyme	
AME content, MJ/kg DM						
AMEdiet d 4-7	14.24	14.03	0.078	14.58	14.38	0.134
AMEdiet d 18-21	14.57[a]	14.32[b]	0.075	14.65	14.52	0.069
AMEdiet d 32-35	14.41	14.22	0.067	14.72[c]	14.38[d]	0.067
AMEFFRB d 4-7	-	-	-	20.10	17.93	1.468
AMEFFRB d 18-21	-	-	-	17.93	16.90	0.762
AMEFFRB d 32-35	-	-	-	18.59	16.01	0.656
Fat metabolisability, %						
Days 4-7	92.2	93.0	0.93	90.9	90.5	0.66
Days 18-21	94.4	93.3	0.43	92.6	93.5	0.38
Days 32-35	95.3	94.9	0.37	94.7	93.2	0.49

[1] Values are least-squares means±SE.

[a,b] Between basal diets and within rows, values not having the same superscript differ significantly (p<0.05).

[c,d] Between FFRB-containing diets and within rows, values not having the same superscript differ significantly (p<0.05).

Table 5. The effects of enzyme supplementation of diets on ADG, ADFI and feed conversion ratio (FCR)[1]

	Basal Diet		SE	90 g/kg FFRB		SE
	+ Enzyme	-Enzyme		+Enzyme	-Enzyme	
Day 0-7						
ADG	23.7	24.4	0.31	23.1	22.5	0.33
ADFI	25.4	25.3	0.32	26.4	25.3	0.42
FCR, g feed/g gain	1.07	1.05	0.006	1.14	1.12	0.013
Day 8-13						
ADG	45.0	42.9	0.62	43.8	42.8	0.56
ADFI	57.4	55.9	0.83	57.3	56.2	0.68
FCR, g feed/g gain	1.31	1.32	0.018	1.31	1.32	0.014
Day 14-21						
ADG d	66.9	63.7	0.87	65.8	65.1	0.61
ADFI	97.1	93.4	1.49	97.9	94.4	0.88
FCR, g feed/g gain	1.45	1.49	0.014	1.49	1.45	0.010
Day 22-31						
ADG	79.0	78.3	1.61	84.5	83.4	1.25
ADFI	129.6	131.4	2.71	139.8	139.6	1.90
FCR, g feed/g gain	1.68	1.68	0.022	1.69	1.68	0.015
Day 32-35						
ADG	82.8	79.2	2.19	89.7	90.3	1.79
ADFI	156.4	157.4	3.19	164.1	164.1	2.72
FCR, g feed/g gain	1.91	2.00	0.028	1.86	1.86	0.037
Day 0-35						
ADG d	57.8	56.4	0.69	59.4	59.0	0.48
ADFI	90.2	89.5	1.23	94.2	92.1	0.77
FCR, g feed/g gain	1.56	1.57	0.010	1.59	1.56	0.008

[1] Values are least-squares means±SE.

AME content between days 4-7 (p=0.110) and by 1.7% between days 11-14 (15.27 vs. 15.02 MJ/kg DM, p=0.002). Between days 4-7 and 11-14, diet AME content was 3.8% (14.78 vs. 14.21, p<0.001) and 3.3% (14.69 vs. 14.22, p<0.001) higher in diets with 90 g/kg FFRB than 180 g/kg FFRB, respectively, and was numerically higher in diets containing enzyme (p=0.080). Inclusion of enzyme increased the AME content of FFRB numerically between days 4-7 (10.42 vs. 9.06 MJ/kg DM, p=0.107) and significantly between days 11-14 (11.94 vs. 9.93, p=0.041). The AME content of FFRB was depressed by between 7.4 and 11.5% with the inclusion of 180 g/kg compared to 90 g/kg, however this difference was not statistically significant (p=0.183). No significant interactions between FFRB and enzyme were noted (table 6).

Addition of the enzyme preparation failed to enhance fat digestibility in all diets. Inclusion of 180 g/kg FFRB depressed fat digestibility in comparison to 90 g/kg FFRB between days 4-7 (91.3 vs. 79.0%, p<0.01) and days 11-14 (84.9 vs. 80.8, p=0.073). Fat digestibility was significantly lower (p<0.001) for the basal diets and those containing 90 g/kg FFRB between days 11-14 compared to days 4-7 (table 6).

2) Bird performance

Between days 0-7, 8-14 and in the entire 14-day growth period, enzyme supplementation increased (p<0.05) ADG in the basal diet by an average of 4 %. A trend for an improvement in FCR over the 14-day period was also observed (1.13 vs. 1.15, p=0.056) (table 7).

Between days 0-7, the substitution of 90 g/kg FFRB in the basal diet improved ADG (22.6 vs. 21.5, p<0.001), ADFI (24.0 vs. 23.5 g/day, p<0.001) and FCR (1.06 vs. 1.10, p<0.001) in comparison to the substitution of 180 g/kg. This improvement in FCR with the inclusion of 90 g/kg rather than 180 g/kg FFRB was also seen between days 8-14 (1.23 vs. 1.32, p<0.001). A significant main effect of the enzyme included in FFRB-containing diets on FCR

Table 6. Influence of enzyme supplementation on AME content of the whole diet, the AME content of the FFRB, and fat metabolisability determined at different times during growth[1]

	Basal diet		SE	90 g/kg FFRB		SE	180 g/kg FFRB		SE
	+Enzyme	-Enzyme		+Enzyme	-Enzyme		+Enzyme	-Enzyme	
AME content, MJ/kg DM									
AMEdiet d 4-7	15.41	15.31	0.038	14.91	14.65	0.151	14.36	14.06	0.148
AMEdiet d 11-14	15.27[a]	15.02[b]	0.052	14.82	14.56	0.121	14.31	14.15	0.120
AMEFFRB d 4-7	-	-	-	10.82	9.74	0.399	10.03	8.37	0.381
AMEFFRB d 11-14	-	-	-	12.82	9.83	0.441	11.06	10.03	0.441
Fat metabolisability, %									
Days 4-7	94.5	94.9	0.38	91.7	91.0	0.57	79.0	79.1	1.85
Days 11-14	91.2	91.0	0.64	86.5	83.4	1.43	81.5	80.2	1.68

[1] Values are least-squares means±SE.

[a,b] Between basal diets and within rows, values not having the same superscript differ significantly (p<0.05).

Table 7. The effects of enzyme supplementation of diets on ADG, ADFI and feed conversion ratio (FCR)[1]

	Basal Diet		SE	90 g/kg FFRB		SE	180 g/kg FFRB RB		SE
	+ Enzyme	-Enzyme		+Enzyme	-Enzyme		+Enzyme	-Enzyme	
Day 0-7									
ADG	24.2[a]	23.4[b]	0.27	23.1	22.1	0.49	21.1	21.9	0.49
ADFI	24.7	24.1	0.25	24.2	23.7	0.45	23.0	24.1	0.45
FCR, g feed/g gain	1.02	1.03	0.006	1.05	1.08	0.008	1.09	1.10	0.008
Day 8-14									
ADG	49.8[a]	47.7[b]	0.59	49.5[c]	46.1[d]	0.75	44.4[d]	44.7[d]	0.73
ADFI	59.3	57.8	0.59	59.9	57.9	0.76	58.3	59.4	0.74
FCR, g feed/g gain	1.19	1.21	0.007	1.21	1.26	0.010	1.32	1.33	0.015
Day 0-14									
ADG	36.2[a]	34.7[b]	0.37	35.9[c]	33.3[d]	0.56	32.0[d]	32.6[d]	0.56
ADFI	40.7	39.8	0.32	41.6	39.7	0.66	39.5	40.6	0.66
FCR, g feed/g gain	1.13	1.15	0.006	1.16	1.19	0.009	1.24	1.25	0.011

[1] Values are least-squares means±SE.

[a,b] Between basal diets and within rows, values not having the same superscript differ significantly (p<0.05).

[c,d] Between FFRB-containing diets and within rows, values not having the same superscript differ significantly (p<0.05).

between days 8-14 (1.26 vs. 1.30, p=0.077) was also observed. A significant interaction between enzyme supplementation and level of FFRB inclusion was observed for ADG between days 8-14, with birds fed 90 g/kg FFRB plus enzyme growing, on average, 10% faster ($p<0.05$) than the other three treatments. The same interaction was also seen for ADG between days 0-14, with the average improvement also being 10% ($p<0.05$). Significant main effects were observed for level of FFRB (1.17 vs. 1.24, $p<0.001$) and enzyme supplementation (1.20 vs. 1.23, $p<0.05$) on FCR between days 0-14 (table 7).

DISCUSSION

The data obtained from these two experiments failed to support the hypothesis that a lipase-based enzyme preparation would enhance the AME content of full-fat rice bran (FFRB) by increasing fat digestibility. Nevertheless, and dependent in part upon bird age and the geographical origin of the FFRB, significant improvements in the presence of the enzyme in AME content of both basal and test diets, and FFRB *per se*, were observed independently of improvements in fat digestibility. The increase in AME content, especially with FFRB obtained from Thailand, was associated with increased growth and enhanced FCR. These data suggest that side activities of the enzyme preparation, i.e., protease, cellulase and xylanase, must have worked singularly or in combination to cause the responses in energy metabolisability and production measured.

These data are in general agreement with the work of Pluske et al. (1997) who observed improvements in AME content and production when the same lipase-based enzyme preparation was used in diets containing higher levels of FFRB (200 and 400 g/kg). More recently, Martin and Farrell (1998) conducted several experiments investigating the response of broilers fed either 200 or 400 g/kg Australian FFRB between 3-21 days of age to a microbial feed lipase. These authors reported ambiguous results, with the lipase (included at 0.23 g/kg) providing a growth response in one study but not in another despite the same level of FFRB (400 g/kg) and enzyme being used. Furthermore, in agreement with our studies, Martin and Farrell (1998) reported no improvement in fat metabolisability with the use of the lipase and an improvement in AME content as birds aged.

Fat digestibility values obtained in this paper (79-95%) were considerably higher than those obtained by other workers using birds of similar ages (Askbrant and Farrell, 1987; Warren and Farrell, 1990; Martin and Farrell, 1998). This was most likely attributable to the lower levels of FFRB (90 and 180 g/kg) used. Nevertheless, in Experiment 2, the substitution of 180 g/kg FFRB in the basal diet decreased fat digestibility during both collection periods. This was associated with depressed AME content of both the diet and FFRB (table 6). Use of the lipase-based enzyme preparation significantly improved the AME content of both the diet and FFRB, however the failure to detect a significant main effect for enzyme on fat digestibility confirms that improvements in AME content were attributable to the side activities contained in the enzyme preparation.

An explanation for the lack of effect of lipase on fat digestibility may be related to the quantity and type of substrate present. For example, the fat from FFRB used in Experiment 2 comprised only 270 and 450 g/kg of the total fat present in the complete diets containing 90 and 180 g/kg FFRB, respectively. Given that only 180 to 200 g/kg of the rice bran fat is saturated (Nicolosi et al., 1994), the levels of saturated fatty acids (50 and 90 g/kg of total for the 90 and 180 g/kg FFRB-containing diets, respectively) available for enzymatic hydrolysis were low. A more effective response to this lipase-based enzyme may occur, therefore, in diets containing higher concentrations of saturated fats.

Another possible reason for the lack of effect of the lipase on fat digestion, particularly in the diet substituted with 180 g/kg FFRB, may have been the interference of other compounds present in the rice bran. It has been demonstrated that the soluble non-starch polysaccharide (NSP) fraction of rice bran is not anti-nutritive (Annison et al., 1995), and that both soluble and insoluble NSP are seemingly unresponsive to exogenous glycanase supplementation (Aboosadi et al., 1996; Farrell and Martin, 1998a). In cereals such as wheat and barley there is evidence that the NSP interfere with the emulsification and digestive actions of bile salts and pancreatic lipase to reduce fat digestion (e.g., Choct and Annison, 1992; Bedford, 1996; Langhout et al., 1997), and that the use of glycanases can reverse this effect. Nevertheless, it is thought that some components of rice bran such as cellulose (Farrell and Martin, 1998a), phytate-P (Farrell, 1994; Rutherfurd et al., 1997; Farrell and Martin, 1998b), or both, may exert properties that reduce its nutritive value for broilers, especially at high levels.

The AME value for FFRB varied according to bird age, the geographical origin of the rice bran and the level of FFRB inclusion. These data confirm, in part, the work of Wang et al. (1997) who reported that the response to enzyme supplementation in diets containing FFRB varied with geographical location. This effect can most likely be ascribed to differences in processing methods, rice cultivar, the growing environment, or a combination of all factors, during growth.

In Experiment 1, AME values for FFRB ranged from 16.01 to 20.10 MJ/kg DM, while in Experiment 2 values ranged from 8.37 to 12.82 MJ/kg DM contingent upon the level of FFRB and enzyme supplementation. The AME values for FFRB reported in both experiments are generally higher than the range of 9.6 to 10.8 MJ/kg DM reported by Warren and Farrell (1990). This is most likely attributable to the higher fat digestibility observed, but may also be a reflection of factors such as the level of FFRB used in the AME determination along with other issues such as length of storage, differences in bran extraction techniques and methodological influences. For example, a small error (variation from the sample mean) in the AME content of either the basal or FFRB-containing diets has a large influence on the AME value of FFRB (Martin and Farrell, 1998). This is most likely explained by the use of a lower level of FFRB (90 g/kg) in this study. Hence, and in the equation used for calculation of AME content of an ingredient, the small denominator of 0.09 (proportion of FFRB used in the diet) makes a notable difference to the AME content of FFRB. Higher inclusion levels (> 400 g/kg) may provide more reliable estimates of the AME content of FFRB, however inclusion rates of this level would not be used commercially (Pluske et al., 1997; Martin and Farrell, 1998).

The AME content of FFRB from Thailand was considerably lower than that of the Australian FFRB, although a similar AME content of diets with 90 g/kg FFRB was found in both experiments. The large difference was partly due to the lower AME content of diets containing FFRB from Thailand compared to the basal diets in Experiment 2 (table 6), whereas in Experiment 1 the AME values for the basal diets were less than the test diets with FFRB. This is difficult to explain because the basal diets from both experiments were of similar energy and protein formulation. However, some meat and bone meal was substituted for fishmeal in Experiment 2, and if the meat and bone meal was less metabolisable than the fishmeal, then this could have influenced the AME values for the basal diets.

An unexpected observation, especially in Experiment 2, was the improvement in AME content and bird production in the maize-soybean basal diet. Given that a diet of this type is typical of that used in broiler production in many parts of the world, there may be scope for the use of such an enzyme preparation to improve the efficiency of utilisation of these feed ingredients.

In conclusion, the data presented in this study failed to support the hypothesis that a lipase-based enzyme preparation would enhance the AME content of FFRB by increasing fat digestibility. However, principally in Experiment 2 when FFRB from Thailand was used, the enzyme enhanced the AME content of both diet and FFRB *per se*, as well as bird performance, in the first 14 days of age independently of any improvement in fat digestion. Fat digestibility improved with bird age, and deteriorated with higher levels (180 vs. 90 g/kg) of FFRB inclusion in the basal diet. These data suggest that the responses to such an enzyme preparation depend upon bird age, geographical origin of the rice bran, and the level of FFRB included in the diet. Nevertheless, the use of this enzyme preparation offers promise as a means of increasing the nutritive value of FFRB for broiler chickens.

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