Enhancing poultry performance

Final Report

An evaluation of VTR phytase in broiler chickens offered wheat-based diets

Poultry Research Foundation
within the University of Sydney

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Objective

This study was to evaluate the efficacy of exogenous phytase in wheat-soybean meal based-diets in broiler chickens from 1 to 42 days post-hatch housed on 'deep litter' or conditions similar to the commercial Australian situation.

Methodology

The experimental design was a 2 × 2 factorial array of treatments to evaluate the effect of two dietary levels of calcium (Ca), phosphorus (P) and sodium (Na) as positive (PC) and negative (NC) control diets and two levels of exogenous phytase (0 and 1000 FTU/kg feed) for a total of four dietary treatments. The diets were based on wheat and soybean meal based and formulated for starter (1 to 21 days post-hatch) and finisher (22 to 42 days post-hatch). In the finisher period, all diets contained 15% whole grain wheat. Otherwise, wheat was hammer-milled through 4 screen prior to incorporation into diets which were steam-pelleted at a temperature of 80°C with a conditioner residence time of 14 seconds The PC diets were formulated to meet 2014 Ross 308 nutrient specifications. The NC diets were formulated with reductions of 1.6 g/kg Ca, 1.3 g/kg P and 0.3 g/kg Na relative to the PC diets. A filler (sand) was used in order to maintain the same overall ingredient composition in both PC and NC diets. PC and NC diets were then supplemented VTR phytase at 1000 FTU/kg to comprise the remaining treatments. The composition and nutrient specifications of the starter and finisher diets are shown in Tables 1 to 4. Celite, a source of acid-insoluble ash (AIA) was added to the starter diets as an inert dietary marker. The analysed phytase activities of the experimental diets are shown in Table 5 which comfirms the accurate addition of exogenous phytase to the appropriate diets and the thermostability of the exogenous phytase. The analysed dietary concentrations of amino acids in the four starter diets are shown in Table 6.

The experimental data was generated by standard procedures in all instances. However, mention should be made of the methodology uderlying amino acid disappaearnce rates. Importantly, amino acid disappaearnce rates effectively represent intestinal uptakes of amino acids and aguably this kinetic assessment is more indicative than static amino acid digestibility coefficients. Amino acid disappearance rates are calculated from the following equation:

$$\text{AA disappearance rate}_{(g/bird/day)} = \text{dietary AA concentration}_{(g/kg)} \text{ x feed intake}_{(g/bird/day)} \text{ x AA digestibility coefficient.}$$

The experimental protocol was specifically approved by the Animal Ethics Committee of The University of Sydney. A total of 960 one day-old male Ross 308 birds were radomly assigned to 24 floor pens with 40 birds per pen and each treatment had 6 replicates. Pens were located in an enviromentally-controlled deep litter facility on the Camden Campus of the University of Sydney as illustrated in Figure 1. The temparature was maitained at 35°C for the first 3 days and then gradually reduced to 21°C. Body weights and feed intakes were recorded on day 1, 21 and 42 to calculate body weight gain and mortality corrected FCR. On day 21 5 birds selected at random from each pen were sacrificed to collect ileal digesta and toe samples to detemine protein and amino acid digestibility coefficients and disappearance rates and bone mineralisation. Experimental data was analysed by two-way analyses of variance useing the IBM® SPSS® Version 24 statistical package. The experimental units were pen means and differences were considered significant at the 5% level of probability.

Results

The overall performance of birds in the present study was outstanding. The off-sex, male Ross 308 broilers used in this feeding study outperformed 2014 Aviagen performance objectives for weight gain by 15.9% and FCR by 15.5% from 1 to 42 days post-hatch.

The effecets of treatments on growth performance and bone mineralisation are presented in Tables 7 to 9. In the starter phase, the transition from PC to NC diets significantly compromised weight gain by 2.11% and FCR by 1.71%. Birds offered the negative control diet with phytase had similar weight gains to birds offered the positive contro diet without phytase. Furthermore, the addition of phytase to the PC diet increased weight gain by 2.43% and feed intake by 1.61%. As a main effect, phytase significantly increased weight gain by 2.36% and feed intake by 1.82%. (Figure 2). In the grower phase, there was a treatment interaction ($P < 0.05$) between diet type and phytase inclusion. This was generated by phytase significantly increasing weight gain by 3.30% (2501 versus 2421 g/bird) following adddition to the negative control diet. Birds offered the negative control diet with phytase had numerically better weight gains than birds offered the positive control diet without or with phytase (Figure 3). As main effects, phytase tended to increase weight gain by 1.55% (3482 versus 3429 g/bird; $P = 0.083$) from 1 to 42 days post-hatch and the addition of phytase to NC starter and finisher diets increased weight gain by 3.02 % (3488 versus 3386) as shown in Figure 4.

Diet type significantly influenced mortality rates, the majority of which were observed in the finisher period. At 42 days post-hatch mortality rates of birds offered PC diets were higher than NC diets (8.2 % versus 2.3%; $P < 0.005$). The higher nutient specifiactions of the PC diets almost certainly contributed to this observation.

A significant treatment interaction ($P < 0.05$) was observed for percentage bone ash at 21 days post-hatch. Curiously, phytase numerically increased toe ash in birds offered PC diets but numerically decreased toe ash in NC birds.

The apparent digestibility coefficients of essential and non-essential amino acids are shown in Tables 10 and 11. Phytase increased lysine digestibility by 1.41% (0.868 versus 0.856; $P < 0.04$). The NC diet significantlty depressed digestibilities of alanine (1.94%), serine (2.30%) and tyrosine (1.87) and phytase increased tyrosine digestibility by 1.43% (0.854 versus 0.842; $P < 0.02$).

The disappearance rates of essential and non-essential amino acids are shown in Tables 12 and 13. Across the essential amino acids, there was a treatment interaction for methionoine. Otherwise, the NC diet significantly increased disappearance rates of arginine, histidine, leucine and threonine. However, phytase increased disappearance rates of eight essential amino acids to highly significant extents; for example, threonine disappearance rates were increased by 6.82% (0.423 versus 0.396; $P < 0.001$). There was a treatment interction for proline across the non-essential amino acids. Phytase significantly increased disappearance rates of eight non-essential amino acids; for example, glycine disappearance rates were increased by 5.08% (0.434 versus 0.413; $P = 0.001$). Instructively, phytase increased the total amino acid disapperance rate by 4.67% (10.31 versus 9.85 g/bird/day; $P < 0.001$).

Discussion

In the present study, the ‘protein effect’ of phytase was far more evident when consideration is given to apparent disappearance rates of amino acids. Given this outcome, the main effect of phytase expressed as percentage increases in apparent disappearance rates of amino acids are presented in Table 14, where the lysine result should be treated with caution. The reason that the phytase responses in amino acid disappearance rates are more pronounced than in amino acid digestibility coefficients stem from the phytase induced 1.82% significant increase in feed intakes in the starter period (Table 7) coupled with higher analysed amino acid concentrations in the phytase-supplemented diets (Table 6).

A significant treatment interaction and curious oycomes were observed for percentage toe ash at 21 days post-hatch. However, the overall 12.84% toe ash in 21 day-old broilers is indicative of entirely satisfcatory bone mineralisation. The likelihood is that there was sufficient phosphorus and calcium in all dietary treatments to support adequate bone mineralisation if not growth performance.

Table 1 Composition of starter diets (1 to 21 days post-hatch)

Ingredient (g/kg)	Positive control	Positive control plus phytase	Negative control	Negative control plus phytase
Wheat (ground)	507	507	525	525
Soybean meal	294	294	290	60
Canola meal	75	75	75	290
Soy oil	66	66	60	75
Lysine HCl	2.71	2.71	2.76	60
Methionine	2.66	2.66	2.63	2.76
Threonine	1.24	1.24	1.24	2.63
Valine	0.40	0.40	0.38	1.24
Isoleucine	-	-	-	0.38
Sodium chloride	2.23	2.23	2.19	-
Sodium bicarbonate	2.61	2.61	1.57	2.19
Limestone	6.13	6.13	7.27	1.57
Dicalcium phosphate	17.62	17.62	8.10	7.27
Xylanase	0.05	0.05	0.05	8.10
Phytase	-	0.10	-	0.05
Choline chloride (60%)	0.90	0.90	0.90	0.10
Celite	20.0	20.0	20.0	0.90
Sand	0.10	-	0.10	20.0
Vitamin-mineral premix[1]	2.00	2.00	2.00	-
				2.00

[1]The vitamin-mineral premix supplied per tonne of feed: [MIU] retinol 12, cholecalciferol 5, [g] tocopherol 50, menadione 3, thiamine 3, riboflavin 9, pyridoxine 5, cobalamin 0.025, niacin 50, pantothenate 18, folate 2, biotin 0.2, copper 20, iron 40, manganese 110, cobalt 0.25, iodine 1, molybdenum 2, zinc 90, selenium 0.3.

Table 2 Nutrient specifications of starter diets

Item (g/kg)	Positive control	Positive control plus phytase	Negative control	Negative control plus phytase
Metabolisable energy (MJ/kg)	12.77	12.77	12.77	12.77
Crude protein	232	232	232	232
Calcium	7.60	9.20	6.00	7.60
Total phosphorus	6.50	6.50	4.94	4.94
Available phosphorus	3.80	5.10	2.50	3.80
Phytate phosphorus	2.20	2.20	2.21	2.21
Non-phytate phosphorus	4.30	4.30	2.73	2.73
Digestible amino acids				
Lysine	12.12	12.12	12.12	12.12
Methionine	5.61	5.61	5.61	5.61
Threonine	8.00	8.00	8.00	8.00
Tryptophan	2.61	2.61	2.61	2.61
Isoleucine	8.24	8.24	8.24	8.24
Leucine	14.38	14.38	14.38	14.38
Arginine	13.08	13.08	13.08	13.08
Valine	9.57	9.57	9.57	9.57
Sodium	1.80	2.10	1.50	1.80
Potassium	9.38	9.38	9.38	9.38
Chloride	2.50	2.50	2.50	2.50
DEB (mEq/kg)	248	261	234	247

Table 3 Composition of finisher diets (22 to 42 days post-hatch)

Ingredient (g/kg)	Positive control	Positive control plus phytase	Negative control	Negative control plus phytase
Wheat (ground)	422	422	441	441
Whole wheat	150	150	150	150
Soybean meal	224	224	220	220
Canola meal	75	75	75	75
Soy oil	78	78	72	72
Lysine HCl	2.16	2.16	2.23	2.23
Methionine	2.00	2.00	1.97	1.97
Threonine	0.88	0.88	0.88	0.88
Valine	-	-	-	-
Isoleucine	-	-	0.01	0.01
Sodium chloride	1.50	1.50	1.46	1.46
Sodium bicarbonate	2.93	2.93	1.90	1.90
Limestone	4.57	4.57	5.71	5.71
Dicalcium phosphate	14.21	14.21	4.69	4.69
Xylanase	0.05	0.05	0.05	0.05
Phytase	-	0.10	-	0.10
Choline chloride (60%)	0.90	0.90	0.90	0.90
Celite	20.0	20.0	20.0	20.0
Sand	0.10	-	0.10	-
Vitamin-mineral premix[1]	2.00	2.00	2.00	2.00

[1]The vitamin-mineral premix supplied per tonne of feed: [MIU] retinol 12, cholecalciferol 5, [g] tocopherol 50, menadione 3, thiamine 3, riboflavin 9, pyridoxine 5, cobalamin 0.025, niacin 50, pantothenate 18, folate 2, biotin 0.2, copper 20, iron 40, manganese 110, cobalt 0.25, iodine 1, molybdenum 2, zinc 90, selenium 0.3.

Table 4 Nutrient specifications of finisher diets

Item (g/kg)	Positive control	Positive control plus phytase	Negative control	Negative control plus phytase
Metabolisable energy (MJ/kg)	13.30	13.30	13.30	13.30
Crude protein	205	205	205	205
Calcium	6.08	7.68	6.08	6.08
Total phosphorus	5.62	5.62	4.06	4.06
Available phosphorus	3.20	4.50	1.90	3.20
Phytate phosphorus	2.02	2.02	2.03	2.03
Non-phytate phosphorus	3.60	3.60	2.03	2.03
Digestible amino acids				
Lysine	10.09	10.09	10.09	10.09
Methionine	4.66	4.66	4.63	4.63
Threonine	6.76	6.76	6.76	6.76
Tryptophan	2.29	2.29	2.29	2.29
Isoleucine	7.16	7.16	7.16	7.16
Leucine	12.62	12.62	12.62	12.62
Arginine	11.17	11.17	11.17	11.17
Valine	8.12	8.12	8.12	8.12
Sodium	1.60	1.90	1.30	1.60
Potassium	7.93	7.93	7.89	7.89
Chloride	2.00	2.00	2.00	2.00
DEB (mEq/kg)	216	229	202	215

Table 5 Analysed phytase activities[1]

Experimental diet	Phytase activity (FTU/kg)	
	Mash diet	Pelleted diet
Starter – positive control	370	345
Starter - positive control plus phytase	1118	1095
Starter – negative control	320	381
Starter – negative control plus phytase	1021	1217
Finisher – positive control		375
Finisher - positive control plus phytase		1156
Finisher – negative control		361
Finisher – negative control plus phytase		1392
Phytase feed enzyme	13777	

[1]Spectrometric phytase analyses completed by Pacific Lab Services, Singapore. Report Number: 2018-12-11-003

Table 6 Analysed dietary concentrations (g/kg) of amino acids in the four starter diets

Amino acid	PC diet without phytase	PC diet with phytase	NC diet without phytase	NC diet with phytase
Arginine	13.5	13.8	13.9	14.4
Histidine	5.9	6.0	6.1	6.3
Isoleucine	9.7	9.9	10.0	10.2
Leucine	16.5	16.7	17.1	17.4
Lysine	12.9	13.1	13.4	14.4
Methionine	4.2	4.0	4.1	4.4
Phenylalanine	10.9	11.0	11.2	11.4
Threonine	9.0	9.2	9.4	9.9
Valine	10.9	11.10	11.2	11.6
Alanine	8.9	9.0	9.1	9.4
Aspartic acid	20.3	20.6	21.0	21.6
Glutamic acid	47.9	48.0	48.8	48.7
Glycine	9.5	9.6	9.8	10.1
Proline	15.0	15.1	15.4	15.2
Serine	10.8	10.9	11.2	11.4
Tyrosine	5.3	5.5	5.3	5.5
Total	211.1	213.5	216.9	222.1

Table 7 Effects of dietary treatments on growth performance in starter phase from 1 to 21 days post-hatch and bone mineralisation expressed as toe ash

Treatment		Weight gain	Feed intake	FCR	Toe ash	Mortalities
Diet	Phytase	(g/bird)	(g/bird)	(g/g)	(%)	(%)
Positive C.	0 FTU/kg	985	1158	1.176	12.90b	2.08
	1000 FTU/kg	1009	1177	1.168	13.35b	2.08
Negative C.	0 FTU/kg	965	1152	1.194	12.72a	0.83
	1000 FTU/kg	986	1173	1.189	12.39a	0.83
SEM		9.298	9.032	0.0060	0.1678	0.802
Main effects Diet						
PC		997b	1168	1.172a	13.12	2.08
NC		976a	1162	1.192b	12.55	0.83
Main effects Phytase						
0 FTU/kg		975a	1154a	1.185	12.81	1.46
1000 FTU/kg		998b	1175b	1.179	12.87	1.46
Significance (P =)						
Diet		0.034	0.543	0.004	0.003	0.135
Phytase		0.023	0.035	0.296	0.713	1.000
Diets x Phytase interaction		0.887	0.949	0.103	0.030	1.000

Item	Weight gain	Feed intake	FCR
2014 Ross performance objective	917	1218	1.328
Overall performance	986	1165	1.182

Table 8 Effects of dietary treatments on growth performance in finisher phase from 22 to 42 days post-hatch

Treatment		Weight gain	Feed intake	FCR	Mortalities
Diet	Phytase	(g/bird)	(g/bird)	(g/g)	(%)
Positive C.	0 FTU/kg	2487ab	3770	1.516	4.89
	1000 FTU/kg	2467ab	3696	1.499	7.37
Negative C.	0 FTU/kg	2421a	3778	1.561	1.44
	1000 FTU/kg	2501b	3865	1.545	1.43
SEM		23.134	77.441	0.0289	1.464
Main effects Diet					
PC		2480	3733	1.507	6.13b
NC		2461	3821	1.553	1.44a
Main effects Phytase					
0 FTU/kg		2454	3774	1.538	3.17
1000 FTU/kg		2484	3780	1.522	4.40
Significance (P =)					
Diet		0.502	0.268	0.114	0.004
Phytase		0.207	0.934	0.549	0.409
Diets x Phytase interaction		0.042	0.311	0.983	0.404

Item	Weight gain	Feed intake	FCR
2014 Ross performance objective	1983	3709	1.870
Overall performance	2469	3777	1.530

Table 9 Effects of dietary treatments on overall growth performance from 1 to 42 days post-hatch

Treatment		Weight gain	Feed intake	FCR	Mortalities
Diet	Phytase	(g/bird)	(g/bird)	(g/g)	(%)
Positive C.	0 FTU/kg	3472	4928	1.419	6.97
	1000 FTU/kg	3476	4874	1.403	9.46
Negative C.	0 FTU/kg	3386	4929	1.456	2.28
	1000 FTU/kg	3488	5037	1.444	2.26
SEM		29.023	81.121	0.0183	1.803
Main effects Diet					
PC		3474	4901	1.411	8.22b
NC		3437	4983	1.450	2.27a
Main effects Phytase					
0 FTU/kg		3429	4929	1.438	4.63
1000 FTU/kg		3482	4956	1.423	5.86
Significance (P =)					
Diet		0.217	0.321	0.059	0.004
Phytase		0.083	0.743	0.468	0.502
Diets x Phytase interaction		0.107	0.329	0.908	0.496

Item	Weight gain	Feed intake	FCR
2014 Ross performance objective	2981	5050	1.694
Overall performance	3456	4943	1.431

Table 10 Effects of dietary treatments on apparent ileal digestibility coefficients of essential amino acids at 21 days post-hatch

Treatment								Phenyl-		
Diet	Phytase	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	alanine	Threonine	Valine
PC	0 FTU/kg	0.871	0.843	0.835	0.840	0.857	0.944	0.854	0.783	0.823
	1000 FTU/kg	0.890	0.859	0.858	0.858	0.872	0.942	0.872	0.804	0.840
NC	0 FTU/kg	0.877	0.844	0.833	0.841	0.855	0.946	0.855	0.781	0.822
	1000 FTU/kg	0.877	0.840	0.833	0.839	0.864	0.943	0.855	0.781	0.820
SEM		0.0055	0.0057	0.0064	0.0064	0.0055	0.0071	0.0065	0.0071	0.0059
Main effects Diet										
Positive control		0.880	0.851	0.846	0.849	0.864	0.954	0.863	0.794	0.832
Negative control		0.870	0.842	0.833	0.840	0.860	0.955	0.855	0.781	0.821
Main effects Phytase										
0 FTU/kg		0.874	0.844	0.834	0.841	0.856a	0.945	0.854	0.782	0.822
1000 FTU/kg		0.883	0.849	0.845	0.849	0.868b	0.943	0.863	0.792	0.830
Significance (P =)										
Diet (D)		0.520	0.124	0.060	0.197	0.401	0.835	0.240	0.082	0.112
Phytase (P)		0.101	0.322	0.089	0.224	0.039	0.728	0.196	0.167	0.267
DxP interaction		0.085	0.090	0.084	0.133	0.564	0.945	0.173	0.154	0.165

ab Means within columns not sharing a common suffix are significantly different at the 5% level of probability

Table 11 Effects of dietary treatments on apparent ileal digestibility coefficients of non-essential amino acids at 21 days post-hatch

Treatment									
Diet	Phytase	Alanine	Aspartic acid	Glutamic acid	Glycine	Proline	Serine	Tyrosine	Mean
PC	0 FTU/kg	0.815	0.793	0.893	0.782	0834	0.816	0.846	0.839
	1000 FTU/kg	0.833	0.816	0.904	0.800	0.851	0.838	0.867	0.857
NC	0 FTU/kg	0.808	0.795	0.894	0.779	0.835	0.810	0.839	0.838
	1000 FTU/kg	0.808	0.794	0.892	0.775	0.841	0.806	0.841	0.838
SEM		0.0072	0.0071	0.0044	0.0075	0.0059	0.0066	0.0074	0.0060
Main effects Diet									
Positive control		0.824b	0.804	0.905	0.791	0.842	0.827b	0.856b	0.848
Negative control		0.808a	0.793	0.900	0.777	0.838	0.808a	0.840a	0.838
Main effects Phytase									
0 FTU/kg		0.811	0.794	0.893	0.780	0.835	0.813	0.842	0.839
1000 FTU/kg		0.820	0.804	0.898	0.787	0.846	0.822	0.854	0.847
Significance (P =)									
Diet (D)		0.046	0.128	0.258	0.075	0.446	0.008	0.044	0.117
Phytase (P)		0.225	0.176	0.273	0.371	0.081	0.181	0.013	0.179
DxP interaction		0.234	0.080	0.159	0.150	0.884	0.054	0.212	0.156

ab Means within columns not sharing a common suffix are significantly different at the 5% level of probability

Table 12 Effects of dietary treatments on apparent disappearance rates (g/bird/day) of essential amino acids at 21 days post-hatch

Treatment								Phenyl-		
Diet	Phytase	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	alanine	Threonine	Valine
PC	0 FTU/kg	0.648	0.274	0.446	0.764	0.610a	0.219b	0.513	0.388	0.495
	1000 FTU/kg	0.689	0.289	0.476	0.804	0.641b	0.211a	0.538	0.415	0.507
NC	0 FTU/kg	0.669	0.283	0.457	0.789	0.629b	0.213ab	0.525	0.402	0.505
	1000 FTU/kg	0.705	0.296	0.475	0.816	0.695c	0.232c	0.544	0.432	0.531
SEM		0.0065	0.0027	0.0048	0.0082	0.0062	0.0025	0.0054	0.0047	0.0056
Main effects Diet										
Positive control		0.668a	0.282a	0.461	0.784a	0.625	0.215	0.526	0.402a	0.507
Negative control		0.687b	0.289b	0.466	0.802b	0.662	0.222	0.535	0.417b	0.518
Main effects Phytase										
0 FTU/kg		0.658a	0.278a	0.452a	0.777a	0.619	0.216	0.519a	0.396a	0.500a
1000 FTU/kg		0.697b	0.292b	0.475b	0.810b	0.668	0.222	0.541b	0.423b	0.525b
Significance (P =)										
Diet (D)		0.011	0.010	0.356	0.037	< 0.001	0.010	0.103	0.004	0.057
Phytase (P)		< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.031	0.001	< 0.001	< 0.001
DxP interaction		0.752	0.690	0.199	0.427	0.012	< 0.001	0.604	0.780	0.814

abc Means within columns not sharing a common suffix are significantly different at the 5% level of probability

Table 13 Effects of dietary treatments on apparent disappearance rates (g/bird/day) of non-essential amino acids at 21 days post-hatch

Treatment									
Diet	Phytase	Alanine	Aspartic acid	Glutamic acid	Glycine	Proline	Serine	Tyrosine	Total
PC	0 FTU/kg	0.400	0.888	2.357	0.409	0.593a	0.486	0.247	9.74
	1000 FTU/kg	0.420	0.915	2.434	0.420	0.625b	0.512	0.267	10.21
NC	0 FTU/kg	0.403	0.915	2.393	0.417	0.614b	0.498	0.244	9.96
	1000 FTU/kg	0.424	0.955	2.427	0.437	0.676c	0.513	0.258	10.41
SEM		0.0047	0.0104	0.0209	0.0051	0.0063	0.0056	0.0027	0.0999
Main effects Diet									
Positive control		0.410	0.915	2.395	0.420	0.609	0.499	0.257b	9.98a
Negative control		0.414	0.935	2.410	0.427	0.645	0.505	0.251a	10.18b
Main effects Phytase									
0 FTU/kg		0.402a	0.901a	2.375a	0.413a	0.604	0.492a	0.246a	9.85a
1000 FTU/kg		0.422b	0.949b	2.430b	0.434b	0.650	0.513b	0.263b	10.31b
Significance (P =)									
Diet (D)		0.454	0.074	0.496	0.188	< 0.001	0.294	0.033	0.050
Phytase (P)		< 0.001	< 0.001	0.016	0.001	< 0.001	0.001	< 0.001	< 0.001
DxP interaction		0.986	0.538	0.317	0.873	0.025	0.921	0.304	0.930

abc Means within columns not sharing a common suffix are significantly different at the 5% level of probability

Table 14 The main effect of phytase expressed as percentage increases in apparent disappearance rates (g/bird/day) of amino acids

Amino acid	Percentage increase (%)
Arginine	5.93
Histidine	5.04
Isoleucine	5.09
Leucine	4.25
Lysine	7.92
Methionine	2.78
Phenylalanine	4.24
Threonine	6.82
Valine	5.00
Alanine	4.98
Aspartic acid	5.33
Glutamic acid	2.32
Glycine	5.08
Proline	7.62
Serine	4.27
Tyrosine	6.91
Total	4.67

Figure 1. The experimental floor pens in the deep litter shed in the University of Sydney.

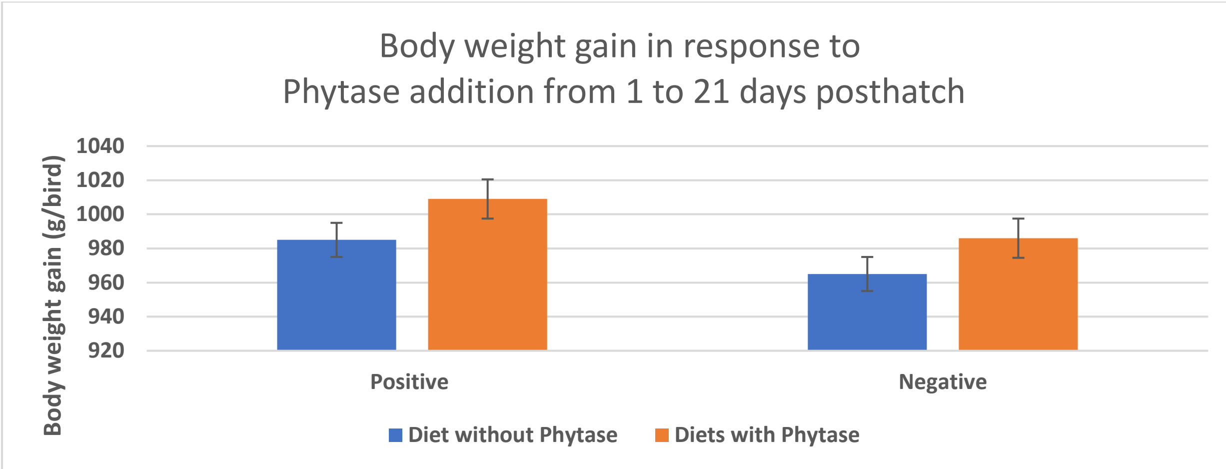

Figure 2. Chicken body weight gain in response to Phytase addition from 1 to 21 days post hatch

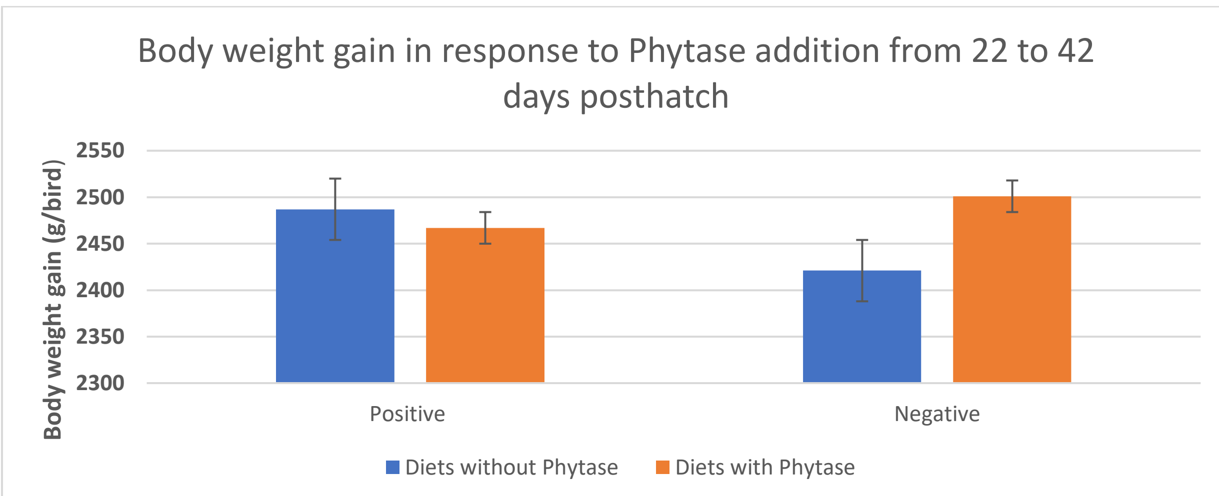

Figure 3. Chicken body weight gain in response to Phytase addition from 22 to 42 days post hatch

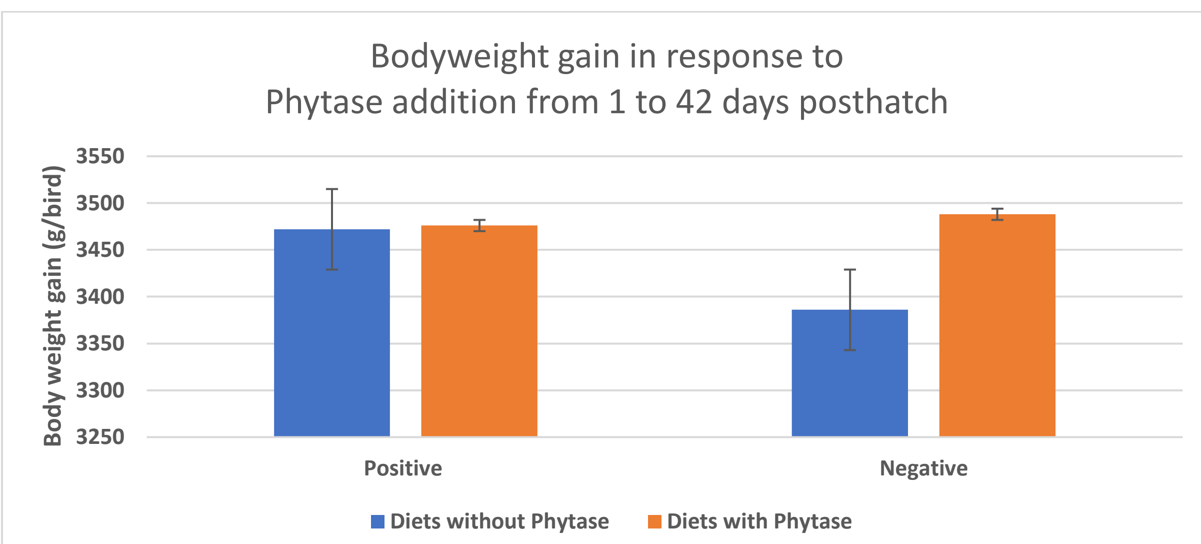

Figure 4 Chicken body weight gain in response to Phytase addition from 1 to 42 days post hatch