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Vasil Pirgozliev

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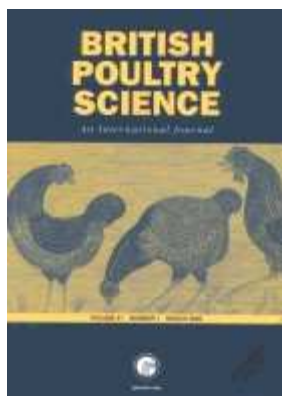
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The effects of supplementary bacterial phytase on dietary true metabolisable energy, nutrient digestibility and endogenous losses in precision fed turkeys

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5 1 **The effects of supplementary bacterial phytase on dietary true metabolisable energy,**
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8 2 **nutrient digestibility and endogenous losses in precision fed turkeys**
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12 4 V. PIRGOZLIEV, M. R. BEDFORD¹, T. ACAMOVIC AND ALLIMEHR, M.*
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15 6 *ASRC, SAC, West Mains Road, Edinburgh, EH9 3JG, UK, and ¹AB Vista Feed Ingredients,*
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59 20 **Correspondence to:** Dr. V. Pirgozliev, ASRC, SAC, West Mains Road, Edinburgh, EH9
60 21 3JG, UK

22 * Present address: University of Urmia, Faculty of Veterinary Medicine, Urmia, Iran

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4 24 **Abstract** 1. A total of 40 female BUT9 turkeys were used in a precision-feeding assay to
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6
7 25 investigate the effect of dietary phytase on true metabolisable energy corrected for N retention
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9 26 (TME_N), true nutrient digestibility (TND), and the excretion of endogenous mucin, measured
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11 27 as sialic acid (SA).

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13
14 28 2. Five treatments were used in this study: control (C), C + 250 phytase units (FTU) per kg
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16 29 feed, C + 500 FTU, C + 2500 FTU, and glucose only for endogenous losses estimation. Diets
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18 30 were formulated to be nutritionally adequate with the exception that the P content was
19
20 31 relatively low (3.6 g/kg non-phytate P).

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22
23 32 3. Inclusion of phytase increased TND in a quadratic manner with the optimum being
24
25 33 achieved at approximately 500 FTU, at which TND was 37 % greater than in the control. The
26
27 34 concentration of SA in the excreta decreased linearly with increased phytase supplementation.
28
29 35 Dietary TME_N , true dry matter digestibility (TDMD) and true mineral digestibility
30
31 36 coefficients were not significantly affected by phytase supplementation.

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33
34 37 4. Phytase inclusion increased digestibility coefficients for indispensable, dispensable and
35
36 38 total amino acids in a linear manner. The scale of the response to phytase was greatest with
37
38 39 threonine and least with lysine digestibility, suggesting a specific mechanism of action that
39
40 40 benefits gut health.

41
42 41 5. The strong negative relationship between secretion of SA and threonine digestibility
43
44 42 suggests that a large part of the threonine benefit may be from reduced mucin synthesis. This
45
46 43 supports the hypothesis that dietary phytase may play a role in improving the health status of
47
48 44 the intestine and, as a result, reduces the maintenance energy requirements of turkeys.

45 INTRODUCTION

46
47 46 The majority of P in plants, including maize and soybean meal, is contained in phytic acid or
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49 47 its salts, collectively known as phytates (Nelson *et al.*, 1971; Reddy *et al.*, 1982). Phytate is
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4 48 viewed as an anti-nutrient since it chelates minerals and reacts with dietary protein, thus
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6 49 reducing the availability of many nutrients (Selle and Ravindran, 2007). Poultry do not
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8
9 50 produce meaningful quantities of endogenous phytase, the enzyme that can hydrolyse the
10
11 51 ester bonds between the phosphate groups and the inositol ring in phytates. As a result,
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13
14 52 supplementation of poultry diets with commercially produced phytases is routine. The
15
16 53 beneficial effect of this enzyme is understood to be due to the direct hydrolytic effects on
17
18 54 phytate and the subsequent improvement in the availability of minerals, amino acids and
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20
21 55 energy, concomitant with reduced endogenous losses from the gastrointestinal tract (GIT)
22
23 56 (Selle and Ravindran, 2007; Cowieson and Ravindran, 2007; Pirgozliev *et al.*, 2009a).

25
26 57 The majority of studies on phytase supplementation of feed have been conducted with
27
28 58 broiler chickens, with relatively few having been conducted with turkeys, possibly as a result
29
30 59 of an assumption that both species will have a similar response. However, Pirgozliev *et al.*
31
32 60 (2007) demonstrated that turkeys were more responsive to phytase than chickens and, as a
33
34 61 result, cast doubt on the aforementioned assumption. Phytase activity, and therefore phytate
35
36 62 hydrolysis, in the intestines depends on intestinal pH, endogenous phytase activity and transit
37
38 63 time, parameters that may differ between the two species (Maenz and Classen, 1998; Kerr *et*
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40 64 *al.*, 2000; Simon and Igbasan, 2002). It therefore seems evident that application of broiler data
41
42 65 to turkeys may be ill-founded. There is a lack of information that relates exogenous phytase
43
44 66 activity with metabolisable energy, nutrient digestibility and endogenous losses when maize-
45
46 67 soybean meal diets are fed to young turkeys.

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51 68 The objective of this experiment was to address this issue and to further investigate the
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53 69 effects of phytase dose on excretion of intestinal mucin, as measured by the marker sialic acid
54
55 70 (SA) in precision fed female turkeys.
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59 71

MATERIALS AND METHODS

Diets

An *Escherichia coli*-derived phytase (Quantum™, EC 3.1.3.26; AB Vista Feed Ingredients, Marlborough, UK) was used in this experiment. Five treatments were used in this study: a control (C), C + 250 phytase units (FTU) per kg feed (C250), C + 500 FTU/kg (C500), C + 2500 FTU/kg (C2500) and glucose (G) only for endogenous losses estimation. Diets were formulated to be nutritionally adequate with the exception of P, which was present at a relatively low level (3.6 vs 7.0 g/kg diet; Table 1). The enzyme was added to the diets in powder form and all diets were fed in meal form.

Table 1 near here

Bird husbandry and excreta collection

A precision feeding experiment (McNab and Blair, 1988) was conducted to compare the effect of three dietary concentrations of phytase on the true digestibility of dietary nutrients, TME_N and SA excretion. A total of 40 female BUT9 turkeys were allocated to each of the 5 treatments used in this study (C, C250, C500, C2500 and G), each treatment being replicated 8 times in a randomised block design. Initially, the experimental birds were reared on a standard commercial wheat-based broiler diet from 1-d-old until they reached 45 d of age. The birds were then placed on a raised slatted floor pen without access to feed, litter or excreta. Water was supplied *ad libitum* throughout the study *via* a suspended nipple drinker line. To alleviate the stress of feed deprivation, the birds were given 50 ml of glucose solution (600g/l) after 24 h. After a further 24 h, the birds were given 50 g of the test diets and placed in individual cages (0.5m x 0.8m), designed for excreta collection, at a constant house temperature of 20°C and 23 h of light per d. The turkeys used for endogenous loss estimation were fed 50 ml glucose solution instead of the experimental diets. Excreta were quantitatively collected for 48 h after feeding.

96 The study was approved Animal Experimental Committee of SAC.

97 **Laboratory analysis**

98 After collection, excreta were freeze-dried, weighed and milled to pass through a 0.75-mm
99 mesh. The gross energy (GE) of feed and excreta was determined using an adiabatic bomb
100 calorimeter (Parr Instrument Company, Moline, IL, 61265, USA). The nitrogen content of the
101 excreta was determined by the method of Sweeney (1989) using an FP-200 nitrogen analyser
102 (LECO[®], St. Joseph, MI, USA). The TME_N of each of the experimental diets was then
103 calculated as described by McNab and Blair (1988). Amino acid content in feed and excreta
104 was determined by HPLC following oxygen-free hydrochloric acid digestion (Jones *et al.*,
105 1981). The system comprised a Dionex ASI-100 autosampler fitted with a Dionex P580 pump
106 and a Dionex RF-2000 detector (Sunnyvale, California, USA). The flow rate used was 1
107 ml/min and the column used was a Spherisorb ODS2 (150 x 4.6mm fitted with a Waters
108 guard cartridge). Since the method of hydrolysis destroys methionine, cystine and tryptophan,
109 data for these amino acids are not reported. The coefficient of metabolisability of glycine is
110 not presented because of confounding effect of glycine yield from acid hydrolysis of uric acid
111 in excreta (Soares *et al.*, 1971).

112 The mineral contents of feed and excreta were determined by inductively coupled
113 plasma emission spectrometry (Optima 4300 DV Dual View ICP-OE spectrometer, Perkin
114 Elmer, Beaconsfield, UK), (Tanner *et al.*, 2002). The concentration of excreta sialic acid was
115 determined by the periodate-resorcinol method described by Jourdian *et al.* (1971).

116 The true digestibility coefficients for DM, N, amino acids and minerals were
117 determined as follow:

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119
$$([\textit{intake} + (\textit{endogenous loss}) - \textit{excreted}] / \textit{intake})$$

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7 121 where *intake* is the intake of DM, N, amino acid or minerals by precision fed birds,
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9 122 *endogenous loss* is the DM, N, amino acid or mineral excreted by glucose fed birds, and
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11 123 *excreted* is the DM, N, amino acid or mineral excreted by bird fed experimental diets.
12
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14 124 **Statistical analysis**

15
16 125 The observational unit was a cage with one bird. Statistical analyses were performed by
17
18 126 GenStat (GenStat, 11th edition, Lawes Agricultural Trust, VSN International Ltd, Oxford,
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20
21 127 UK). The data were analysed by ANOVA with a random term block and a fixed term
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23 128 treatment. Polynomial contrasts were performed to test for linear and quadratic relationships
24
25 129 between phytase dose and the variable in question. Correlation coefficients were also
26
27 130 generated to test for a possible relationship between the different variates. In all instances,
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29 131 differences were reported as significant at $P \leq 0.05$ and trends were noted when the P value
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31 132 was 0.05 - 0.10.
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34

35 133 **RESULTS**

36
37 134 All birds remained healthy throughout the study period. There were no effects of diet on
38
39 135 dietary TME_N , TDMD of SA excretion over the 48-h collection period (Table 2). The
40
41 136 significant quadratic response of TND to phytase supplementation suggested that the
42
43 137 optimum phytase addition for nitrogen retention was in the range of 500 FTU/kg feed, at
44
45 138 which, TND was 37.3% higher than the control. SA concentration in the faeces was reduced
46
47 139 in a significant linear fashion with increasing phytase dosage.
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51 140 Despite the relatively large numerical increments in Ca and P digestibility with
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53 141 increasing phytase dosage, these differences were not significant (Table 3). The digestibility
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55 142 of all remaining minerals was unaffected by phytase dosage.

Tables 2 & 3 near here

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4 143 Exogenous phytase supplementation significantly improved the coefficients of
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6 144 digestibility of most of the measured dietary amino acids (Table 4) and in a dose dependent,
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8
9 145 linear manner. Threonine was the most responsive amino acid and histidine the least
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11 146 responsive.

Tables 4 & 5 near here

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14 147 Total SA excretion related negatively to most of the determined parameters (Table 5),
15
16 148 the most pronounced being that with TME_N ($r = -0.896$; $P < 0.001$) and true dietary threonine
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18 149 digestibility coefficient ($r = -0.909$; $P < 0.001$).

21 150 DISCUSSION

22
23 151 The fact that TND was subject to a quadratic dose relationship with phytase dose, the
24
25 152 optimum being in the region of 500 FTU, suggests that nitrogen digestibility responds very
26
27 153 rapidly to the first few units of phytase then reaches a plateau and may even decrease with
28
29 154 further increments in phytase. Whilst the initial beneficial effect was as expected, the decline
30
31 155 with higher doses is novel and may be specific to turkeys. The fact that the relationship
32
33 156 between dose and response was quadratic with TND but linear with all amino acids suggests
34
35 157 that the apparent loss in N digestibility beyond 500 FTU is a result of increased losses of non
36
37 158 protein nitrogen. This may be a consequence of the precision feeding procedure which limits
38
39 159 total nutrient intake and perhaps provides the animal with nutrients out of synchronisation
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41 160 with needs. Indeed, Härtel (1986) demonstrated that there is a lack of correlation between data
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43 161 obtained by precision compared to *ad libitum* fed birds. In addition, the results may be
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45 162 confounded by the use of excreta instead of ileal samples for amino acid determination. It has
46
47 163 been demonstrated that amino acid metabolism by microflora in the lower gut of chickens
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49 164 may be substantial and that amino acid digestibility measured in the terminal ileum would
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51 165 differ from that measured in the excreta (Ravindran *et al.*, 1999).

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4 166 Phytase supplementation more noticeably improved the digestibility of threonine,
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6 167 which is prevalent in endogenous secretion, than of lysine, which is primarily of dietary
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8 168 origin. Threonine comprises about two-thirds of the amino acid composition of mucin, and
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10 169 over half of the absorbed dietary threonine is used by the enterocytes (Allen, 1989). This
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12 170 suggests that phytase supplementation results in less mucin being excreted as has been
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14 171 reported earlier (Cowieson *et al.*, 2004).
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18 172 Whilst the SA content of the excreta was significantly reduced with increased phytase
19
20 173 dosage, total SA losses were not. It should be noted, however, that the percentage reductions
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22 174 in these parameters were actually greater for total losses, suggesting that lack of significance
23
24 175 may have been achieved with either greater precision or replication. Regardless, the general
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26 176 trends were in agreement with the literature. Threonine digestibility was inversely related to
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28 177 total SA losses and SA concentration in the excreta. In situations associated with increased
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30 178 endogenous excretions from the gastrointestinal tract, *e.g.* relatively high dietary phytate,
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32 179 threonine availability may limit intestinal mucin synthesis and consequently reduce gut barrier
33
34 180 functionality. Alternatively, increased mucin secretion will increase threonine losses and
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36 181 hence reduce its metabolisability. These data therefore confirm the hypothesis that phytase
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38 182 application reduces mucin losses in a dose dependent manner, and, as a result, this is
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40 183 accompanied by a dose dependent increment in threonine digestibility (Cowieson *et al.*, 2004,
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42 184 2006; Pirgozliev *et al.*, 2007, 2008).
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49 185 The positive effect of dietary phytase on the utilisation of N and amino acids may be a
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51 186 result of several mechanisms. The stepwise manner of dephosphorylation of dietary phytate
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53 187 will lead to production of various *myo*-inositol isomers and phosphates (Venekamp *et al.*,
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55 188 1995; Greiner *et al.*, 2000). The conditions of the gastrointestinal tract (time, pH, protease
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57 189 exposure) of poultry are not ideal for phytase to function optimally, so it is unlikely that
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4 190 commercial dosages of phytase will be able to dephosphorylate dietary phytate completely.
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6 191 Typically, 500 FTU of an *Aspergillus* phytase will result in only 40% IP6 destruction
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8 192 (Ravindran *et al.*, 2001). However, with increased phytase dosage, *e.g.* 2500 FTU/kg feed,
9
10 193 there will likely significantly less intact IP6, with relatively high number of lower ester forms
11
12 194 (Ravindran *et al.*, 2001; Zyla *et al.*, 2004; Pirgozliev *et al.*, 2008). It has been already shown
13
14 195 that the extent of interactions among N, amino acids and *myo*-inositol isomers will depend on
15
16 196 the degree of phosphorylation of the inositol ring (Knuckles *et al.*, 1989; Harland and Narula,
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18 197 1999). Lower molecular weight *myo*-inositol isomers such as mono- and di-phosphates have
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20 198 limited capacity to form chelates and to inhibit the digestibility of protein (Knuckles *et al.*,
21
22 199 1989; Harland and Narula, 1999). It has been also reported that removal of phosphate residues
23
24 200 from phytate results in a reduced impairment of intestinal uptake of essential dietary minerals,
25
26 201 *e.g.* P (the topic reviewed by Greiner and Konietzny, 2006). Presumably, some of the
27
28 202 beneficial effects noted in the current study associated with dietary phytase supplementation
29
30 203 were due to dephosphorylation of dietary phytate into lower molecular weight *myo*-inositol
31
32 204 isomers and a reduced capacity to interfere with amino acid utilization (Ravindran *et al.*,
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34 205 2001; Cowieson *et al.*, 2006).

35
36 206 Dietary phytase has quite consistently increased AME of broiler diets based on wheat
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38 207 and/or sorghum (Selle and Ravindran, 2007), so the lack of a significant difference in dietary
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40 208 TME_N in this study was not expected. However, the differences in the morphological and
41
42 209 physiological development of the chickens gut compared to those of turkeys at the same age
43
44 210 (Sklan *et al.*, 1982), may explain the fact that the changes in dietary metabolisable energy in
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46 211 this study did not exactly follow the same pattern noted with chickens. It has been also
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48 212 suggested that that metabolisable energy measures are not sensitive enough for evaluation of
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4 213 energetic effect of phytases since they do not take intake into account and *post* absorptive
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6 214 effects, both of which contribute to net energy (Pirgozliev *et al.*, 2009b).
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9 215 Including phytase in the diet did not result in significant increments in mineral
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11 216 digestibility coefficients in this study, although it has been often reported in work with
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13 217 chickens (Selle and Ravindran, 2007). However, Rodehutsord and Dieckmann (2005) have
14
15 218 demonstrated that different poultry species utilise dietary minerals with varying degrees of
16
17 219 efficiency. For example, utilisation of plant P was 58% in broilers and only 39% in turkeys.
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19 220 The lack of sufficient mineral supply in the experimental diets in this study may therefore
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21 221 partly explain the lack of response to phytase. Research by Létourneau-Montminy *et al.*
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23 222 (2008) also suggested that differences in level of production, *e.g.* growth (associated with
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25 223 amino acid digestibility) and bone mineralisation (associated primarily with mineral
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27 224 digestibility), may require different mineral balance and also different supplemental phytase
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29 225 activities.
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35 226 It may be concluded that young turkeys can tolerate phytase activities much higher
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37 227 than 1000 FTU and have been shown to benefit from such doses. The results from this study
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39 228 show that dietary phytase primarily influences the digestibility of dietary nitrogen and amino
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41 229 acids, with the effect on threonine being most noticeable. It is unclear why nitrogen
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43 230 digestibility peaks at 500 FTU/kg then falls, whilst amino acid digestibility continued to
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45 231 improve, but this is possibly related to an imbalance in amino acids leading to increased uric
46
47 232 acid losses. The linkage between threonine digestibility and mucin losses, as measure by SA
48
49 233 losses, further emphasises the importance of this amino acids in mucin synthesis. Clearly
50
51 234 phytate and phytase play a role in determining mucin losses and, as a result, the threonine
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53 235 requirements of the animal. However, to understand the mode of action of dietary phytases
54
55 236 further research on *myo*-inositol isomers of lower molecular weight needs to be completed.
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Table 1. *Ingredient composition (g/kg 'as fed') of the control experimental diet*

Feedingstuff	(g/kg)		
Maize	475.7		
Soya bean meal (48)	444.5		
Vegetable oil	30.0		
Limestone	25.0		
Mono DCP	10.0		
Salt	3.5		
Lysine HCl	2.0		
Methionine	4.3		
Vitamin mineral premix	5.0		
Total	1000		
<i>Calculated analysis (as fed basis)</i>			
ME (MJ/kg)	12.19		
Sodium g/kg	0.16		
Total P (g/kg)	6.40		
Non-phytate P (g/kg)	3.60		
<i>Analysed values (DM)²</i>			
GE (MJ/kg) ³	19.40		
CP (N x 6.25) g/kg	288		
DM (g/kg)	881		
<i>Amino acid composition (g/kg DM)</i>		<i>Mineral composition (g/kg DM)</i>	
Alanine	14.40	Calcium	15.2
Arginine	17.77	Potassium	13.40
Aspartate	34.28	Magnesium	2.15
Glutamate	58.25	Manganese	0.12
Histidine	6.69	Sodium	1.45
Isoleucine	15.29	Phosphorus	7.17
Leucine	26.08	Sulfur	3.52
Lysine	19.92	Zinc	0.09
Phenylalanine	15.07		
Serine	10.06		
Threonine	9.74		
Tyrosine	6.37		
Valine	15.38		

¹The vitamin and mineral premix contained vitamins and trace elements to meet the requirements specified by NRC (1984). All the experimental diets were designed to be low in P. The premix provided (units/kg diet): retinol 3600 µg, cholecalciferol 125 µg, α-tocopherol 34 mg, menadione 3 mg, thiamine 2 mg, riboflavin 7 mg, pyridoxine 5 mg, cobalamin 15 µg, nicotinic acid 50 mg, pantothenic acid 15 mg, folic acid 1 mg, biotin 200 µg, iron 80 mg, copper 10 mg, manganese 100 mg, cobalt 0.5 mg, zinc 80 mg, iodine 1 mg, selenium 0.2 mg and molybdenum 0.5 mg.

²Analyses were performed in duplicate.

³Gross energy.

Table 2. *The effect of phytase on true metabolisable energy corrected for nitrogen retention (TME_N), true dry matter (TDMD) and true nitrogen (TND) digestibility coefficients, and sialic acid (SA) excretion when precision fed to 47-d-old female turkeys*

Parameters/ Treatments	C ¹	C+250 ²	C+500 ²	C+2500 ²	LSD ³	P ⁴	L ⁵	Q ⁶
TME_N (MJ/kg DM)	15.97	16.22	16.37	16.33	1.057	NS	NS	NS
TDMD	0.788	0.806	0.813	0.815	0.0652	NS	NS	NS
TND	.590	0.615	0.810	0.668	0.1127	<0.05	<0.05	<0.05
SA ($\mu\text{g/g}$ excreta)	2.110	2.253	1.913	1.859	0.2983	<0.05	<0.05	NS
SA (μg excreted/48 h)	38.6	38.7	31.6	31.2	11.12	NS	0.099	NS

¹Control maize-based diet was low (3.6 g/kg non-phytate P) in available phosphorus.

²Phytase activity (units/kg) in diet.

³Least significant differences between means.

⁴Significance between treatments determined by ANOVA.

⁵Linear effects of added dietary phytase activities.

⁶Quadratic effects of added dietary phytase activities.

^{4,5,6}Results are statistically significant when $P \leq 0.05$ (the P values around 0.1 are described as showing a tendency).

Table 3. *The effect of phytase on true digestibility of dietary minerals when precision fed to 47-d-old female turkeys*

Minerals/ Treatments	C ¹	C+250 ²	C+500 ²	C+2500 ²	LSD ³	P ⁴	L ⁵	Q ⁶
Ca	0.651	0.656	0.646	0.738	0.0981	NS	0.107	NS
K	0.526	0.529	0.573	0.526	0.2127	NS	NS	NS
Mn	0.470	0.415	0.478	0.490	0.1529	NS	NS	NS
Mg	0.458	0.533	0.593	0.580	0.2137	NS	NS	NS
Na	0.640	0.699	0.748	0.703	0.2557	NS	NS	NS
P	0.429	0.640	0.600	0.558	0.1990	NS	NS	0.074
S	0.731	0.753	0.780	0.731	0.1399	NS	NS	NS
Zn	0.502	0.463	0.485	0.587	0.2711	NS	NS	NS

¹Control maize-based diet was low (3.6 g/kg non-phytate P) in available phosphorus.

²Phytase activity (units/kg) in diet.

³Least significant differences between means.

⁴Significance between treatments determined by ANOVA.

⁵Linear effects of added dietary phytase activities.

⁶Quadratic effects of added dietary phytase activities.

^{4, 5, 6} Results are statistically significant when $P \leq 0.05$ (the P values around 0.1 are described as showing a tendency).

Table 4. *The effect of phytase on the true digestibility coefficients of dietary amino acids when precision fed to 47-d-old female turkeys*

Amino acids/ Treatments	C ¹	C+250 ²	C+500 ²	C+2500 ²	LSD ³	P ⁴	L ⁵	Q ⁶
Indispensable								
Arginine	0.935	0.935	0.962	0.959	0.0216	<0.05	<0.05	NS
Histidine	0.928	0.922	0.956	0.949	0.0218	<0.05	<0.05	NS
Isoleucine	0.891	0.893	0.917	0.923	0.0284	0.069	<0.05	NS
Leucine	0.902	0.905	0.928	0.931	0.0242	<0.05	<0.05	NS
Lysine	0.934	0.924	0.958	0.961	0.0234	<0.05	<0.05	NS
Phenylalanine	0.898	0.906	0.927	0.931	0.0241	<0.05	<0.05	NS
Threonine	0.831	0.813	0.870	0.883	0.0508	<0.05	<0.05	NS
Valine	0.868	0.868	0.897	0.904	0.0372	0.105	<0.05	NS
Dispensable								
Alanine	0.864	0.862	0.895	0.900	0.0382	0.097	<0.05	NS
Aspartic acid	0.909	0.901	0.922	0.940	0.0275	<0.05	<0.05	NS
Glutamic acid	0.930	0.927	0.943	0.954	0.0183	<0.05	<0.05	NS
Serine	0.874	0.858	0.908	0.907	0.0467	0.092	<0.05	NS
Tyrosine	0.869	0.869	0.924	0.915	0.0450	<0.05	<0.05	NS
Average indispensable	0.897	0.894	0.926	0.929	0.0287	<0.05	<0.05	NS
Average dispensable	0.889	0.883	0.918	0.923	0.0334	0.05	<0.05	NS
Average total amino acids	0.895	0.891	0.923	0.927	0.0302	<0.05	<0.05	NS

¹Control maize-based diet was low (3.6 g/kg non-phytate P) in available phosphorus.

²Phytase activity (units/kg) in diet.

³Least significant differences between means.

⁴Significance between treatments determined by ANOVA.

⁵Linear effects of added dietary phytase activities.

⁶Quadratic effects of added dietary phytase activities.

^{4, 5, 6} Results are statistically significant when $P \leq 0.05$ (the P values around 0.1 are described as showing a tendency).

Table 5. Correlation matrix for the dietary metabolisable energy, nitrogen, dry matter, mineral and amino acids response criteria of female turkeys to dietary phytase supplementation

	TME _N (DM)	TDMD	TND	TDThre	TDDisp	TDIndisp	TDTotal	TDS	TDP	TDCa	SATotal	SAConc
TME _N (DM)	1.000											
TDMD	0.983	1.000										
TND	0.858	0.933	1.000									
TDThre	0.873	0.810	0.680	1.000								
TDDisp	0.878	0.815	0.664	0.987	1.000							
TDIndisp	0.867	0.801	0.675	0.990	0.996	1.000						
TDTotal	0.872	0.807	0.672	0.990	0.999	1.000	1.000					
TDS	0.914	0.942	0.896	0.760	0.752	0.736	0.742	1.000				
TDP	0.772	0.833	0.807	0.401	0.416	0.424	0.422	0.725	1.000			
TDCa	0.807	0.808	0.647	0.719	0.708	0.700	0.703	0.752	0.614	1.000		
SATotal	-0.896	-0.866	-0.792	-0.909	-0.877	-0.877	-0.878	-0.843	-0.612	-0.797	1.000	
SAConc	-0.472	-0.412	-0.421	-0.717	-0.659	-0.664	-0.663	-0.444	-0.076	-0.519	0.786	1.000

d.f. = 10. Correlation coefficients greater than 0.576 and 0.708 are statistically significant at 5% ($P < 0.05$) and 1% level ($P < 0.001$), respectively.

Key: TME_N (DM), TDMD and TND are the determined dietary true metabolisable energy corrected for nitrogen retention, true dry matter and true nitrogen digestibility coefficients.

TDThre, TDDisp, TDIndisp and TDTotal are the determined true digestibility coefficients of dietary threonine, dispensable, indispensible and total amino acids.

TDS, TDP and TDCa are the determined true digestibility coefficients of dietary sulfur, phosphorus and calcium.

SATotal is the total amount of sialic acid excreted during the 48 hour experimental period. SAConc is the concentration of the excreted sialic acid.