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1 **Metabolizable energy content of wheat distillers' dried grains with solubles supplemented**
2 **with or without a mixture of carbohydrases and protease for broilers and turkeys**

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18 **ABSTRACT**

19 Two experiments were conducted to determine the apparent metabolizable energy (**AME**) and
20 nitrogen-corrected AME (**AME_n**) of wheat distillers' dried grains with solubles (**wheat-DDGS**)
21 without or with supplementation of an enzyme mixture containing xylanase, amylase and
22 protease (**XAP**) in broilers and turkeys. One hundred twenty-six male Ross 308 broilers
23 (Experiment 1) or 126 male BUT 10 turkeys (Experiment 2) were offered a nutrient-adequate
24 diet from d 1 to 14. On d 14, birds in each experiment were allocated to six treatments consisting
25 of three levels of wheat-DDGS (0, 300, or 600 g/kg) and two levels of XAP (0 or 250 mg/kg of
26 diet) in a randomized complete block design. The AME or AME_n content of wheat-DDGS was
27 determined from the slope of regression of wheat-DDGS-associated energy intake (kcal) against
28 wheat-DDGS intake (kg). In experiment 1, wheat-DDGS inclusion in the diets linearly decreased
29 ($P < 0.05$) DM retention, AME and AME_n, irrespective of XAP supplementation. The AME of
30 wheat-DDGS without or with XAP for broilers was 3,587 or 3,700 kcal/kg DM, respectively and
31 AME_n was 3,356 and 3,459 kcal/kg DM for wheat-DDGS without and with XAP, respectively.
32 In experiment 2, wheat-DDGS inclusion in the diet linearly decreased ($P < 0.05$) DM retention
33 irrespective of XAP supplementation. Diet AME and AME_n linearly decreased ($P < 0.05$) as the
34 level of wheat-DDGS increased in the diets without added XAP, whereas there was no effect of
35 increasing wheat-DDGS level on dietary AME or AME_n in the XAP-supplemented diets. The
36 AME of wheat-DDGS without and with supplemental XAP for turkeys were 3,355 and 3,558
37 kcal/kg DM, respectively and AME_n was 3,109 and 3,294 kcal/kg DM, respectively, for wheat-
38 DDGS without and with XAP. Supplemental XAP increased ($P > 0.05$) the AME and AME_n of
39 wheat-DDGS for broilers and turkeys by up to 6%. It was concluded that wheat-DDGS is a
40 valuable source of AME for broilers and turkeys.

41 **Keywords:** broilers, DDGS, enzyme supplementation, metabolizable energy, turkeys

42 **INTRODUCTION**

43 The use of wheat for bioethanol production is expected to increase in the future (Batal and Dale,
44 2006). This will also increase the quantity of wheat Distillers Dried Grains with Solubles
45 (**wheat-DDGS**) available as a feed ingredient for poultry. Wheat-DDGS is a viable feedstuff for
46 poultry because nutrient (other than starch) levels are concentrated 3-fold in the wheat-DDGS
47 after the starch fraction in the wheat is converted to ethanol (Nyachoti et al. 2005). Wheat is
48 commonly used as a source of ME for poultry and it is likely that wheat-DDGS will also be a
49 good source of ME for poultry. The apparent metabolizable energy (**AME**) and nitrogen-
50 corrected AME (**AME_n**) contents of corn-DDGS have been determined in broilers (Batal and
51 Dale, 2006; Adeola and Ilekeji, 2009) and the inclusion of corn-DDGS in diets for broilers and
52 turkeys have been reported to support growth performance (Thacker and Widyaratne, 2007; Loar
53 et al. 2010). Compared with corn-DDGS, there is insufficient information about the nutritive
54 value of wheat-DDGS for broilers and turkeys. In addition, the use of wheat-DDGS for poultry
55 may reduce competition between wheat demand for poultry and bioethanol production. In view
56 of the possibility of using wheat-DDGS as a feed ingredient for broilers and turkeys, it is
57 essential to determine its utilizable energy content.

58 Exogenous enzymes may ameliorate the anti-nutritive effects of non-starch polysaccharides
59 (**NSP**) and phytate, and hence enhance the digestibility of feed ingredients and reduce nutrient
60 excretion to the environment by poultry (Adeola and Cowieson, 2011; Woyengo and Nyachoti,
61 2011). The efficacy of exogenous enzymes to improve the nutritive value of bioethanol co-
62 products has been determined mostly for bioethanol co-products derived from corn (Adeola and

63 Ileleji, 2009; Adeola et al. 2010). On the other hand, information about the value of exogenous
64 enzymes to improve energy utilization in wheat-DDGS in broilers and turkeys is currently
65 lacking in the literature. Development of nutrient matrix values for exogenous enzymes in wheat-
66 DDGS will help in formulating diets that closely match bird requirement and prevent excessive
67 surfeit.

68 The objective of the current study was to determine the AME and AME_n of wheat-DDGS
69 without or with an enzyme mixture containing xylanase, amylase and protease (**XAP**) activities
70 for broilers and turkeys.

71 **MATERIALS AND METHODS**

72 *Animals and Management*

73 The Scotland's Rural College's Animal Experimentation Committee approved all bird handling
74 and sample collection procedures.

75 One hundred twenty-six male Ross 308 broilers chicks (Experiment 1) or 126 male BUT 10
76 turkeys (Experiment 2) were used for determination of AME and AME_n contents of wheat-
77 DDGS. Birds had *ad libitum* access to the diets and water during the entire pre- and experimental
78 periods and were reared in a house with facilities to control temperature, light, and humidity. In
79 each of the experiments, the birds were offered a pre-experimental diet formulated to meet
80 energy and nutrient requirements according to breeder recommendation for Ross 308 broilers
81 (Aviagen, 2007) or BUT 10 turkeys (Aviagen, 2013), respectively. In each experiment, birds
82 were allocated to experimental diets in a randomized complete block design using d 14

83 bodyweight as blocking criterion and transferred to metabolism cages on d 14. Each treatment
84 had seven replicate cages and three birds per replicate cage.

85 *Diets and Sample Collection*

86 The pre-experimental diet offered from d 1 to 14 in experiment 1 and 2 contained (as-is), 3,035
87 kcal/kg of ME, 230 g/kg of CP and 6.8 g/kg of P. Six experimental diets were used in each of the
88 two experiments. These diets consisted of a wheat-soyabean meal based reference diet
89 containing no wheat-DDGS and two test diets containing 300 or 600 g/kg of wheat-DDGS,
90 respectively and each of these three diets without or with added XAP (0.25 g/kg). At inclusion
91 rate of 0.25 g/kg, the XAP supplied 2,000, 200 and 4,000 U/kg of xylanase, amylase and
92 protease activities, respectively. The xylanase was a endo-1,4-beta-xylanase produced by a
93 *Trichoderma longibrachiatum* and expressed in the same organism. The amylase was produced
94 by *Bacillus amyloliquifaciens* and expressed in *Bacillus subtilis*. The subtilisin (protease) was
95 derived from *Bacillus subtilis*. The three enzymes were produced separately and later blended to
96 produce the xylanase-amylase-protease (XAP) admixture. One unit (U) of xylanase was defined
97 as the quantity of the enzyme that liberates one mmol of xylose equivalent per minute. One unit
98 of amylase was defined as the amount of the enzyme catalyzing the hydrolysis of one millimole
99 glucosidic linkage per minute and one protease unit was defined as the quantity of the enzyme
100 that solubilized one mg of azo-casein per minute. Energy-yielding ingredients such as wheat,
101 soybean meal (SBM), gluten meal and soy oil were substituted with wheat-DDGS in a way that
102 their ratios were the same across all the experimental diets.

103 Titanium dioxide (TiO₂) was added to the experimental diets (3 g/kg of diet) as an indigestible
104 marker to enable determination of ME content by the index method. Experimental diets were

105 offered from d 14 to 21 in both experiments. The ingredient and chemical compositions of the
106 experimental diets used in both experiments are shown in Table 1. Excreta were collected daily
107 from each cage for 3 d (d 18 to 20), dried and pooled for each cage prior to analysis.

108 *Chemical analysis*

109 Samples of diets, wheat-DDGS and excreta were analyzed for GE, DM, Ti, and N where
110 necessary. Excreta were oven dried and ground to pass through a 0.5 mm screen using a mill
111 grinder (Retsch ZM 100, F. Kurt Retsch GmbH & Co.KG, Haan, Germany) before chemical
112 analysis. To determine DM content, samples were dried at 105°C for 24 hours (AOAC
113 International 2006, method 934.01) in a drying oven (Uniterm, Russel-Lindsey Engineering Ltd.,
114 Birmingham, England, UK). Gross energy was determined in a Parr adiabatic bomb calorimeter
115 using benzoic acid as an internal standard (Model 6200, Parr Instruments, Moline, Illinois,
116 USA). Nitrogen was determined by the combustion method (AOAC International 2006, method
117 968.06). Analysis for Ti was performed as described by Short et al. (1996). Xylanase activity in
118 the experimental diets was measured using a kit (Megazyme International Ireland Ltd., Bray,
119 Ireland) based on the method by McCleary (1991). Amylase activity was measured using
120 Phadebas (Megazyme International Ireland Ltd.) tablets according to the method described by
121 McCleary and Sheehan (1989). Protease activity was determined using the modified method of
122 Lynn and Clevette-Radford (1984) with azo-casein as substrate.

123 *Calculations and Statistical Analysis*

124 Energy retention was calculated using the index method and AME was calculated as a product of
125 energy retention coefficient and the gross energy content of the diet. Nitrogen-correction AME

126 was calculated using the correction factor of 8.73 as the caloric correction factor for retained
127 nitrogen (Titus, 1956).

128 Wheat-DDGS-associated AME intake was calculated following Adeola et al. (2010) procedures
129 and described using the following equations: If the coefficients of AME for the assay diet, basal
130 diet and test ingredient (wheat-DDGS) are represented by Cad, Cbd and Cti, respectively.
131 Assuming additivity in diet formulation, the proportional contribution of energy by the basal
132 (Pbd) and test ingredients (Pti) to the assay diet will be equal to 1. Mathematically; $Pbd + Pti = 1$
133 or $Pbd = 1 - Pti$.

134 Therefore;

135 1. $Cad = (Cbd \times Pbd) + (Cti \times Pti)$

136 By solving for Cti,

137 2. $Cti = [Cad - (Cbd \times Pbd)]/Pti$

138 Substituting $1 - Pti$ for Pbd;

139 3. $Cti = \left\{ Cbd + \left[\frac{Cad - Cbd}{Pti} \right] \right\}$

140 The product of Cti at each non-zero levels of wheat-DDGS substitution rates, the GE of wheat-
141 DDGS and wheat-DDGS intake in kg is the wheat-DDGS-associated AME intake in kcal.

142 Data were analyzed using the Generalized Linear Models of Genstat Statistical Package (11th
143 edition, VSN International). Statistical significance was set at $P < 0.05$ and tendency at $0.05 < P$
144 < 0.10 for all mean comparisons. Dietary DM retention, AME and AME_n data were analyzed as a

145 3 × 2 factorial of wheat-DDGS inclusion level (0, 300 or 600 g/kg) and XAP (not added or
146 added) using ANOVA procedures. Orthogonal contrasts were used to determine the differences
147 in utilizable energy between the dietary treatments with different inclusion levels of wheat-
148 DDGS and those without or with added XAP. The regression of wheat-DDGS associated AME
149 or AME_n (kcal) against wheat-DDGS intake (kg) was done using regression analysis procedures.
150 The slope of the linear regression equation represented the AME or AME_n value of wheat-
151 DDGS. In the seven blocks, each consisting of six treatments (3 levels of wheat-DDGS and 2
152 levels of XAP), regression of wheat-DDGS-associated AME or AME_n against wheat-DDGS
153 intake generated seven intercepts and seven slopes. The slope data were analyzed using
154 ANOVA. The additional energy provided by the XAP supplementation was calculated as the
155 differential between the slopes of diets not supplemented with XAP and those supplemented with
156 XAP.

157 **RESULTS**

158 **Dietary dry matter and energy retention**

159 The chemical composition of the wheat-DDGS used in the current study is presented in Table 2.
160 The analyzed CP, AA, crude fiber and gross energy contents in the wheat-DDGS were greater
161 compared with wheat.

162 Dietary DM and energy retention for broilers receiving graded levels of wheat-DDGS without-
163 or with added XAP in experiment 1 are presented in Table 3. For broilers, there were no wheat-
164 DDGS × XAP interactions for diet DM retention, AME or AME_n. Increasing the inclusion level
165 of wheat-DDGS from 0 to 600 g/kg in the diets linearly decreased ($P < 0.05$) DM retention and

166 diet AME but decreased ($P < 0.05$) diet AME_n in a quadratic manner (Table 3). Supplemental
167 XAP tended to improve ($P < 0.10$) DM retention, diet AME and AME_n.

168 Dietary DM and energy retention for turkeys receiving graded levels of wheat-DDGS without- or
169 with added XAP in experiment 2 are presented in Table 4. For turkeys, there was no wheat-
170 DDGS \times XAP interaction for diet DM retention. Increasing the dietary inclusion level of wheat-
171 DDGS from 0 to 600 g/kg linearly decreased ($P < 0.05$) DM retention, irrespective of XAP.
172 There were wheat-DDGS \times XAP interactions ($P < 0.05$) for diet AME and AME_n. The
173 interaction noted was because increasing the inclusion level of wheat-DDGS linearly decreased
174 ($P < 0.05$) AME and AME_n in the diets not supplemented with XAP. On the other hand, AME or
175 AME_n there was no effect of increasing wheat-DDGS inclusion level on diet in the XAP-
176 supplemented diets.

177 **Apparent metabolizable energy content in wheat distillers dried grains with solubles for** 178 **broilers and turkeys**

179 The AME and AME_n values of wheat-DDGS without- or with supplemental XAP for broilers are
180 presented in Table 5. From the slope of the linear regression equations, the AME \pm SEM (kcal/kg
181 DM) of wheat-DDGS for broilers without- or with supplemental XAP were $3,587 \pm 53$ or $3,700$
182 ± 81 , respectively. Corresponding AME_n \pm SEM (kcal/kg DM) were $3,356 \pm 47$ and $3,459 \pm 71$,
183 respectively. Addition of XAP increased ($P > 0.05$) the AME or AME_n of wheat-DDGS for
184 broilers by 113 or 103 kcal/kg DM, respectively.

185 The AME and AME_n values of wheat-DDGS without- or with supplemental XAP for turkeys are
186 presented in Table 5. The AME \pm SEM values (kcal/kg DM) of wheat-DDGS without- or with

187 supplemental XAP for turkeys were $3,355 \pm 108$ or $3,558 \pm 96$, respectively. Corresponding
188 $AME_n \pm SEM$ values (kcal/kg DM) were $3,109 \pm 97$ or $3,294 \pm 85$, respectively (Table 5).
189 Supplemental XAP increased ($P > 0.05$) the AME or AME_n of wheat-DDGS for turkeys by 203
190 or 185 kcal/kg DM, respectively.

191

192

DISCUSSION

193 The objective of the current study was to determine the AME and AME_n contents of wheat-
194 DDGS without or with added XAP for broilers and turkeys. Because the experiments were
195 designed in a 3 × 2 factorial arrangement, this also afforded the determination of dietary DM
196 retention, AME and AME_n.

197 The chemical characteristics of the wheat-DDGS used in the current study are comparable to
198 those used in the study of Bolarinwa and Adeola (2012) as well as the mean values of 930 g/kg
199 of DM, 380 g/kg of CP, 4,780 kcal/kg of GE, 77 g/kg of CF, 54 g/kg of EE, 344 g/kg of NDF,
200 139 g/kg of ADF and 53 g/kg of ash from eleven sources of wheat-DDGS (Olukosi and Adebisi,
201 2013). Nonetheless, there is wide variability in the chemical composition of wheat-DDGS among
202 sources (Olukosi and Adebisi, 2013) which in turn may affect its nutritional characteristics for
203 poultry.

204 Increasing the inclusion level of wheat-DDGS in the reference diet decreased DM retention,
205 irrespective of XAP supplementation for broilers and turkeys in the current study. Bolarinwa and
206 Adeola (2012) noted a linear reduction in DM and energy retention when 20% wheat-DDGS was
207 incorporated in a wheat-SBM based diet for broilers. Similarly, Adeola et al. (2010) reported an
208 average reduction in AME and AME_n of 23% with the inclusion of 600 g/kg of corn-DDGS in a
209 corn-SBM reference diet for broilers. Adeola and Ileleji (2009) reported a 20% decrease in
210 energy retention as the level of corn-DDGS increased to 60% in a corn-SBM reference diet for
211 broilers. Dietary fiber reduces DM retention in broilers due to its low digestibility (Adeola et al.
212 2010). The increase in dietary fiber associated with increasing wheat-DDGS levels in the

213 reference diet may explain the reductions in DM retention and energy retention noted in the
214 current study.

215 Although, fiber hydrolyzing enzymes are used during bioethanol production to reduce mash
216 viscosity, the concentration of NSP in corn-DDGS increases at least 3-fold compared with corn
217 (Widyaratne and Zijlstra, 2007). The anti-nutritional effects of NSP for poultry are well
218 described in the literature (Adeola and Bedford 2004; Choct et al., 2004). Carbohydrases are able
219 to hydrolyze NSP into sugars that can be utilized by the bird (Bedford, 2000) whereas proteases
220 help to improve protein utilization (Adeola and Cowieson, 2011). The wheat-DDGS used in the
221 current study contained 389 g/kg of NDF that are substrates for carbohydrase enzymes. Xylanase
222 and amylase or a combination of both enzymes have been shown to be effective in improving
223 energy value and nutrient digestibility of wheat-based diets for poultry (Choct et al. 2004;
224 Adeola and Cowieson, 2011).

225 Liu et al. (2011) reported a 20% reduction in hemicellulose levels and a 619 kcal/kg increase in
226 AME in diets containing corn-DDGS when investigating the effect of supplemental xylanase on
227 growth performance and nutrient digestibility in broilers. Also, addition of an NSP hydrolyzing
228 enzyme to a diet containing 20% corn-DDGS significantly increased dietary AME for broilers in
229 a study by Lee et al. (2010). Supplemental XAP tended to improve dietary energy retention in
230 broilers and there was no effect of increasing wheat-DDGS inclusion level up to 60% in the diets
231 supplemented with XAP for turkeys in the current study.

232 The AME value of wheat-DDGS for broilers was determined to be 3,587 kcal/kg DM in the
233 current study. This value is greater than 2,653 or 2,216 kcal/kg DM for two wheat-DDGS
234 samples, reported in the Bolarinwa and Adeola (2012) study, as well as the range of 2,144 to

235 2,868 kcal/kg DM for 10 samples of wheat-DDGS noted in Cozannet et al. (2010) study. It is
236 common practice to correct the AME value of feed ingredients for nitrogen retention in order to
237 account for variability in energy utilization that may occur due to differences in age and species
238 of the animal as well as the protein quality of a diet. Correction for N retention resulted in a 6.4%
239 reduction in the AME value of the wheat-DDGS for broilers in the current study which is similar
240 to the 7% reduction reported by Bolarinwa and Adeola (2012). The AME_n value of wheat-DDGS
241 for broilers was determined to be 3,356 kcal/kg DM in the current study. Similarly, the AME_n
242 value determined in the current study was greater compared with the mean values of 2,278, 2,373
243 and 2,605 kcal/kg DM reported by Bolarinwa and Adeola (2012), Cozannet et al. (2010) and
244 Vilarino et al. (2007), respectively for broilers. The AME and AME_n value of wheat-DDGS for
245 turkeys was determined to be 3,355 and 3,558 kcal/kg DM, respectively in the current study.
246 Cozannet et al. (2010) used the difference method in their study and determined the AME value
247 of 10 samples of wheat-DDGS to range from 1,840 to 2,749 kcal/kg DM for turkeys.
248 Furthermore, Cozannet et al. (2010) reported the AME_n values of wheat-DDGS for turkeys to
249 range from 1,769 to 2,557 kcal/kg DM.

250 The gross energy in the wheat-DDGS used in the current study was greater compared with the
251 average of those used in the study of Bolarinwa and Adeola (2012) (5,162 vs 4,517 kcal/kg DM,
252 respectively). Nonetheless, energy metabolizability in the wheat-DDGS in the current study was
253 68% and was close to the 63% reported by Bolarinwa and Adeola (2012) for broilers. It appears
254 therefore that the gross energy content of wheat-DDGS is influential in defining its AME value
255 for broilers. On the other hand, although the gross energy content in the wheat-DDGS used in the
256 current study were similar to those used in the study of Cozannet et al. (2010) (5,162 vs. 4,971
257 kcal/kg DM, respectively), energy metabolizability in the wheat-DDGS for turkeys was greater

258 in the current study (65 vs. 47%, respectively). However, it is notable that the wheat-DDGS used
259 in the current study contained greater levels of ether extract (7.4 vs. 4.7 g/kg) compared with
260 those used in the study of Cozannet et al. (2010).

261 It was noted that the AME or AME_n values of wheat-DDGS were 232 or 247 kcal/kg DM,
262 respectively, greater for broilers compared with turkeys in the current study. Similarly, Cozannet
263 et al. (2010) observed that the mean AME and AME_n for 10 samples of wheat-DDGS were 127
264 and 208 kcal/kg DM, respectively, greater for broilers at 21 d of age compared with turkeys at 13
265 wks old. It is speculated that the difference in energy utilization in wheat-DDGS between
266 broilers and turkeys in the current study is due to differences in physiological maturity between
267 the two species at 21 d of age. However, this speculation is hardly supported by the similarity
268 between the observations noted in the current study and the study of Cozannet et al. (2010)
269 where the AME of wheat-DDGS for turkeys was determined at 13 wks of age. On the other
270 hand, it is possible that the greater AME and AME_n for wheat-DDGS noted in the current study
271 for turkeys compared with the study of Cozannet et al. (2010) are due to differences in the
272 chemical characteristics of wheat-DDGS used.

273 The differences in reported energy values of wheat-DDGS show the need to develop a
274 standardized method for determining energy value of wheat-DDGS for poultry. Although the
275 differences in the nutrient composition of wheat-DDGS among sources might be implicated in
276 causing variability to the utilizable energy value of the co-product, the methodology, age and
277 species of poultry used for determining its energy value are also potential sources of variation.

278 Exogenous enzymes such as carbohydrases and proteases or a combination of these are often
279 incorporated into poultry diets; however, there is a dearth of information on the efficacy of these

280 enzymes to improve the nutritive value of wheat-DDGS. In addition to improving energy value
281 and nutrient digestibility, supplementing diets containing wheat-DDGS with exogenous enzymes
282 may reduce variability in the nutritive value of wheat-DDGS. The efficacy of exogenous
283 enzymes to improve the nutritive value of bioethanol co-products has been determined mostly
284 for corn-DDGS (Adeola and Ileleji, 2009; Adeola et al. 2010; Liu et al., 2011) but greater
285 benefits may be derived from using exogenous enzymes in diets containing wheat-DDGS
286 because wheat contains greater levels of NSP than corn.

287 In Adeola et al. (2010) study, a cocktail of xylanase and amylase increased the AME and AME_n
288 of corn distillers grains by 5.7% and 6.2%, respectively. In the current study, the increases noted
289 in the energy value of the wheat-DDGS due to XAP supplementation were marginal and were
290 not statistically significant. The lack of significant XAP effect in the current study is least
291 expected because feed ingredients or diets that contain substantial concentrations of fiber
292 respond to a greater extent to carbohydrase supplementation (Bedford, 2000). Adeola and
293 Cowieson (2011) noted a trend that indicated that the effects of carbohydrase supplementation
294 are repressed when the energy value of the feed ingredient or diet being treated is high. The
295 AME value of wheat-DDGS noted in the current study for broilers or turkeys were greater
296 compared with other reported values in the literature (Cozannet et al. 2010; Bolarinwa and
297 Adeola, 2012) and was also greater than the AME content of wheat. Perhaps, the high utilizable
298 energy content in the wheat-DDGS used in the current study was partly responsible for the
299 marginal effect of XAP. Also, analyzed xylanase and protease activities were approximately
300 20% lower than was expected in the XAP-supplemented diets for broilers and turkeys in the
301 current study, and may be partly responsible for the marginal increment in AME in the wheat-
302 DDGS noted. Nevertheless, considering that the wheat-DDGS contain substantial levels of

303 soluble fiber, it is unlikely that a combination of carbohydrases and proteases will not
304 significantly improve its utilizable energy for broilers and turkeys. It is therefore recommended
305 that further studies be conducted to evaluate the efficacy of carbohydrases to improve the energy
306 value of wheat-DDGS for broilers and turkeys.

307 In conclusion, the AME and AME_n (kcal/kg DM) contents of wheat-DDGS are 3,587 and 3,700,
308 respectively for broilers whereas the AME and AME_n (kcal/kg DM) contents of wheat-DDGS for
309 turkeys are 3,355 and 3,558, respectively. Supplemental XAP increased the metabolizable
310 energy in wheat-DDGS by up to 203 kcal/kg DM for broilers or turkeys in the current study.

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385

Table 1. Analyzed nutrient composition of wheat distillers dried grains with solubles (as-is basis)

Item	g/kg
Dry matter	858
Crude protein	326
Gross energy (kcal/kg)	4,422
Crude fiber	80.0
Ether extract	72.5
Neutral detergent fiber	389
Acid detergent fiber	223
Ash	46.0
Calcium	1.10
Phosphorus	6.50
Potassium	11.3
Sodium	5.20
Amino acids	
Indispensable amino acids	
Arg	11.8
His	8.30
Ile	13.7
Leu	22.6
Lys	7.70
Phe	15.8
Thr	11.5
Met	4.50
Trp	3.80
Val	16.2
Dispensable amino acids	
Ala	14.0
Asp	18.3
Cys	5.90
Glu	84.9
Gly	14.9
Pro	30.2

Table 2. Ingredient and analyzed nutrient composition of experimental diets to determine apparent metabolizable energy content of wheat distillers dried grains with solubles without or with supplementation of a mixture of carbohydrases and protease for broilers and turkeys.

Item	Broilers			Turkeys		
	0	300	600	0	300	600
Wheat	561	385.2	209.2	484.5	328.9	173.5
Soybean meal (48% CP)	291.2	199.9	108.6	340	230.9	121.7
Soybean oil	54.2	37.2	20.2	30	20.4	10.7
Gluten meal ¹	31.6	15.7	0	58	32.3	6.6
Wheat-DDGS	0	300	600	0	300	600
Limestone (38% Ca)	18.5	18.5	18.5	13	13	13
Dicalcium phosphate ²	14	14	14	35	35	35
Common salt	1	1	1	3	3	3
Vitamin/mineral premix ³	3	3	3	4	4	4
DL-Methionine	1	1	1	1.5	1.5	1.5
L-Lysine HCl	2.5	2.5	2.5	6	6	6
Marker premix ⁴	15	15	15	15	15	15
XAP premix	7	7	7	10	10	10
Total	1000	1000	1000	1000	1000	1000
Analyzed energy and nutrient composition ⁵						
Dry matter, g/kg	880	880	870	883	883	874
Gross energy, kcal/kg	4,143	4,265	4,262	4,001	4,078	4,195
CP (N x 6.25), g/kg	226	256	276	258	277	293
Ca (calculated)	11.1	11.1	11.1	13.6	13.5	13.5
P (calculated)	6.2	7.2	7.9	10.6	11.2	11.9

¹XAP premix replaced gluten meal at 7 g/kg.

²Contains 21.3% Ca and 18.7% P.

³Vitamin A, 16,000 IU; vitamin D3, 3,000 IU; vitamin E, 25 IU; vitamin B1, 3 mg; vitamin B2, 10 mg; vitamin B6, 3 mg; vitamin B12, 15 µg; hetra, 5 mg; nicotinic acid, 60 mg; pantothenic acid, 14.7 mg; folic acid, 1.5 mg; Biotin, 125 µg; choline chloride, 25 mg; iron, 20 mg; copper, 10 mg; manganese, 100 mg; cobalt, 1.0 mg; zinc, 82.2 mg; iodine, 1 mg; selenium, 0.2 mg; and molybdenum, 0.5 mg.

⁴Contained 1 g of titanium dioxide added to 4 g of gluten meal.

⁵Values are means of duplicate analyses.

Table 3. Dry matter retention (%) and metabolisable energy (kcal/kg) for broilers receiving diets containing graded levels of wheat distillers dried grains with solubles without or with supplementation of a mixture of carbohydrases and protease¹.

	DM	AME	AME _n
DDGS effect			
0 g/kg of wheat-DDGS	72.7	3,609	3,394
300 g/kg of wheat-DDGS	65.1	3,322	3,131
600 g/kg of wheat-DDGS	60.9	3,250	3,059
S.E.	1.32	57.4	50.2
P values for DDGS effect	<0.001	<0.001	<0.001
XAP effect			
Without XAP	65.2	3,346	3,155
With XAP	67.2	3,442	3,227
S.E.	1.08	47.8	40.6
P values for XAP effect	0.062	0.063	0.057
DDGS × XAP interaction			
	0.920	0.976	0.982
P values for contrasts			
Diet (linear)	<0.001	<0.001	<0.001
Diet (quadratic)	0.142	0.059	0.038

¹Average analyzed enzyme activities were 1421 U/kg of xylanase, 262 U/kg of amylase and 3064 U/kg of protease, respectively.

S.E - standard error of difference of mean

Table 4. Dry matter retention (%) and metabolisable energy (kcal/kg) for turkeys receiving diets containing graded levels of wheat distillers dried grains with solubles without or with supplementation of a mixture of carbohydrases and protease¹.

	DM	AME	AME _n
DDGS effect			
Without XAP			
0 g/kg of wheat-DDGS	67.3	3,293	3,090
300 g/kg of wheat-DDGS	63.7	3,175	2,946
600 g/kg of wheat-DDGS	54.3	2,872	2,658
With XAP			
0 g/kg of wheat-DDGS	64.4	3,132	2,922
300 g/kg of wheat-DDGS	62.9	3,126	2,902
600 g/kg of wheat-DDGS	56.7	3,019	2,801
Pooled S.E	1.39	61.3	57.6
P values for main effect and interaction			
P values for DDGS effect	<0.001	<0.001	<0.001
P values for XAP effect	0.699	0.681	0.622
DDGS × XAP interaction	0.170	0.038	0.015
P values for contrasts			
Without XAP			
Diet (linear)	<0.001	<0.001	<0.001
Diet (quadratic)	0.056	0.163	0.203
With XAP			
Diet (linear)	0.002	0.234	0.153
Diet (quadratic)	0.216	0.534	0.571

¹Average analyzed enzyme activities were 1421 U/kg of xylanase, 262 U/kg of amylase and 3064 U/kg of protease, respectively.

S.E - standard error of difference of mean

Table 5. Regression equations for the apparent metabolizable energy content of wheat distillers dried grains with solubles without or with supplementation of a mixture of carbohydrases and protease for broilers and turkeys^{1,2}

Measurements	Regression equation	SE of slope	r ²	P-value
Broilers				
AME, kcal/kg DM				
Without XAP	Y = 3,587X + 3.2	58.8	0.995	<0.001
With XAP ³	Y = 3,700X – 2.5	87.5	0.989	<0.001
AME _n , kcal/kg DM				
Without XAP	Y = 3,356X + 4.9	52.3	0.995	<0.001
With XAP ³	Y = 3,459X – 1.3	77.3	0.990	<0.001
Turkeys				
AME, kcal/kg DM				
Without XAP	Y = 3,355X + 48	91.3	0.985	<0.001
With XAP ³	Y = 3,558X + 8.2	77.1	0.991	<0.001
AME _n , kcal/kg DM				
Without XAP	Y = 3,109X + 44	81.8	0.986	<0.001
With XAP ³	Y = 3,294X + 9.6	68.1	0.992	<0.001

¹AME and AME_n values of wheat-DDGS determined from regression of wheat-DDGS-associated AME or AME_n against wheat-DDGS intake; Y is in kcal, intercept is in kcal, and slope is in kcal/kg DM. The slope of the regression equation is the AME or AME_n value of the wheat-DDGS.

²Supplemental XAP did not significantly (P > 0.05) increase the AME or AME_n values of wheat-DDGS for broilers and turkeys

³Average analyzed enzyme activities were 1421 U/kg of xylanase, 262 U/kg of amylase and 3064 U/kg of protease, respectively

S.E - standard error of difference of mean