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Effect of Dietary Levels of Tallow and NSP-Degrading Enzyme Supplements on Nutrient Efficiency of Broiler Chickens

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Abstract: In a completely randomized design with 3×3 factorial arrangements and 4 replicates, 144 day-old Hubbard classic male broiler chickens were used to evaluate the effect of dietary levels of tallow and NSP-degrading enzyme supplements on nutrient efficiency of broiler chickens. The tallow was used at the levels of 0.0, 2.0 and 4.05%. The enzyme levels added into the diets were 0.0, 0.05 and 0.10%. For nutrient digestibility using Cr_2O_3 as indigestible marker, feces samples were collected from 18-21 days of age. Two birds from each replicate of treatment were killed for ileal digesta collection. Apparent metabolizable energy (aME) in all treatments affected by tallow and enzyme levels (p<0.01). Increasing the level of tallow in the diet significantly reduced apparent lipid digestibility of feces (ALD_f) and enzyme addition significantly improved it (p<0.01). This improvement was highest when the level of tallow in the diet was 4%. Apparent protein digestibility (APD) was not affected by treatments but improved when enzyme added to each level of tallow. Apparent lipid digestibility of ileal digesta (ALD_i) was significantly reduced by levels of tallow but enzyme addition improved it (p<0.01).

Key words: Tallow, enzyme, broiler, feces digestibility, ileal digestibility

INTRODUCTION

High molecular weight carbohydrate complexes, such as water soluble pentosans (WSP) were shown to increase the viscosity of the fluid phase of the intestinal chyme in broilers (Bedford *et al*., 1991; Choct *et al*., 1992; Salih *et al*., 1991). Increasing intestinal viscosity changes the physiology of the bird. It decreases mixing of the pancreatic enzymes with dietary nutrients. It may limit nutrient degradation bydigestive enzymes, so digestibility of the nutrients will be decreased (Fengler *et al*., 1988; Moharrery, 2006). Addition of enzyme into the wheat, barley, rye and triticale-based diets reduces intestinal viscosity contents and improves nutrient efficiency and increases intestinal nutrients absorption (Choct *et al*., 1995). Addition of enzyme to wheat-soybean meal based diet in broilers increased metabolisible energy (Choct *et al*., 1995). Theses results are in agreement with those of Jeroch *et al*. (1995) and Farner (1960). A relationship between viscosity and performance in broilers was demonstrated (Bedford *et al*., 1991; Bedford and Classen, 1992). A relationship between the diversity of cereal quality and viscosity has not been completely investigated. Most of the researchers believe that the beneficial effects (50-70%) of feed enzymes to increase nutrients digestibility, are related to a decrease in intestinal chyme viscosity (Jeroch *et al*., 1995). A distinct relationship between the ileal viscosity and fat digestibility in broilers was found (Lee *et al*., 2004; Van der Klis *et al*., 1993). They found an improvement in fat digestibility by dietary endoxylanase addition, which is related to a decrease in intestinal chyme viscosity. Langhout *et al*. (1999) showed that by replacing soybean oil with tallow, fat digestibility and consequently metabolisable energy of the diet decreased. Effects of enzyme supplemention on digestibility depend on fat types added to the diet. Addition of enzyme to a diet containing 6.5% soybean oil had no significant effect on digestibility parameters but improved fat digestibility (Langhout *et al*., 1999). The effect of feed enzymes on intestinal viscosity and animal fats might be different from those of vegetable oils. Therefore, the objective of this study was to evaluate the effect of dietary levels of tallow and NSP-degrading enzyme supplements on nutrient efficiency in broiler chickens.

MATERIALS AND METHODS

This study was conducted at Poultry Research Station of Ferdowsi University of Mashhad, Iran in 2007.

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Table 1: Composition of experimental diets for age 0-21 days

	Treatments								
Ingredients (%)	1	2	3	4	5	6	7	8	9
Wheat	62.02	62.02	62.02	62.02	62.02	62.02	62.02	62.02	62.02
Soybean meal	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Fish meal	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76
Tallow	0	0	0	2	2	2	4	4	4
Di-calcium phosphate	1	1	1	1	1	1	1	1	1
Calcium carbonate	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Salt	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vit. Min. premix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
DL-Methionine	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
L-Lysine	0	0	0	0	0	0	0	0	0
Enzyme[2]	0	0.0005	0.001	0	0.0005	0.001	0	0.0005	0.001
Corn starch	8	8	8	4	4	4	0	0	0
Sand	0	0	0	4	4	4	8	8	8
Calculated analysis ME (kcal kg^{-1})	2900	2900	2900	2900	2900	2900	2900	2900	2900
Crude protein (%)	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8

[1]Supplied per kilogram of diet: vitamin A, 10000 IU; vitamin D_3, 9790 IU; vitamin E, 121 IU; B_{12}, 20 µg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 µg; thiamin, 4 mg; zinc sulfate, 60 mg; manganese oxide, 60 mg; [2]Endofeed W from GNC Bioferm Inc., Canada

In a completely randomized design with 3×3 factorial arrangement, 144 day-old Hubbard classic male broiler chickens were randomly assigned in 36 battery cages of 4 replicates per treatment. Three levels of 0.0, 2.0 and 4.0% tallow and 3 levels of NSP-degrading enzyme (0.00, 0.05 and 0.10% Endofeed W from GNC Bioferm Inc., Canada, with minimum activity of 1200 Ug^{-1} xylanase and 880 U g^{-1} beta-glucanase) were added into the diets during 0-21 days of age (Table 1). The diets met the (NRC, 1994), recommendations. Feed and water provided ad libitum. Birds were maintained under continuous light. Chromic oxide (0.3 g kg^{-1}) was added to the diets as analytical marker and the experimental diets containing chromic oxide were given to the chickens during a 2-day adaptation period (days 17-18) and during the collection period (days 19-21). At 19-21 days of age, excreta samples were collected twice daily (6.00 and 18.00) from all chickens in 4 pens per treatment. The collected excreta of 3 days for each pen were pooled. Contaminants such as feathers and scales were removed carefully and then stored in closed containers at -20°C immediately. Two birds from each replicate were randomly selected, killed, opened and the ileal contents from Meckel's diverticulum to 40 mm proximal to the ileo-caecal junction were collected. Ileal contents collected from the chickens in each pen was pooled and stored at -20°C for later analysis. Protein (N×6.25) was determined by the Kjeldahl method using a Kjeltec Auto Analyser 1030 (AOAC, 1990). Gross energy contents of the diet and excreta were measured with an adiabatic bomb calorimeter (AOAC, 1990). Fat concentrations of the diet, excreta and ileal digesta were measured by a modified-ether extraction method (Soxtec system HT6). Chromic oxide was determined using the method of Fenton and Fenton (1979). Data were analyzed based on a general linear model procedure of SAS (1993) and treatment means when significant ($p<0.05$), were compared using Duncan's multiple range test (Duncan, 1955).

RESULTS

The results of nutrient digestibility of the broiler chickens fed tallow and enzyme are given in Table 2. Fecal fat digestibility was significantly affected by tallow and enzyme ($p<0.001$) and significant interaction between tallow and enzyme was observed ($p<0.05$). The highest and the lowest fecal fat digestibility were seen in treatment 3 (0.0% fat and 0.10% enzyme) and treatment 7 (4% fat and 0.0% enzyme), respectively. The levels of 2 and 4% fat reduced fecal apparent fat digestibility ranging from 10.2 and 16.3%, respectively. Addition of enzyme improved fecal apparent fat digestibility. However, levels of enzyme had no significant effect. Addition of 0.05 and 0.10% enzyme into the diets improved fecal apparent fat digestibility ranging from 11.7 and 15.6%, respectively. The fat and enzyme affected ileal apparent fat digestibility ($p<0.05$) and a significant interaction between fat and enzyme was observed. Addition of 2 and 4% fat reduced ileal apparent fat digestibility ranging from 12 and 16.5%, respectively. Addition of 0.05 and 0.10% enzyme into the diets improved ileal apparent fat digestibility ranging from 11.5 and 15.5%, respectively. Again the highest and the lowest ileal apparent fat digestibility was seen in treatment 3 (0.0% fat and 0.10% enzyme) and treatment 7 (4% fat and 0.0% enzyme), respectively. Addition of fat and enzyme into the diets of broilers had no effect on apparent protein digestibility ($p>0.05$). The metabolizable energy of the diets was significantly affected by fat and enzyme addition ($p<0.05$). As the levels of fat in the diets

Table 2: Effect of levels of tallow and enzyme on fecal apparent fat digestibility (ALD_f), ileal apparent fat digestibility (ALD_i), apparent protein digestibility (APD) and apparent metabolisible energy (AME) of broilers from 18-21 days of age

Nutrient digestibility/ treatments	ALD_f (%)	ALD_i (%)	APD (%)	AME ($MJ\,Kg^{-1}$)
Tallow level (%)				
A_1	82.15^a	84.42^a	81.60	12.89^a
A_2	73.74^b	74.32^b	80.662	12.36^{ab}
A_3	68.79^c	70.52^b	80.65	11.36^b
p-value	0.001	0.001	0.767	0.009
Enzyme level (%)				
B_1	67.72^a	69.11^b	79.78	11.15^b
B_2	76.73^b	78.45^a	80.95	12.31^a
B_3	80.23^c	81.75^a	82.18	13.15^a
p-value	0.001	0.012	0.294	0.008
Tallow*enzyme				
A_1B_1	78.58^b	80.84^b	80.29	11.82
A_1B_2	82.34^a	85.24^a	81.74	12.86
$A1B_3$	85.54^a	87.53^a	82.78	13.94
A_2B_1	66.12^d	68.21^d	79.95	11.25
A_2B_2	76.23^{bc}	78.15^{bc}	80.13	12.65
A_2B_3	78.88^{ab}	81.23^a	81.90	13.18
A_3B_1	58.46^e	61.75^e	79.10	10.33
A_3B_2	71.63^c	72.25^c	81.03	11.43
A_3B_3	76.27^{bc}	78.85^b	81.85	12.33
±SEM	0.6639	0.6415	0.6116	0.1895
p-value	0.0452	0.0476	0.9932	0.9915

A_1-A_3 are 0.0, 2 and 4% tallow, B_1-B_3 are 0.0, 0.05, 0.1% enzyme; [a-e]Means in each column with different superscripts are significantly different ($p<0.05$)

increased, the metabolizable energy of the diets decreased. However, at the level of 2% fat no significant effect was seen. At the level of 4% fat, apparent metabolizable energy decreased up to 12%. Addition of enzyme into the diets significantly improved metabolizable energy values (6.4 and 15.2%, respectively).

DISCUSSION

Digestibility of dietary fat is dependent on the fat and cereal type, which is used in the diet (Antoniou and Marquardt, 1982; Ward and Marquardt, 1983). When birds fed wheat-based diets, the presence of non-starch polysaccharides (NSP: arabinoxylans) can give rise to highly viscous conditions in the small intestine and increase intestinal viscosity seemed to interfere more dramatically with the digestibility of more saturated tallow than that of digestibility of more unsaturated soy oil (Danicke *et al*., 2000; Langhout and Schutte, 1997) and decrease contact between digestive enzymes and substrates, hence, depressing nutrient absorption and broiler performance (Choct *et al*., 1992, 1995; Almirall *et al*., 1995). The effect of viscosity on digestion may be explicable by poorer emulsification and subsequent absorption of tallow because of the greater reliance on micelle formation (Friesen *et al*., 1992; Brenes *et al*., 1993). Bile salt secretion is thought to be the most limiting factor in the process of fat absorption in the young chick. An increase in fat digestibility after bile salt supplementation was already described (Gomez and Polin, 1976; Polin and Hussein, 1982). The effect was found to be more pronounced in younger chickens when tallow was the dietary fat. The influence of lipase and bile salts on fat digestibility was tested by Polin *et al*. (1980). Both exogenous lipase and bile salt supplementation were shown to improve the fat digestibility. Almirall *et al*. (1995) revealed a significant depression in endogenous lipase activity in the presence of high viscosity barley in the small intestine of chickens. This may amplify the problems associated with the pancreas and digesta of the chick (Nir *et al*., 1993). Kussaibati *et al*. (1982) demonstrated an interaction effect between bile salt supplementation and the microflora populations in the gastro-intestinal tract on fat digestibility. They concluded that saturated fatty acid absorption is more dependent on adequate bile salt secretion than the absorption of unsaturated fatty acids. In addition, the microflora in the gut contributes to bile salt degradation (Campbell *et al*., 1983; Feighner and Dashkevicz, 1988). In addition to the direct effects of NSP on nutrient digestion, some secondary effects are attributable to higher levels of gut microflora in the small intestine (Choct *et al*., 1996). Choct *et al*. (1999) indicated that excess fermentation in the small intestine of the chicken might be detrimental to nutrient digestion and absorption. In the light of these reports it is clear that feeding tallow in the presence of high concentrations of NSP is highly detrimental. The reduction in viscosity after xylanase supplementation was shown to have a crucial effect in improving the digestibility of the tallow containing diet. Danicke *et al*. (1997) showed that fat digestible was improved by xylanase in both fat type groups but to a greater extent for the tallow diets. AME content of the diets improved by enzyme addition containing fat that are in agreement with the results of others (Mathlouthi *et al*., 2002; Danicke *et al*., 2000, Moharrery, 2006).

CONCLUSION

Under the conditions of this study, it was concluded that as tallow level in the diets increases, enzyme addition shows more positive effect more on AME content of the diets than those of other nutrients.

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REFERENCES

Almirall, M., M. Francesch, M. Anna, J.R. Prez-Vendrell and E. Esteve-Garcia, 1995. The differences in intestinal viscosity reproduced by barley and beta-glucanase alter digesta enzyme activities and ileal nutrient digestibilities more in broiler chicks than in cocks. J. Nutr., 125: 947-955. jn.nutrition.org/ cgi/ reprint/125/4/947.pdf.

Antoniou, T. and R.R. Marquardt, 1982. The utilization of rye by growing chicks as influenced by calcium, vitamin D_3 and fat type and level. Poult. Sci., 59: 758-769. www.pjbs.org/ijps/fin251.pdf.

AOAC, 1990. Official Methods of Analysis. 15th Edn. Association of Official Analytical Chemists. Arlington, VA. www.ecology.kee.hu/pdf/0302_ 0610 65.pdf.

Bedford, M.R., H.L. Classen and G.L. Campbell, 1991. The effect of pelleting, salt and pentosanase on the viscosity of intestinal contents and performance of broilers fed rye. Poult. Sci., 70: 1571-1577. japr.highwire.org/cgi/reprint/5/1/86.pdf.

Bedford, M.R. and H.L. Classen, 1992. Reduction of intestinal viscosity through manipulation of dietary rye and pentosanase concentration is effected through changes in the carbohydrate conversion of the intestinal aqueous phase and results in improved growth rate and feed conversion efficiency of broiler chicks. J. Nutr., 122: 560-569. www.trakya. edu.tr/Enstituler/FenBilimleri/Dergi/pdf/141Maria. pdf.

Brenes, A., W. Guenter, R.R. Marqurdt and B.A. Rotter, 1993. Effect of β-glucanase/pentosanase enzyme supplementation on the performance of chickens and laying hens fed wheat, barley, naked oats and rye diets. Can. J. Anim. Sci., 73: 941-951. ps.fass. org/cgi/reprint/78/6/841.pdf.

Campbell, G.L., H.L. Classen and K.A. Goldsmith, 1983. Effect of fat retention on the rachitogenic effect of rye fed to broiler chicks. Poult. Sci., 62: 2218-2223. jn.nutrition.org/cgi/reprint/116/4/560.pdf.

Choct, M., R.J. Hughos and M.R. Bedford, 1999. Effect of a xylanase on individual bird variation, starch digestion throughout the intestine and ileal and cecal volatile fatty acid production in chickens fed wheat. Br. Poult. Sci., 40: 419-422. www.pjbs.org/ijps/fin275. pdf.

Choct, M., R.J. Hughos, M.R. Bedford, A.J. Morgan and G. Annison, 1996. Increased small intestinal fermentation is partly respomsible for the anti-nutritive activity of non-starch polysaccharide in chickens. Br. Poult. Sci., 37: 609-621. www.pjbs.org/ ijps/fin640.pdf.

Choct, M., R.G. Hughes, R.P. Trimble, K. Angkanaporn and G. Annison, 1995. Non-starch polysaccharides-degrading enzymes increase the performance of broiler chickens fed wheat of low apparent metabolizable energy. J. Nutr., 125: 485-492. jn.nutrition.org/cgi/reprint/125/3/485.pdf.

Choct, M., G. Annison and R.P. Trimble, 1992. Soluble wheat pentosans exhibit different anti-nutritive activities in intact and cecectomized broiler chickens. J. Nutr., 122: 2457-2465. jn.nutrition.org/cgi/reprint/ 122/12/2457.pdf.

Duncan, D.B., 1955. Multiple range and f-tests. Biometrics, 11: 1-42. comunidad.veterinaria.org/ articulos/articulo.cfm?articulo=31207&pag=1&area= 1&buscar=&donde=1- 19k.

Danicke, S., H. Jeroch, W. Bottcher and O. Simon, 2000. Interaction between dietary fat type and enzyme supplementation in broiler diets with high pentosan contents: Effects on precaecal and total tract digestibility of fatty acids, metabolizability of gross energy, digesta viscosity and weights of small intestine. Anim. Feed Sci. Technol., 84: 279-294. www.cipav.org.co/lrrd/lrrd17/4/rahm17038.html.

Danicke, S., O. Simon, H. Jeroch and M.R. Bedford, 1997. Interactions between dietary fat type and xylanase supplementation when rye-based diets are fed to broiler chickens; 2 performance, Nutrient digestibility and the fat-soluble vitamin status of livers. Br. Poult. Sci., 38: 546-556. lib.bioinfo.pl/pmid:9510999-65k-Cached.

Farner, D.S., 1960. Digestion and Digestive System. Biology Comparative Physiology of Bird. In: Marshall, A.J. (Ed.) London: Academic Press, pp: 411. www.scielo.cl/scielo.php?pid=S0716-98681998000 200004&script=sci_arttext.

Feighner, S.D. and M.P. Dashkevicz, 1988. Effect of dietary carbohydrates on bacterial cholyltaurine hydrolase in poultry intestinal homogenates. Applied Environ.Microbiol., 54: 337-342. www.pubmedcentral. nih.gov/articlerender.fcgi?artid=202453.

Fengler, A.I., J.R. Pawilik and R.R. Marquardt, 1988. Improvement in nutrient and changes in excreta viscosities in chickens fed rye-containing diets supplemented with fungal enzymes, sodium taurocholate and peniciline. Can. J. Anim. Sci., 68: 483-491. www.pjbs.org/ijps/fin59.pdf.

Fenton, T.W., M. Fenton, 1979. An improved procedure for the determination of chromic oxide in feed and feces. Can. J. Anim. Sci., 59: 631-634. jds.fass.org/ cgi/reprint/72/10/2549.pdf.

Friesen, O.R., W. Guenter, R.R. Marquardt and B.A. Rotter, 1992. The effect of enzyme supplementation on the apparent metabolizable energy and nutrient digestibilites of wheat, barley, oats and rye for the young broiler chick. Poult. Sci., 71: 1710-1721. www.animalscience.com/uploads/additionalFiles/WPSABalatonfured/350-352Sagdeghi.pdf.

Gomes, M.X. and D. Polin, 1976. The use of bile salts to improve absorption of tallow in chicks on to 3 weeks of age. Poult. Sci., 55: 2189-2195. www.ansc.purdue.edu/swine/swineday/sday00/4.pdf.

Jeroch, H., A. Hauschild and A. Muller, 1995. Influence of mechanical treatment and enzyme supplementation on nutritive value of peas for broiler chickens. Boden Kultur, 46 (3): 263-268. www.rirdc.gov.au/reports/EGGS/UQ-21E.pdf.

Kussaibati, R., J. Guillaume, B. Leclercq and J.P. Lafont, 1982. Effects of the intestinal microflora and added bile salts on the metabolizable energy and digestible of saturated fats in the chicken. Arch. Fur. Geflugelkunde, 46: 42-46. ps.fass.org/cgi/reprint/82/5/805.pdf.

Langhout, D.J., J.B. Schutte, P. van Leeuwen, J. Wiebenga and S. Tamminga, 1999. Effect of dietary high and low-methylated citrus pectin on activity of the ileal microflora and morphology of the small intestinal wall of broiler chicks. Br. Poult. Sci., 40: 340-347. www.pjbs.org/ijps/fin632.pdf.

Langhout, D.J. and J .B. Schutte, 1997. Effects on chick performance and nutrient digestibility of an endo-xylanase added to a wheat-rye-based diet in relation to fat source. Br. Poult. Sci., 38: 557-563. ps.fass.org/cgi/reprint/81/7/987.pdf.

Lee, K.W., H. Everts, H.J. Kappert, J. Van Der Kuilen, A.G. Lemmens, M. Frehner amd A.C. Beynen, 2004. Growth performance, intestinal viscosity, fat digestibility and plasma cholesterol in broiler chickens fed a rye-containing diet without or with essential oil components. Int. J. Poult. Sci., 3 (9): 613-618. www.pjbs.org/ijps/fin251.pdf.

Mathlouthi, N., S. Mallet, L. Saulnier, B. Quemener and M. Lar, 2002. Effects of xylanase and beta-glucanase addition on performance, nutrient digestibility and physico-chemical conditions in the small intestine contents and caecal microflora of broiler chickens fed a wheat and barley-based diet. Anim. Res., 51: 395-406. animres.edpsciences.org/articles/animres/pdf/2002/05/04.pdf.

Moharrery, A., 2006. Comparison of performance and digestibility characteristics of broilers fed diets containing treated hulled barley or hulless barley. Czech J. Anim. Sci., 51 (3): 122-131. www.cazv.cz/attachments/CJAS_51_122-131.pdf.

National Research Council, 1994. Nutrition Requirements of Poultry. 9th Edn. National Academy Press, Washington, DC. www.aip.org/history/catalog/icos/4078.html- 4k.

Nir, I., Z. Nitsan and M. Mahagna, 1993. Comparative growth and development of the digestive organs and of some enzymes in broiler and egg type chicks after hatching. Br. Poult. Sci., 34: 523-532. www.animalscience.com/uploads/additionalFiles/WPSABalatonfured/51-53zelenka.pdf.

Polin, D. and T.H. Hussein, 1982. The effect of bile acid on lipid and nitrogen retention, carcass composition and dietary metabolizable energy in very young chicks. Poult. Sci., 61: 1697-1707. jn.nutrition.org/cgi/reprint/115/5/675.pdf.

Polin, D., T.L. Wing, P. Ki and K.E. Pell, 1980. The effect of bile acids and lipase on absorption of tallow in young chicks. Poult. Sci., 59: 2738-2743. jn.nutrition.org/cgi/reprint/115/5/675.pdf.

Salih, M.E., H.L. Classen and G.L. Campbell, 1991. Response of chickens fed on hull-less barley to dietary beta-glucanase at different ages. Anim. Feed Sci. Technol., 33: 139-149. www.animalscience.com/uploads/additionalFiles/WPSABalatonfured/394-396Palander.pdf.

SAS Institute Inc., 1993. SAS User's Guide: Version 6.03 Ed., SAS Institute Inc., Cary, North Carolina. Introduction to SAS: Books About SAS javeeh.net/sasintro/intro159.html-3k.

Van Der Kliss, J.D., M.W.A. Verstegen and A. Vanvoorst, 1993. Effect of soluble polysacharide (*Carboxy methyl* cellulose) on the absorption of minerals from the gastrointestinal tract or broilers. Br. Poult. Sci., 34: 985-997. www.basf.com.mx/animalnutrition/pdfs/kc_9701.pdf.

Ward, A.T. and R.R. Marquardt, 1983. The effect of saturation chain length of pure triglycerides and age of bird on the utilization of rye diets. Poult. Sci., 62: 1054-1062. ps.fass.org/cgi/reprint/77/10/1534.pdf.