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Comparison of Two Blended Animal-Vegetable Fats Having Low or High Free Fatty Acid Content[1]

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Primary Audience: Nutritionists, Feed Manufacturers, Purchasing Agents, Researchers

Summary

A study was conducted to compare the feeding value of two blended animal-vegetable fats having different levels of free fatty acids (FFA) but similar fatty acid profiles and unsaturated:saturated (U:S) fatty acid ratios. One contained 29.8% FFA (AV-LO), while the other contained 44.7% FFA (AV-HI). Poultry oil (PO) and corn oil (CO) were fed as reference standards. Diets had either 4, 6, or 8% supplemental CO, adjusting nutrient levels to dietary energy. Other fat sources were substituted for CO on a wt/wt basis. Each treatment was fed to four replicate pens of fifty male broilers from day-old to 42 days of age.

There were no significant differences between the two blended fat sources in body weight, feed utilization, calorie:gain ratio, or mortality at 21 or 42 days of age. Body weight of birds fed the two blended fat sources was significantly less than that of birds fed PO at 21 days, but did not differ significantly at 42 days of age. Results of this study indicate that blended animal-vegetable fats with fatty acid profiles and U:S ratios similar to PO resulted in similar performance; the FFA level of these blended fats did not adversely influence performance of the broilers.

Key words: Broilers, fat quality, fat supplements, feed utilization, free fatty acids
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Description of Problem

More than forty years ago, researchers found that the addition of supplemental fats to poultry diets would improve growth rate and efficiency of feed utilization [1, 2, 3, 4, 5]. Consequently, today most diets for broiler chickens in the United States contain supplemental fats. Poultry oil produced from the rendering of poultry offal is widely used, and many commercial blends of animal and vegetable fats are available that attempt to emulate the fatty acid profile of poultry oil. Depending upon the raw material used to produce these blends, they may vary considerably in free fatty acid (FFA) content. Presence of FFA in fats or animal by-products was once considered an indication of rancidity [6, 7, 8]

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and questions regarding the utilization of fat sources with high FFA content still linger in the poultry industry. The objective of the present study was to compare performance of broilers fed diets supplemented with animal-vegetable blends of similar fatty acid composition but differing widely in the FFA content.

MATERIALS AND METHODS

This 42-day feeding trial compared four sources of supplemental fats, each fed at three dietary levels. The sources included corn oil (CO), poultry oil (PO), a commercial animal-vegetable fat blend with low (29.8%) FFA content (AV-LO), and a commercial animal-vegetable blend with high (44.7%) FFA content (AV-HI). Although corn oil does not typically serve as a fat source in commercial poultry diets, it frequently becomes a reference standard in tests involving fat utilization. Samples of fats were subjected to analysis by a commercial laboratory [9] to determine fatty acid composition (Table 1). The two animal-vegetable fat blends were similar in fatty acid composition. Linoleic acid content of the PO sample was lower than that reported by Edwards [10] but similar to that of other

TABLE 1. Composition of supplemental fats

	CORN OIL	POULTRY OIL	LOW FREE FATTY ACID BLEND	HIGH FREE FATTY ACID BLEND
Fatty acids, % of sample[A]				
$C_{10:0}$	–	–	–	0.2
$C_{12:0}$	–	–	0.2	0.5
$C_{14:0}$	–	0.6	1.2	1.1
$C_{14:1}$	–	0.2	0.2	0.2
$C_{15:0}$	–	0.2	0.2	0.2
$C_{16:0}$	11.2	23.2	19.1	18.6
$C_{16:1}$	–	7.1	2.8	0.5
$C_{17:0}$	–	–	0.4	0.4
$C_{17:1}$	–	–	0.2	0.2
$C_{18:0}$	2.1	6.4	14.2	14.2
$C_{18:1}$	26.9	43.0	36.1	35.9
$C_{18:2}$	57.9	17.9	21.2	23.6
$C_{18:3}$	0.8	0.6	1.9	2.6
$C_{20:0}$	0.5	0.2	0.8	0.8
$C_{20:1}$	0.2	0.4	0.4	0.2
$C_{22:0}$	0.1	0.4	0.5	0.6
$C_{24:0}$	0.1	–	0.1	0.1
Total unsaturated fatty acids, %	85.9	69.2	62.9	63.3
Total saturated fatty acids, %	13.9	31.0	36.6	36.6
Unsaturated/saturated ratio	6.18	2.23	1.72	1.73
Moisture, %	0.1	0.5	0.6	1.2
Insoluble impurities, %	0.01	0.27	0.32	0.32
Unsaponifiables, %	1.17	2.35	3.14	4.18
Total fatty acids, %	95.00	94.60	92.88	93.18
Free fatty acids, %	0.2	3.12	29.8	44.7
Iodine value	124.4	78.2	80.7	82.8
Initial peroxide value, me/kg	1.0	2.7	0.4	0.4

[A]Values may not total 100% due to rounding

PO sources from this laboratory [11] and recent commercial assays [12].

Diets were formulated for starter (0 to 21 days) and grower (21 to 42 days) periods using a minimum of 105% of the amino acid recommendations for male broilers [13]. Within each age period, diets were formulated with 4, 6, or 8% supplemental CO to provide optimum nutrient density (nutrients maintained in proportion to dietary energy). These levels helped to minimize the possible influence of the lipid content of the basal diet on fatty acid utilization and to enhance possible differences in metabolizable energy content of the supplemental oils while remaining within practical bounds. CO was assigned a metabolizable energy value of 8800 ME kcal/kg [14]; when other fat sources were used, they replaced CO on an equal weight basis. Table 2 shows the composition of diets. Diets were steam pelleted using a 4 mm die, but chicks received crumbles during the starter period.

Male chicks of a commercial broiler strain [15] came from a local hatchery. Fifty chicks

TABLE 2. Ingredient composition and calculated nutrient content of broiler diets with different levels of supplemental fats

INGREDIENT	0 TO 21 DAYS			21 TO 42 DAYS		
	%					
Test fat[A]	4.00	6.00	8.00	4.00	6.00	8.00
Yellow corn	57.79	53.66	49.52	62.81	58.85	54.85
Soybean meal (47.5% CP)	29.28	31.32	33.37	25.05	26.95	28.85
Poultry by-product meal	5.00	5.00	5.00	5.00	5.00	5.00
Lysine HCl	0.06	0.04	0.02	0.02	0.00	0.00
Alimet 88%[B]	0.21	0.23	0.24	0.21	0.22	0.24
Vitamin premix[C]	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral mix[D]	0.10	0.10	0.10	0.10	0.10	0.10
Ground limestone	0.97	0.98	1.00	0.19	0.19	0.19
Dicalcium phosphate	1.50	1.56	1.62	1.51	1.57	1.64
Salt	0.44	0.46	0.48	0.46	0.47	0.48
Bacitracin supplement[E]	0.05	0.05	0.05	0.05	0.05	0.05
Salinomycin supplement[F]	0.10	0.10	0.10	0.10	0.10	0.10
	100.00	100.00	100.00	100.00	100.00	100.00
CALCULATED NUTRIENT CONTENT						
ME, kcal/kg	3158	3244	3330	3222	3310	3398
Crude protein, %	21.85	22.45	23.05	20.23	20.78	21.34
Arginine, %	1.44	1.49	1.55	1.31	1.36	1.41
Lysine, %	1.22	1.25	1.28	1.07	1.11	1.15
Methionine, %	0.54	0.56	0.57	0.52	0.53	0.55
TSAA, %	0.90	0.93	0.95	0.86	0.88	0.91
Threonine	0.82	0.85	0.88	0.76	0.78	0.81

[A]Corn oil, poultry oil, low free fatty acid blend, high free fatty acid blend

[B]Liquid methionine hydroxy analogue, Novus International, St. Louis, MO

[C]Provides per kg of diet: vitamin A, 9,900 IU; cholecalciferol, 3,300 ICU; vitamin E, 13 IU; vitamin B_{12}, 0.013 mg; riboflavin, 6.6 mg; niacin, 66 mg; d-pantothenic acid, 16.5 mg; choline, 660 mg; menadione, 1.1 mg; folacin, 1.1 mg; thiamin, 1.1 mg; pyridoxine, 3.3 mg; d-biotin, 0.11 mg; Se, 0.20 mg; ethoxyquin, 125 mg.

[D]Provides per kg of diet: Mn ($MnSO_4.H_2O$), 100 mg; Zn ($ZnSO_4.7H_2O$), 100 mg; Fe ($FeSO_4.7H_2O$), 50 mg; Cu ($CuSO_4.5H_2O$), 10 mg; I ($Ca(IO_3)_2.H_2O$), 1 mg.

[E]BMD-50, A.L. Laboratories, Ft. Lee, NJ

[F]Bio-Cox, Agri-Bio, Gainesville, GA

were randomly placed in each of forty-eight pens in a commercial type house with curtain sidewalls, each pen having two tube feeders and an automatic waterer. Supplemental feeders and waterers were used during the first seven days with feed and tap water provided *ad libitum*. Thermostatically controlled gas brooders, automatic sidewall curtains, and ventilation fans maintained house temperature and air flow. Four pens of chicks were assigned to each of the twelve experimental treatments.

Researchers determined pen body weights and feed consumption at 21 and 42 days of age and mortality twice daily. Birds that died were weighed for adjustment of feed conversion. Data were subjected to statistical analysis [16, 17].

RESULTS AND DISCUSSION

At 21 days of age, birds fed diets supplemented with animal-vegetable fat blends with high FFA content did not differ significantly in body weight, feed utilization, energy utilization, or mortality from those fed diets supplemented with animal-vegetable fat blends having a similar fatty acid profile with a low FFA content (Table 3). Among the sources tested, birds fed diets supplemented with PO were significantly heavier than those fed diets with the two AV blends; birds fed diets with CO did not differ significantly in body weight from those fed PO or the two AV blends. There were no significant differences among fat sources in feed utilization or mortality. Birds fed CO had the lowest ratio of feed calories to gain but did not differ from those fed diets with PO or the animal-vegetable blend with high FFA content. There was no significant difference in calorie conversion between birds fed the two animal--vegetable blends with low or high FFA content. Increasing levels of dietary fat resulted in significant improvements in body weight and feed utilization at 21 days of age, but had no significant effect on calorie conversion or mortality. There were no significant interactions of fat source and fat level at 21 days of age.

At 42 days of age, there were no significant effects of fat source on body weight, feed utilization, or mortality (Table 4). Birds fed diets supplemented with CO had the lowest calorie conversion but did not differ significantly from those fed PO or the animal-vegetable blend with high FFA content. There was no significant difference in calorie conversion among birds fed the animal-vegetable blends with low or high FFA content or PO. Increasing levels of dietary fat increased body weight and improved feed utilization, but had no significant effect on mortality and calorie conversion.

TABLE 3. Effect of source and level of supplemental fat on 21-day performance of male broilers

SOURCE	LEVEL	BODY WEIGHT	FEED:GAIN RATIO	CALORIE:GAIN RATIO	MORTALITY
	(%)	(g)	(g/g)	(ME kcal/kg)	(%)
Corn oil		596^{ab}	1.375	4376^{b}	5.14
Poultry oil		623^{a}	1.383	4524^{ab}	3.17
AV-HI[A]		577^{b}	1.396	4518^{ab}	3.12
AV-LO[B]		581^{b}	1.433	4721^{a}	4.10
SEM		11	0.02	88	1.12
Prob > F		0.03	0.22	0.05	0.55
	4	556^{b}	1.450^{b}	4569	4.46
	6	602^{a}	1.364^{a}	4519	4.81
	8	615^{a}	1.375^{a}	4514	2.37
SEM		10	0.017	76	1.00
Prob > F		0.003	0.003	0.86	0.17

[A]AV-HI = Animal-vegetable fat blend with 44.7% free fatty acid content.

[B]AV-LO = Animal-vegetable fat blend with 29.8% free fatty acid content.

[a,b]Means in column comparisons with same superscript do not differ significantly ($P \leq .05$).

TABLE 4. Effect of source and level of supplemental fat on 42-day performance of male broilers

SOURCE	LEVEL	BODY WEIGHT	FEED:GAIN RATIO	CALORIE:GAIN RATIO	MORTALITY
	(%)	(g)	(g/g)	(ME kcal/kg)	(%)
Corn oil		1928	1.700	5548[b]	6.79
Poultry oil		1949	1.736	5704[ab]	5.00
AV-HI[A]		1883	1.721	5655[ab]	4.59
AV-LO[B]		1896	1.760	5787[a]	5.34
SEM		20	0.018	59	1.26
Prob > F		0.11	0.11	0.05	0.23
	4	1885[b]	1.761[b]	5633	5.71
	6	1910[ab]	1.738[b]	5715	6.58
	8	1947[a]	1.689[a]	5672	4.00
SEM		18	0.015	53	1.00
Prob > F		0.05	0.006	0.56	0.46

[A]AV-HI = Animal-vegetable fat blend with 44.7% free fatty acid content.

[B]AV-LO = Animal-vegetable fat blend with 29.8% free fatty acid content.

[a,b]Means in column comparisons with same superscript do not differ significantly ($P \leq .05$).

There were no significant interactions of fat source and fat level.

Fats are one of the most difficult feed ingredients to evaluate for metabolizable energy content [18, 19, 20]. Many factors are known to influence the utilization of different fats by chicks or poults. One of these is age of bird [21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31]. Another is the basal diet utilized and level of inclusion of the fat source [31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45]. Yet another is the ambient temperature [30]. Indeed, degree of saturation of fatty acids [46, 47, 48], ratio of unsaturated to saturated fatty acids [19, 23, 48, 49, 50, 51, 52, 53, 54, 55, 56], positional effects of fatty acids on the triglyceride molecule [19, 46], and percentage of FFA [31, 47, 57, 58, 59, 60] all have an impact on the utilization of fats. Several studies have attempted to predict the metabolizable energy content of supplemental fats from their chemical composition [55, 56, 61, 62, 63] or by near infrared reflectance [64, 65], but with varying degrees of success.

Fat suppliers often blend various sources of fats and oils to attain a high unsaturated:-saturated fatty acid ratio (U:S) and thus produce a product of superior metabolizable energy, as demonstrated by several studies [23, 33, 51, 52, 53, 66, 67, 68]. These blends typically consist of both a restaurant grease or vegetable soapstock with a high level of unsaturated fatty acids and tallows or greases with a high percentage of saturated fatty acids. Vegetable soapstocks, typically high in FFAs, have been shown to support excellent performance in broiler feeds [69, 70, 71, 72, 73, 74].

Although it is now generally accepted that the U:S ratio (including fatty acids contributed by the basal diet) is the primary factor that influences the metabolizable energy content of a fat supplement, there is still controversy regarding the effects of FFA content *per se*. Fatty acids are more readily absorbed in a triglyceride form and thus provide more metabolizable energy than when present as the FFA [75, 76], although this factor is of lesser impact among unsaturated fatty acids [47].

These studies were conducted using diets with little fat provided by the basal diet. Young [49] noted that the utilization of FFA mixtures, particularly those derived from beef tallow, lard, and hydrolyzed animal and vegetable fats, was higher in diets based on practical ingredients than in previous studies based on purified diets. Shannon [57] blended tallow with tallow fatty acids in varying proportions fed to laying hens at different levels. There appeared to be no effect of FFA content on AME at lowest levels of intake, but there was evidence of a progressive reduction in AME with increasing FFA content at higher levels of incorporation. Wiseman and Salvador [63] examined the effect of FFA content of three fat sources (tallow, palm oil, and soybean oil). This study revealed a progressive reduction in AME as the FFA content increased regardless of the fat source. The rate of reduction appeared to be influenced by the degree of saturation of the fat in question, being greater in the order palm, tallow, and soybean oil.

Numerous studies with broiler chickens fed practical diets based primarily upon corn indicate that the FFA content of the fat supplements has little effect upon its nutritive value or acceptance by the chick. Siedler *et al.* [4] evaluated several fat sources, including some with high FFA content; they found that the FFAs contributed by the fats showed no effect on performance of the chick. They concluded that fats properly stabilized by antioxidants are utilized equally well, regardless of the FFA content. Lewis and Payne [77] reported that the presence of 50% FFA in a hydrolyzed animal-vegetable fat did not appear to reduce its value in a broiler diet. De Groote *et al.* [78] compared a number of fat sources in broiler diets, including some with a high FFA content, and concluded that no important differences existed among the different sources concerning the utilization of their metabolizable energy. Alao and Balnave [79] compared various fat supplements, including animal tallows with different FFA content, and reported that, within the limits of their study, the concentration of linoleic acid and other unsaturated fatty acids in animal tallows may have greater nutritional significance than concentrations of FFA.

The results of this study indicate that there was no difference in performance of broilers fed diets supplemented with animal-vegetable fat blends with low or high FFA content. Both sources had similar fatty acid profiles and U:S ratios. Although previous research has suggested that fat supplements containing high levels of FFA were less well utilized than those with the fatty acids in a triglyceride linkage, the reduction was more pronounced in fats that were more saturated. The two commercial fat blends in this study compared favorably with PO in terms of U:S ratio. In addition, broilers fed these three sources had comparable performance in terms of body weight, feed utilization, and calorie usage.

Conclusions and Applications

1. No difference in performance was noted between broilers fed diets supplemented with animal-vegetable fat blends with low (29.8%) or high (44.7%) free fatty acid content.
2. These blends contained similar levels of fatty acids and unsaturated:saturated fatty acid ratios.
3. Feed manufacturers may utilize fat blends with high free fatty acid levels provided these blends are not accompanied by a high peroxide value indicating rancidity and have a suitable ratio of unsaturated:saturated fatty acids.

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