Director's Digest
FATS AND PROTEINS RESEARCH FOUNDATION, INC.

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Fats in Poultry Diets

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Fats provide poultry nutritionists with the unique opportunity of significantly altering the energy density of various diets. Because they contain almost twice as much energy as most other types of ingredients, subtle changes in fat levels can have a meaningful effect on diet energy concentration. Fats also improve the palatability of certain diets, they reduce dust loss in the feed mill and in the poultry house, and also act as a lubricant for the growing number of processing operations utilized in feed manufacture. I general fats are also easily digested, and their digestion and metabolism yield a minimum of waste energy in the body, which is especially important in situations of heat stress.

As will be discussed in this paper, we also know a great deal about the factors that can influence tne digestibility and utilization of fats by poultry. In some instances this information has been available for almost 20 years, although often we do not capitalize on this knowledge during formulation. In reality fat digestibility will be affected by its inclusion level, its composition and the age of bird. The value of fats should, therefore, be a variable within the ingredient matrix, and modern software should be able to capitalize on this stochastic nature of fats inherent value. Certainly at this time we should be considering different AME values for fat dependent on bird age. Following is a review of factors known to influence the economic value of fat added to poultry diets.

Rancidity and oxidation

The feeding value of fats can obviously be affected by oxidative rancidity that occurs prior to, or after feed preparation. Rancidity can influence the organoleptic qualities of fat, as well as color and "texture", and can cause destruction of other fat soluble nutrients, such as vitamins, both in the diet and the body stores. Oxidation is essentially a degradation process that occurs at the double-bond in the glyceride structure. Because presence of double-bonds infers unsaturation, then naturally the more unsaturated a fat, the greater the chance of rancidity. The initial step is the formation of a fatty free radical when hydrogen leaves the α-methylenic carbon in the unsaturated group of the fat. The resultant free radicle then becomes very susceptible to attack by atmospheric oxygen (or mineral oxides) to form unstable peroxide free radicles. These peroxide free radicles are themselves potent catalysts, and so the process becomes autocatalytic and rancidity can develop quickly. Oxidative rancidity leads to a loss in energy value, together with the potential degradation of the birds' lipid stores and reserves of fat soluble vitamins. Fortunately we have some control over these processes through the judicious use of antioxidants, such as ethoxyquin. Most antioxidants essentially function as free radical acceptors - these radicals are, however, stable and do not cause autocatalytic reactions. Their effectiveness, therefore, relies on adequate dispersion in the fat during or immediately after processing. As an additional safety factor, most diets will also contain an antioxidant added via the premix.

In subsequent discussion it is assumed that fats are adequately protected against oxidation and that they contain no unusual or excessive quantities of impurities.

Fatty acid composition

Fat composition will influence overall fat utilization because different components can be digested with varying efficiency. It is generally recognized that following digestion, micelle formation is an important prerequisite to absorption into the portal system. Micelles are complexes of bile salts, fatty acids, some monoglycerides and perhaps glycerol. The conjugation of bile salts with fatty acids is an essential prerequisite for transportation to and absorption through the microvilli of the small intestine. Polar unsaturated fatty acids and monoglycerides readily form this important association. However, micelles themselves have the ability to solubilize non-polar compounds such as saturated fatty acids. Fat absorption is, therefore, dependent upon there being an adequate supply of bile salts and an appropriate balance of unsaturates:saturates.

Taking into account the balance of saturated to unsaturated fatty acids, can, therefore, be used to advantage in designing fat blends. This type of synergistic effect is best demonstrated using pure fatty acids (Table 1). In this study the metabolizable energy of the 50:50 mixture of the unsaturated oleic acid with the saturated palmitic acid, is 5% higher than can be expected based on the mean value of 2710 kcal/kg expected. We, therefore, have a boost of 5% in available energy that likely comes from greater utilization of the palmitic acid because of the presence of the unsaturated oleic acid.

TABLE 1. Metabolizable energy diets containing various fatty acids by laying hens

	Determined ME (kcal/kg)	Expected ME (kcal/kg)
Oleic	2920	
Palmitic	2500	
50:50 mixture	2850	2710 (+5%)

(Atteh and Leeson, 1985)

This type of synergism can, however, have a confounding effect on some research results. If we want to measure the digestibility of say corn, it is possible to feed just corn for a short period of time and conduct a balance study. For obvious reasons it is impossible to feed pure fats, and we have to conduct studies involving graded fat additions to a basal diet, with extrapolation of results to what would happen at 100% feeding level. In these studies we assume the difference in digestibility between any two diets is due solely to the fat added to the diet. If, because of synergism, the added fat improves digestibility of basal diet components, then this "boost" in digestibility is attributed to the fat and an erroneously high value is projected. However, it can be argued that this "boost" to fats value occurs normally when fats are added to diets, and that these higher values more closely reflect the practical value of fat in a poultry diet. Leeson and Summers (1976) proposed this synergism to account for some of the so called "extra-caloric" effect of fat often seen in reported values, where metabolizable energy can sometimes be higher than corresponding gross energy values (which theoretically cannot occur). Table 2 shows results from this type of study where corn oil was assayed using different types of basal diet.

TABLE 2. Variation in ME value of corn oil attributed to fatty acid saturation of the basal diet

Basal diet	Corn oil ME (kcal/kg)
1. Predominantly unsaturated	8390[a]
2. Predominantly saturated	9380[b]
3. Practical ingredients	8510[a]

When the basal diet contains saturated fatty acids, there is an apparent increase in the ME of corn oil. This effect is possibly due to the unsaturates in corn oil aiding in utilization of the basal diet saturates. However, because of methods of diet substitution and final ingredient ME calculation, any such synergism is attributed to the test ingredient (corn oil).

Lewis (1989) concludes that maximum synergism occurs with most fats at 3% inclusion level in the diet, and that the ME values determined from digestibility studies rather than conventional ME studies are "not applicable in the real world". Similarly Ketels and DeGroote (1989) determined the optimum ratio of unsaturates:saturates in terms of overall fat digestibility and ME. These workers suggest an optimum ratio of around 3:1 for unsaturates:saturates for maximizing ME. Contrary to the conclusion of Lewis (1989), Ketels and DeGroote (1989) show a similar ratio for optimum fat digestibility suggesting a direct relationship between this and ME.

While unsaturated fatty acid content of a diet therefore has a marked effect on overall fat ME level, there is often concern over free-fatty acid content. Such acids are more prone to rancidity and are more corrosive to some equipment. Although a large proportion of fatty acids are released in the lumen after hydrolysis, the presence of monoglycerides plays an important part in solubilizing non-polar long-chain saturates (Robb, 1976). Sklan (1979) also showed that overall absorption of fatty acids was highest in chicks (3 weeks old) fed triglycerides and lowest when pure fatty acids were fed. This may well be due to less efficient micelle formation, or less bile production. Sklan (1979) suggests that when FFA-rich products are used, such problems may be corrected by supplying a source of monoglyceride. These data have made some nutritionist wary of fats containing high concentrations of FAA's. However, Alao and Balnave (1985) showed no difference in the ME and utilization of tallow samples containing 2 vs 16% FFA's. These authors concluded that the level of linoleic acid and/or unsaturates in tallow probably has a larger effect on its utilization than does the level of FFA's. Similarly, Waldroup *et al.* (1995) recently showed FFA levels to have no effect on broiler performance.

Another important factor associated with micelle formation is availability of bile salts. As will be discussed later, the age-related effect on utilization of fats is partly accounted for by inefficient bile-salt recycling in very young birds. Atteh and Leeson (1985) clearly showed the advantage to be gained by adding cholic acid (bile salt) to the diet of broiler chickens (Table 3).

TABLE 3. Broiler response to dietary cholic acids

Diet	56d body wt.(g)		Fat retention (%)		Diet ME(kcal/kg)	
	Control	+Cholic acid	Control	+Cholic acid	Control	+Cholic acid
1. Non-fat basal	1800[a]	1750[a]	77[e]	79[f]	3000[a]	3000[a]
2. + Palmitate	1830[a]	1960[b]	32[a]	41[b]	3125[b]	3200[c]
3. + Oleic/palmitate (50/50)	2180[c]	2300[d]	53[c]	69[d]	3300[d]	3500[e]

With approximately 9% palmitate in the diet or 9% of an oleic/palmitate mixture there was a dramatic increase in bird performance and fat utilization in response to added cholic acid. Unfortunately the use of 0.2% cholic acid in the diet as used here is not economically viable at this time.

While it is possible to define optimum ratios of fatty acids and optimum levels of fat with regard to ME, it is sometimes difficult to envisage how such information could be accommodated in a formulation matrix. Miller et al. (1983) outlined two methods for taking into account variable fat ME values related to inclusion level, suggesting overall savings of some 1% in total feed costs.

Intestinal factors, rate of passage and interaction with other ingredients

Conditions within the intestinal lumen will affect the digestion and/or absorption of any nutrient. Freeman (1969) indicates that digesta pH can influence fat utilization, in that acidic conditions reduce micellar solubilization. In rats, it has been shown that fat digestibility is reduced when the diet contains lactic acid. This concept warrants further study considering the use of organic acid mold inhibitors and the use of various feed additives to modify gut pH.

Fat utilization seems to be adversely affected by high levels of ingestible fibre (Table 4, Cherry and Jones, 1982).

TABLE 4. Fat utilization of diets containing various fibre sources

	Basal diet	Wheat-bran diet	Cellulose-diet
Fat intake (g/d)	2.62	3.00	2.57
Excreta fat (mg/d)	291	397	601

Increased levels of cellulose apparently result in reduced fat digestion, possibly through complexes of fibre with bile salts making the latter unavailable for micelle formation.

Diet fat can also affect rate of passage of digesta through the gastro-intestinal tract and this can influence overall diet ME. Sell and co-workers at Iowa State have used this argument to account for the so called "extra-metabolic" effect of fat. Mateos et al. (1982) suggest that fats and oils likely inhibit stomach emptying and transit of digest in the small intestine. These workers found that as fat was added to the diet, the digesta took longer to move through the intestine, and so supposedly the digesta has longer contact time with enzymes and absorptive sites. It is also possible that fats may result in improved utilization of non-fat nutrients in the diet, again for the same reason involving prolonged contact time with digestive enzymes, etc.

Bird age

The fact that young birds cannot utilize dietary fats as well as do older birds, has been documented for many years, and yet this fact has rarely been incorporated in formulation matrices. Sell et al. (1986) clearly demonstrate the ability of young turkeys to metabolize various fat sources (Table 5).

TABLE 5. ME values of fats determined with young turkeys (kcal/kg)

	Age of turkey (weeks)			
Fat type	2	4	6	8
Tallow	6800	7700	8425	8550
Animal-vegetable blend	7100	7850	8540	8930

Katongole and March (1980) likewise show a 20-30% improvement in utilization of tallow for 6 vs 3 week-old broilers and Leghorns. The effect of age on ability to metabolize fats is most pronounced for saturates (Table 6, Whitehead and Fisher, 1975).

TABLE 6. Bird age, fat saturation and fat digestion

Fat type	Weeks age	Fat digestion (%)	Fatty acid deposition (%)				ME (kcal/kg)	Δ
			16:0	18:0	18:1	18:2		
Corn oil	2	96	90	-	95	95	9660	
	8	98	96	-	100	97	10,780	+11.6%
Tallow	2	57	51	49	94	-	7280	
	8	74	84	83	98	-	8030	+10.3%

The reason why adult birds are better able to digest fats, and particularly saturated fats, is not clear. Young birds recycle bile-salts less efficiently, and this may be a factor as described previously. Also there is an indication that fatty acid binding protein is not produced in adequate quantities by young birds. Katongole and March (1980) cite evidence for up to a 5x increase in FABP with chicks from hatch through 8 weeks of age.

Bird type

Because most fat utilization studies have involved broiler or Leghorn birds, then there is little information available across bird strain or type. Recently Soto-Salanova et al. (1991) indicated that young turkey poults inefficiently metabolized high-fat diets, with ME values some 500-700 kcal/kg less than anticipated. This same effect was seen with a number of fat sources. We have found similar results with young turkeys, where reduced diet ME apparently related to poor fat utilization (Basha and Leeson, 1991 unpublished observation, Table 7).

TABLE 7. Diet ME and fat utilization by young poults and broiler chicks

Bird type	Diet fat (%)	Diet ME (kcal/kg)	Fat digestibility (%)
Turkey strain A	4.2	2810[b]	48.2[c]
	12.5	2490[c]	46.3[c]
Turkey strain B	4.2	2830[b]	55.1[b]
	12.5	2518[b]	48.0[c]
Broiler chicken	4.2	3090[a]	67.3[a]
	12.5	2825[b]	64.3[a]

The diet containing 12.5% fat was fairly well utilized by chicks, yet the turkey poults exhibited an extremely low metabolizable energy value when fed this diet.

Soap formation

When fats have been digested, free-fatty acids have the opportunity of reacting with other nutrients. One such possible association is with minerals to form soaps that may or may not be soluble. If insoluble soaps are formed, there is the possibility that both the fatty acid and the mineral will be unavailable to the bird. Atteh and Leeson (1984) indicate substantial soap formation in the digesta of broiler chicks and that this is most pronounced with saturated fatty acids, and with increased levels of diet minerals (Table 8).

TABLE 8. Effect of fat source and diet calcium level on fat digestion and excreta soap formation

	% fat digestion		Excreta soap (% total excreta fat)	
Predominant fat source	0.8% Ca	1.6% Ca	0.8% Ca	1.6% Ca
Control	77[e]	75[e]	13[ab]	21[c]
Oleic acid	90[f]	78[e]	7[a]	9[a]
Palmitic acid	32[b]	18[a]	56[e]	84[f]
Oleic/Palmitic	56[d]	39[c]	35[d]	51[e]

In other studies Atteh and Leeson (1983) indicated such increased fecal soap production is associated with reduced bone ash and bone calcium content of broilers. Soap production seems to be less of a problem with older birds. This is of importance to laying hens that are fed high levels of calcium. In addition to calcium, other minerals, such as magnesium, can form soaps with saturated fatty acids. In older birds and some other animals, there is an indication that while soaps form in the upper digestive tract, they are subsequently solubilized in the lower tract due to changes in pH. Under these conditions both the fatty acid and mineral are available to the bird. Control over digesta pH may, therefore, be an important parameter for control over soap formation.

Conclusions

Fats provide a concentrated source of energy and some essential fatty acids. In general, saturated fatty acids are less well utilized than unsaturates, especially with young birds, although there is synergy between mixtures of fats. Fats can influence the utilization of other diet nutrients, and fat utilization can itself be adversely affected by high levels of fibre and minerals. At low inclusion levels (< 3%), fat ME is most likely influenced by overall diet composition, while at higher inclusion levels, fat composition is the factor most affecting fat utilization.

Fat ME values used in formulation should vary depending upon fat saturation and bird age. Leeson and Summers (1991) recently outlined such potential values.

	Metabolizable energy (kcal/kg)	
Fat type	Birds up to 21d age	Birds > 21d
Tallow	7400	8000
Lard	7600	8400
Poultry fat	8200	9000
Fish oil	8600	9000
Vegetable oil	8800	9200
Coconut oil	6000	7500
Palm oil	7100	7300
Vegetable soapstock	7800	8100
Animal-Vegetable blend	7700	8500

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