Free Fatty Acids in Diet for Laying Hens

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Dietary fats and oils, consisting mainly of triglycerides, are relatively large molecules and cannot be absorbed intact in the small intestines. The triglycerides must be broken down (hydrolyzed) by lipase and colipase, both of which are enzymes produced in the pancreas (note that colipase is secreted in an inactive form and must first be activated by the enzyme, trypsin, also secreted from the pancreas.) The result of the hydrolysis is two free fatty acids and one 2-monoacylglycerol, which can be absorbed by the small intestines. However, fats and oils are not water soluble, meaning that they do not blend well into the water-based digesta where lipase and colipase act. Instead, dietary fats and oils tend to form large fat globules with a relatively small surface-to-volume ratio, minimizing physical contact of lipase with the triglycerides. Moreover, the surface of the small intestines is surrounded by a layer of water—the unstirred water layer—that prevents the fat in water insoluble fat globules from being absorbed into the intestinal cells. To overcome these obstacles, dietary fat is first solubilized in mixed bile-salt micelles, which are minute fat droplets coated with bile salts and phospholipids. Colipase attaches itself to the micelles and 'anchors' lipase to the micelle, after which 2-monoacylglycerols and free fatty acids are released and diffuse through the unstirred water layer. The free fatty acids and the 2-monoacylglycerols are absorbed across the brush border into the enterocytes, where the free fatty acids are bound to a fatty acid binding protein and transported to the endoplasmic reticulum for re-synthesis of triacylglycerols and transport into the blood.

Because free fatty acids are produced in the natural digestion processes, one would think that a dietary supply of already hydrolyzed, free fatty acids would be beneficial in terms of fat utilization. However, in some cases, a high dietary content of free fatty acids may decrease the energy value (or utilization) of the fat (Atteh and Lesson, 1985b; Wiseman and Salvador, 1991; Blanch et al., 1995). The main reason for this apparent discrepancy is a reduced emulsification (and therefore hydrolysis and absorption) of the dietary fat, because the secretion of the emulsifying bile salts is stimulated by the presence of triglycerides and 2-monoacylglycerols—not free fatty acids—in the small intestines (Sklan, 1979). However , the production and secretion and new bile salts though the entero-hepatic circulation) as well as production and secretion of trypsin (necessary for activation of colipase) and fatty acid binding protein (necessary for transport of the absorbed fatty acids) increases with age. Thus, the metabolizable energy content of a corn-soybean meal diet supplemented with soybean oil is maximized as early as two weeks of age in broilers (Batal and Parsons, 2002) and the adverse effects of dietary free fatty acids on fat utilization are minimized the older the birds are. Indeed, Wiseman and Salvador (1991) concluded that "The influence of rate and inclusion [of free fatty acids] appeared to be of minor importance and confined to younger birds." Moreover, the negative effects of dietary free fatty acids on energy utilization is related to

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the degree of saturation of the free fatty acids (Wiseman and Salvador, 1991). Vila and Esteve-Garcia (1996b) found that in three-week-old broilers, dietary saturated free fatty acids (i.e., palmitic acid [C16:0] and stearic acid [C18:0]) decreased the digestibility and metabolizable energy value of the added dietary fat, whereas dietary unsaturated free fatty acids (i.e., oleic acid [C18:1] and linoleic acid [C18:2]) did not. In a companion study, Vila and Esteve-Garcia (1996a) showed that, in two-week-old broilers, the dietary fat's content of free fatty acids were a poor predictor of its metabolizable energy value, suggesting limited effects of the dietary free fatty acid content on energy availability.

The decrease in utilization of dietary fat (i.e., a reduction in the fat's metabolizable energy value) when free fatty acids are fed can also stem from a reaction between the acid group of the free fatty acid and ionized minerals, such as calcium, forming soaps. If these soaps are insoluble, they render both the fatty acids and the minerals unavailable to the bird and thus negatively affect the energy value of the fat and the birds' mineral retention and eggshell quality. However, Atteh and Leeson (1984; 1985c) showed with young broilers and post-peak laying hens that most of the calcium soaps of dietary unsaturated free fatty acids (oleic acid, C18:1) were absorbed by the bird as opposed to calcium soaps formed with saturated free fatty acids (palmitic acid, C16:0). Thus, while some soaps were inevitably excreted in the feces when high amounts of calcium were fed, dietary unsaturated fatty acids had only negligible effects on the metabolizable energy value of the dietary fat and no effects on mineral retention and eggshell quality. A 50:50 mix of saturated and unsaturated fatty acids resulted in intermediate effects on energy values and mineral retention, suggesting that feeding a source of unsaturated fatty acids substantially improves the utilization of saturated fatty acids and minimizes soap formation. Moreover, the fecal soap formation was affected by the age (or perhaps species) of the birds, because the intestinal soap formation was markedly lower in mature laying hens than in the two-week-old broiler chicks, likely due to a higher bile production by the older birds (Atteh and Leeson, 1984, 1985c). Indeed, egg-production performance and eggshell quality of laying hens fed supplemental fat sources in the form of an animal-vegetable blend or free fatty acids were similar despite a high dietary calcium content and fecal soap excretion (Atteh and Leeson, 1985c, a). Similarly, high amounts of dietary free fatty acids had no adverse effects on egg production in a study with laying hens reported by Treat et al. (1960). Atteh and Leeson (1985c) suggested that the calcium soaps probably were formed in the large intestines of the mature birds, where they cannot interfere with energy and nutrient utilization.

In conclusion, the free fatty acid content of dietary fat does affect its energy value, however, the effect is restricted to younger birds with immature digestive systems fed saturated free fatty acids and is unlikely to affect mature laying hens. Soap formation in birds appears to be a natural process during fat digestion (Atteh and Leeson, 1984) and is equally affected by both dietary triacylglycerols and dietary free fatty acids. As long as there is a substantial proportion of unsaturated fatty acids in the dietary fat, soap formation does not negatively affect the energy value of the dietary fat, mineral retention, eggshell quality, or egg production in mature birds.

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