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NUTRITION

Fat digestive physiology and

Commercial feeds are often supplemented with fats and oils to provide a diet with sufficient energy content. To assure that these energy sources are absorbed efficiently by the bird's digestive system one should add emulsifiers. How do these emulsifiers work and how important are they?

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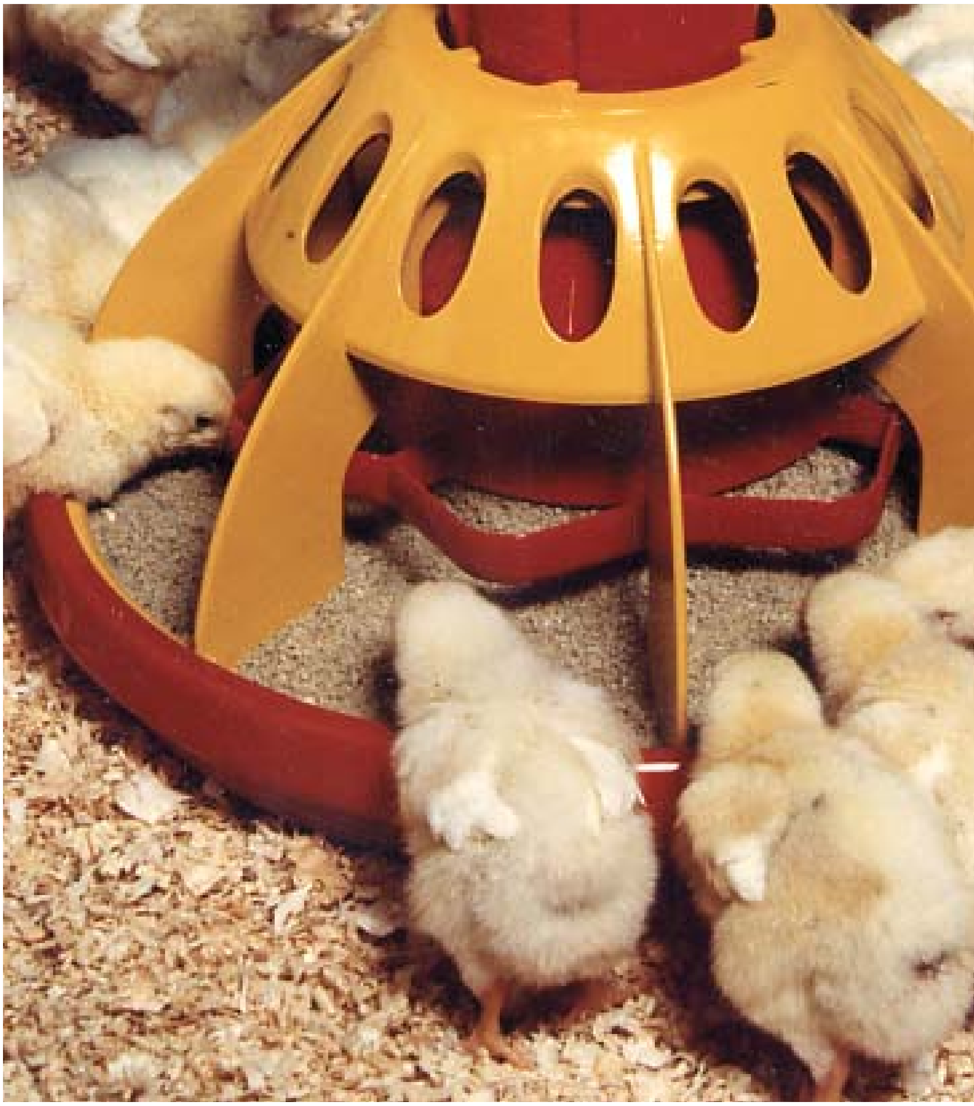


In feed, fats and oils contribute to bird health and daily gain, and also support the physical properties

To meet the needs of modern intensively reared broilers, diets are supplied with a very high nutrient and energy concentration. To achieve this high energetic density, fats and oils are incorporated into commercial diets. Besides their use as an energy source, other nutritive applications of lipids are the supplier of essential fatty acids and the solvent of fat-soluble vitamins. Fats are also added because of their effect on the physical properties of feed, like the reduction of dustiness and reduced particle separation in mash diets.

Between lipid sources there is a very broad range in energy yielding capacity, which originates in their chemical structure, inclusion rate in the diet and the composition of the other dietary components. In addition to feed factors, bird specific factors like health status and age of the bird contribute to the metabolic energy value of a feed fat as well. Lower metabolic energy values of fat sources as the result of an impaired fat digestibility, can be enhanced by supporting the fat digestive capacity of the broiler. Supplementary to physiological emulsifiers (bile salts), exogenous emulsifiers added to the feed can play a role in this.

Absorption of lipolytic products

Dietary fat enters the gastro-intestinal tract as part of the digesta in rather big coagulated particles. Under the influence of bile salts from the gall bladder, these fat particles are emulsified into smaller particles. This increases the surface of fat particles, thereby expanding the target-area of the lipolytic enzyme lipase. A fat molecule (triglyceride) is composed of a molecule glycerol in which each of the three carbons is linked to a fatty acid. Triglycerides are enzymatically digested by lipase into a monoglyceride and two free fatty acids.

At physiological circumstances most of the fatty acids derived after lipase hydrolysis are insoluble. For further transport through the aqueous environment of the intestinal tract, solubilisation of these lipolytic products is required. This is established through the process of micelle formation, which is the aggregation of hydrophobic components (primarily fatty acids) mediated by amphiphatic molecules such as bile salts and monoglycerides. In addition to these physiological amphipatic molecules, specific feed added exogenous emulsifiers have the properties to display this effect.

In the process of micelle formation, the amphiphatic molecule, which comprises both hydrophilic (water-attracting) and hydrophobic (water-repelling) properties in one molecule, functions as a bridge between fat and water, around which hydrophobic molecules (fatty acids) can orientate themselves. The hydrophilic "heads" of the fatty acids will face the aqueous environment of the digesta, leaving the hydrophobic "tails" of the fatty acids to format the core of the micelle (*Figure 1*). These spheric micellar structures are able to solubilise fatty acids in the intestinal tract together with other fat soluble components like phospholipids, cholesterol and fat-soluble vitamins. Micellar solubilisation can increase the aqueous concentration of fatty acids and monoglycerides in the small intestine up to a thousand times.

Although it has recently been suggested

exogenous emulsifiers

of mash and pellets.

Figure 1: Arrangement of fatty acids in a micelle

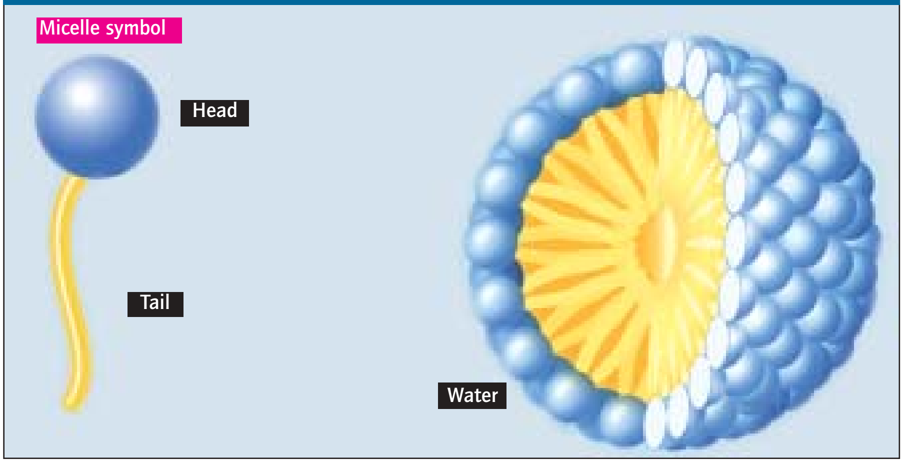
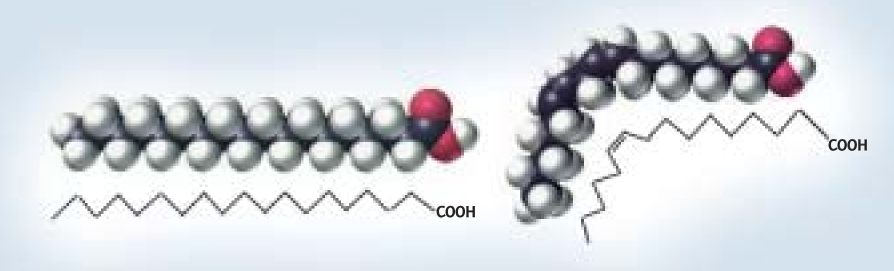


Figure 2: Saturated and unsaturated fatty acid



that certain fatty acids might be absorbed through a carrier-mediated process, it is assumed that most of the absorption of the micellar contents by the enterocyte takes place through passive diffusion. Passive diffusion is the movement of compounds from the intestinal lumen across the cell membrane into the enterocyte, in order to equalise the concentration of the substrate on both sides of the membrane. Contrary to single fatty acids, fatty acids incorporated into micelles are able to create a much higher diffusion gradient locally at the intestinal wall.

Fat composition and digestibility

Most of the fatty acids attached to the glycerol molecule of fat sources commonly used in the feed industry vary in chain length between 8 and 22 carbon atoms. Medium chained fatty acids (C6-C12) are capable of dissolving in the aqueous phase of the digesta without being incorporated into micelles first. This explains the high digestibility of coconut oil, in which nearly 50% of the fatty acids is comprised out of 12 carbon atoms and shorter. The hydrophobic character of the carbon chain of the longer fatty acids is considered to be too high to solubilise in an aqueous environment without micelle formation first.

In addition to chain length, fatty acids can also differ in the degree of saturation. When every carbon atom has the maximum number of hydrogen atoms attached, the fatty acid is saturated. When pairs of hydrogen atoms are missing and carbon atoms are linked through a double bound, the fatty acid is unsaturated. Unsaturated fatty acid molecules bend in an angle at the site of the double carbon bound, whereas saturated fatty acids have a stretched structure (*Figure 2*). The incorporation of more bended fatty acids from unsaturated fat sources in micelles, supplies the structure with a swelling character and the ability to comprise more fatty acids. The improved quality of micelles composed out of more unsaturated fatty acids implies a higher digestibility and consequently metabolic energy value of unsaturated fat sources. This was demonstrated by Wiseman *et al.* who found a curvilinear response of increasing AMEvalues of feed fats with increasing unsaturated/saturated (U/S) ratios.

Besides U/S ratio also the positioning of the fatty acids on the triglyceride is related to the digestibility of fat. As lipase primarily hydrolyses the fatty acids from the 1- and 3- position, the fatty acid, which remains part of the monoglyceride, is positioned on the 2- position. When a fat with a certain U/S ratio is composed out of triglycerides, from which the 2- position is predominantly occupied by a saturated fatty acid, better digestible (micelle improving) unsaturated fatty acids will be available as free fatty acids.

Some of the more economical fat blends available for the industry contain high amounts of free fatty acids (FFA), which are refined out of high quality edible oils during purification processes. The FFA proportion of a fat as a ratio of the total fat content has a marked negative effect on overall fat digestion. Lower energy values are the result of lower levels of monoglycerides after hydrolysis, as compared to fats and oils composed out of triglycerides. As mentioned earlier, as an amphiphatic molecule monoglycerides play an important role in micelle formation.

Bird age and health status

It is generally recognised that younger birds are not able to digest feed fats as efficiently as mature birds. This is due to a limited bile salt secretion and a less efficient bile salt recycling, which is the result of a still maturing digestive capacity. It is obvious that due to this limited bile salt secretion at younger ages, there is a more profound effect of the chemical properties of the supplied feed fat on the utilisation of this fat.

Besides age, the health status of the flock is related with the efficiency of fat digestion as well. It is often observed that fat digestibility is disturbed most severely during and after (sub)-clinical cases of infectious diseases affecting the intestinal epithelium. Besides damaging the absorption capacity by rupturing the intestinal epithelial cells, also the ratio between crypts and depths of the villi is submissive to change. An increased turnover-rate of epithelial cells can result in an increased crypt depth in the gut mucosa.

Release of bile from the gall bladder into the intestine is affected principally by the action of the hormone cholecystokinin (CCK). The release is mediated by sensors located in the crypts of the intestinal mucosa, sensitive to the presence of fat. The lack of stimulation of these CCK secretive cells induced by increased crypt depths as the result of an infectious challenge, decreases bile salt secretion in the intestinal lumen. Consequently micelle formation will take place at a lower extend with an impaired fat absorption as a result.

This was demonstrated by Adams *et. al* (1996) who found that the digestibility of lard was affected more severely than that of coconut oil after a coccidiosis infection (*E. Acervulina*). It was concluded that the reduced bile salt secretion had more impact on the digestibility of the longer chained fatty acids of lard, than those of coconut oil that are less dependent on micelle formation.

Other dietary factors

Diets high in cereals are recognised to have relatively high proportions of antinutritive carbohydrates known as non-starch polysaccharides (NSP's). These NSP's induce increased intestinal viscosity, which impacts the digestibility of all dietary nutrients by interfering with the diffusion of pancreatic enzymes, target substrates and the end products of the digestion process.

An increased viscosity decreases feed passage rate, thereby facilitating the ability of bacteria to populate regions higher in the digestive tract. This eventually can lead to the deconjugation of bile salts by the microflora in the upper intestinal tract, which immediately will result in a reduction in fat utilisation.

Impaired fat digestibility is also associated with higher dietary mineral contents. Free fatty acids available in the digesta, longer unsaturated fatty acids in particular, are submissive to interact with minerals to form soaps. If insoluble soaps are formed with Ca or Mg, there is the possibility that both the fatty acid and the mineral will be unavailable to the bird.

Table 1 - Fat digestibility and improvement in metabolic energy value of different fat blends

U/S	FFA (%)	Avilac E	Fat dig. (%)	ME_n (kcal/kg)	ΔME_n diet (%)	ΔME_n fat (%)
1.6	43.5	-	65.6^{f}	2952^{d}		
1.6	43.5	+	69.8^{de}	3012^{c}	2.1	12.4
2.6	43.5	-	70.4^{de}	3029^{bc}		
2.6	43.5	+	72.9^{bc}	3069^{a}	1.3	7.7
1.6	0.1	-	68.8^{e}	3000^{c}		
1.6	0.1	+	71.3^{cd}	3055^{ab}	1.9	10.6
2.6	0.1	-	73.9^{ab}	3057^{ab}		
2.6	0.1	+	75.8^{a}	3081^{a}	0.8	4.2

abcdef: Means within columns with no common superscript differ significantly ($P < .05$)

Emulsifiers

During all situations in which feed factors (type and level of fat, nutrient interactions) and bird specific factors (age, infection pressure) result in a non-efficient digestion capacity of the available feed fat, nutritional emulsifiers can support the digestive functionality. As a polar amphipatic molecule (consisting out of a hydrophilic and a hydrophobic part) an emulsifier is able to bridge between water- and fat-soluble materials. This enables the emulsifier to contribute to fat utilisation on top of physiological levels of bile salts.

The hydrophilicity and lipophilicity (as characterised by their molecular structure) are different among exogenous emulsifiers. The balance between the two is called the HLB value and ranges between 0 and 20.

The lower the HLB value the more lipophilic the emulsifier; and conversely, the higher the HLB value the more hydrophilic the emulsifier. Translating this to the potential physiological mode of action implies that low HLB emulsifiers would be active in dispersing water in oil, thus decreasing particle size of feed fat droplets and hereby increasing the surface area. High HLB emulsifiers would be more active in dispersing oil in water, hence stimulation of micelle formation and solubilising fatty acids.

Starting from the principle that the most limiting process in fat digestibility is micelle formation, the effect of a hydrophilic (high HLB-value) emulsifier could contribute to fat digestibility of added feed fats. To evaluate this, a digestibility trial was performed in which the effect of a hydrophilic emulsifier (Avilac E from Nutrifeed) on fat blends with differing U/S ratios and FFA contents was tested (*see Table 1*). The added fat blends in the different experimental diets differed from very unfavourable (U/S-ratio 1.6 and FFA 43.5%) to more favourable conditions (U/S-ratio 2.6 and FFA 0.1%).

A general significant tendency for an increased fat digestibility and consequently dietary ME-value for the increase in U/S-ratio, reduction of FFA and the inclusion of the hydrophilic emulsifier can be observed. The effect of this emulsifier on the dietary ME-value is more pronounced at lower U/S-ratios and higher FFA levels. At more favourable conditions with a higher U/S-ratio and no free fatty acids, a numerical effect can be observed.

The results of this digestibility trial show that the addition of a hydrophilic emulsifier to broiler diets improves fat digestibility and consequently dietary metabolic energy value. To which extent this improvement takes place depends on the type and physical properties of the fat added, for which U/S-ratio and FFA level seem very important features.

Addition of a hydrophilic emulsifier to broiler diets appears to improve the digestibility of feed fats under various conditions. Most value could be contributed when lesser digestible feed fats are incorporated in the diet.

Non feed factors such as bird age and especially health status can increase the additional value contributed by emulsifiers. That is particularly true when the ban on the prophylactic use of antibiotic growth promoters will put extra pressure on the health situation in broiler flocks and consequently on fat digestibility.

Hydrophilic emulsifiers such as Avilac E may be useful tools to optimise fat digestibility, especially when formulating broiler feeds with more economic fat sources. ■