# Enhancing the fat digestibility of poultry feeds

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Vegetable oils and animal fats are usually added to poultry diets to increase dietary energy concentrations. Besides their use as an energy source, other nutritive applications of fats include:

- Provide essential fatty acids and serve as solvent of fat-soluble vitamins.
- Increase palatability and feed intake in mash feed.
- Reduce dustiness and separation of ingredient particles in mash feed.
- Increase pellet mill output by lubrication and impact pellet quality.
- Decrease rate of passage of digesta, thereby increasing the utilisation of nutrients.

The efficient utilisation of dietary fat requires digestion and absorption of fat in the gastrointestinal tract.

Many different types of fats and oils that are used by the poultry industry vary in fatty acid composition and in their contribution to metabolisable energy.

Apart from these variations, age and health status of the birds contributes to metabolic energy value of a feed fat as well. Bile salts function to emulsify fat to form fat-containing micelles to ease absorption from the intestinal tract.

However, in modern broilers, the production of bile salts is limited at birth and during early stages of development.

Studies in poultry have indicated that fat digestion is low at early ages due to poor emulsification rather than deficiencies in lipase activity and this has led to considerable interest in the use of biosurfactants as a means of enhancing the utilisation of fats in young birds.

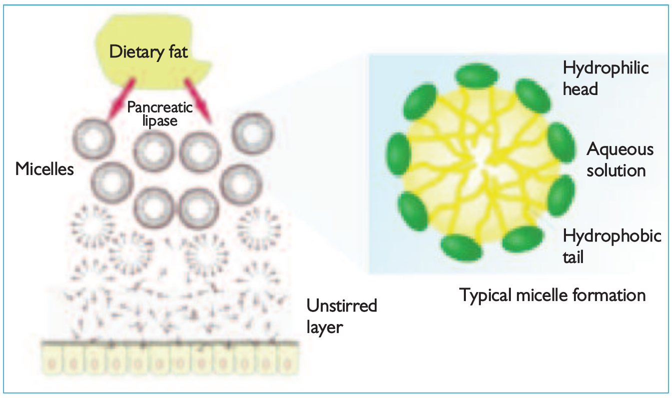


***Fig. 1. Mechanism of fat digestion and micelle formation.***

## Fat digestive physiology

Ingested lipids undergo intestinal emulsification, digestion, micellar solubilisation, cell membrane permeation, intracellular esterification and incorporation into lipoproteins before release to the interstitial fluid.

Bile salts secretion, essential to both emulsification and micelle formation in the intestine, has been found to be influenced by quantity and quality of dietary lipids and by other biosurfactants. 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 (Fig. 1), which is the aggregation of hydrophobic components (primarily fatty acids) mediated by amphipathic molecules such as bile salts and monoglycerides. In addition to these physiological amphipathic molecules, specific biosurfactants have the properties to display this effect.

These spherical 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. Most of the absorption of the micellar contents by the enterocyte takes place through passive diffusion.

***Table 1. Influence of fat type and age of birds on the AME of fats (MJ/kg dry matter).***

| Age of birds (weeks) | Tallow | Soya oil | Tallow: Soya oil (50:50) | Poultry fat | Palm oil |
|---|---|---|---|---|---|
| 1 | 13.90 | 19.31 | 16.79 | 16.96 | 19.96 |
| 2 | 23.58 | 34.71 | 30.30 | 32.78 | 36.79 |
| 3 | 31.78 | 38.94 | 32.24 | 35.01 | 39.55 |
| 5 | 28.17 | 36.56 | 35.44 | 33.28 | 38.35 |

***Table 2. Influence of lysophospholipids on AME of diets containing three different type of fats (Trial 2).***

| Treatments | Tallow (Kcal/kg) | Palm oil (Kcal/kg) | Rice bran oil (Kcal/kg) |
|---|---|---|---|
| Normal AME diet | $3085^{a}$ | $3073^{a}$ | $3076^{a}$ |
| Reduced AME diet | $2982^{b}$ | $2937^{b}$ | $2964^{b}$ |
| Reduced AME diet + lysophospholipids | $3069^{a}$ | $3035^{a}$ | $3045^{a}$ |

$^{a,b}$Means in the same column with different superscripts are significantly different ($P< 0.05$)

## Fat digestibility

Most of the fatty acids from different fat sources vary in chain length and differ in the degree of saturation.

Short and medium chained fatty acids are capable of dissolving in the aqueous phase of the digesta without being incorporated into micelles.

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. Long chain fatty acids (C14+) are considered to be too hydrophobic to solubilise in an aqueous environment without micelle formation first.

Monoglycerides and unsaturated long chain fatty acids, together with conjugated bile salts spontaneously form mixed micelles.

Bile salts, secreted from the gall bladder into the lumen of the small intestine are not absorbed in the upper small intestine. They are continuously re-utilised for subsequent micelle formation and are eventually absorbed in the lower jejunum.

However, bile salt recycling is thought to be inefficient in the young chick.

## Metabolisable energy (ME)

ME values of oils for poultry is available from numerous sources. Dietary fats vary in composition and in their contribution to energy.

The main factor that affects the metabolisable energy value of oils and fats is their digestibility. The age of birds is another important factor affecting the ability to digest fats and ME value of the same.

In addition to different test methods, bird ages, fatty acid saturation of basal diet and oil inclusion levels

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are used to measure ME. It seems obvious that the use of a single value for fat ME during formulation is a compromise, considering the foregoing discussion on factors such as inclusion level, bird age and free fatty acids.

Other factors influence digestibility and ME values of oil:

- **Non-starch polysaccharides** (NSP): Increased digesta viscosity caused by NSP can reduce digestibility of oil by interfering with diffusion of digestive enzymes and target substrates. High viscosity allows intestinal microflora to colonise further up the intestinal tract. Deconjugation of bile salts by microflora in the upper intestinal tract can reduce oil absorption and ME.
- **Minerals and soap formation:** Free fatty acids can react with minerals to form soaps, potentially making both unavailable. The practical significance of soap formation is limited to palmitic and stearic acids when calcium is in excess (more than 1%).
- **Fibre:** High levels of indigestible fibre have been reported to decrease fat digestion. Increased levels of cellulose apparently result in reduced fat digestion, possibly through formation of complex fibre with bile salts.
- **Coccidiosis:** Birds infected with coccidiosis often exhibit inferior oil digestibility. Excess undigested oil in faeces occurring with intestinal coccidiosis may, therefore, result from the loss of reconstituted fat globules following the rupture of parasitised epithelial cell.
- **Mycotoxins:** Aflatoxin has been reported to decrease pancreatic lipase and bile salt secretion sometimes causing lipid malabsorption syndrome.
- **Rate of passage:** Dietary oil has been shown to slow rate of passage, allowing more time for contact between digesta and digestive enzymes, co-factors and absorptive sites. Addition of oil may therefore increase digestion of non-lipid components of the diet.

## Exogenous biosurfactants

Exogenous biosurfactants can improve the fat digestibility during all situations in which feed factors and bird specific factors result in a non-efficient digestion capacity of the available feed fat.

Lysoforte (Kemin's lysophospholipids based product) is a biosurfactant, effective in improving the absorption of oils and fats from feed by the birds.

The following properties of lysophospholipids are responsible for the observed efficiency in increasing the rate and efficiency of fat digestion and absorption:

- Enhanced emulsification leading to the formation of smaller fat/oil droplets in the small intestine, providing more surface area for lipase activity.
- Easier micelle formation due to the very low critical micellar concentration (CMC) of lysophospholipids.

Lysophospholipids are widely used in animal diets to increase the digestion and absorption of oils and fats and to improve animal performance and feed efficiency.

Structured research studies on lysophospholipids demonstrated its positive effect on enhanced fat digestibility.

- **Trial 1. Lysophospholipids stimulate the absorption of saturated fatty acids by living cells.**

Live BHK cells (BHK 21, clone 13) were cultured under standard laboratory conditions at 37°C and 5% carbon dioxide. Live cells were treated with radioactive (C-14) stearic and palmitic acids prepared in Hanks' balanced salt solution. At the same time the cells were treated either with lysophospholipids or standard soy lecithin. Results show that there was a greater uptake of stearic acid and palmitic acid by the cell cultures in the presence of lysophospholipids than in the presence of soy lecithin. This indicates the ability of lysophospholipids to promote absorption of fatty acids.

- **Trial 2. Lysophospholipids increase fat digestibility and improve apparent metabolisable energy (AME) in broiler diets.**

The AME assay was conducted to quantify the positive energy sparing effect of lysophospholipids, at Massey University, New Zealand using diets containing three different fat sources. Lysophospholipids increased (P<0.05) AME in all treatments, resulting in a substantial recovery of metabolisable energy of the reduced ME diet containing different fat sources. Lysophospholipids supplementation produced the greatest effect on metabolisable energy recovery when applied to the diets with palm oil, causing an AME increase of 98kcal/kg in the reduced ME diet. For diets containing tallow and rice bran oil as the fat source, Lysophospholipids supplementation resulted in an AME increase of 87kcal/kg and 81kcal/kg respectively.

- **Trial 3. Effect of fat type and lysophospholipids addition to broiler diets on apparent digestibility of fatty acids.**

A completely randomised design study with a 3x2 factorial arrangement was conducted to evaluate the effects of three different fat sources (soybean oil, tallow, and poultry fat) with or without lysophospholipids supplementation on coefficient of total tract apparent digestibility (CTTAD) of fatty acids in broiler chickens. The CTTAD of C16:0, C18:2, and C18:3n3 was greater (P<0.05) for broilers fed diets containing soybean oil than for those fed diets containing tallow or poultry fat in the starter period.

- **Trial 4. Effect of fat type and lysophospholipids addition on broiler performance.**

The experiment was conducted as a 2x2 factorial arrangement of treatments. Two basal diets were formulated with two fat sources, namely soy oil and tallow, at an inclusion level of 40g/kg in starter diets and 60g/kg in finisher diets, with out and with lysophospholipids. The diets were formulated to meet commercial specifications and AME was maintained at 12.2 MJ/kg in basal diets. The growth performances of broilers during the starter and over all experimental period are presented in Table 4. Weight gain was greater (P<0.001) for birds fed soy oil diet compared with those fed tallow diet during the starter period (d 1-21) as well the whole period (d 1-35). Results clearly demonstrated the addition of lysophospholipids improved the feed conversion efficiency of broilers.

| Fat sources | Lysophos-pholipids | Treat-ments | Day 14 - 17 C16:0 | C18:0 | C18:1n9 | C18:1n7 | C18:2 | C18:3n3 |
|---|---|---|---|---|---|---|---|---|
| Soybean oil | - | T1 | 0.669 | 0.432 | 0.75 | 0.670 | 0.808 | 0.881 |
| | + | T2 | 0.749 | 0.566 | 10.801 | 0.733 | 0.842 | 0.907 |
| Tallow | - | T3 | 0.568 | 0.440 | 0.766 | 0.639 | 0.753 | 0.784 |
| | + | T4 | 0.566 | 0.444 | 0.776 | 0.659 | 0.741 | 0.818 |
| Poultry fat | - | T5 | 0.539 | 0.415 | 0.735 | 0.668 | 0.731 | 0.776 |
| | + | T6 | 0.653 | 0.451 | 0.783 | 0.708 | 0.761 | 0.826 |
| | SEM | | 0.0189 | 0.0172 | 0.0086 | 0.0101 | 0.0101 | 0.0122 |
| **Source of variation (P-value)** | | | | | | | | |
| Fat sources | | 0.002 | 0.215 | 0.697 | 0.074 | <0.001 | 0.001 | |
| Lysophospholipids | | 0.045 | 0.083 | 0.039 | 0.036 | 0.299 | 0.076 | |
| Fat sources xLysophospholipids | | 0.302 | 0.246 | 0.558 | 0.634 | 0.465 | 0.878 | |

Each value represents the mean values of seven pens of six animals each (n=7).- represents without lysophospholipids supplementation; + represents with lysophospholipids supplementation

***Table 3. Effect of fat sources and lysophospholipids on the CTTAD of fatty acids in broilers (Trial 3).***

***Table 4. Effect of lysophospholipids on broiler performance from soy oil and tallow diets (Trial 4).***

| | 0-21 days Weight gain (g/bird) | FCR | 0-35 days Weight gain (g/bird) | FCR |
|---|---|---|---|---|
| Tallow | 966 | 1.49 1.42 | 2396 | 1.61 |
| + lysophospholipids | 963 | | 2434 | 1.53 |
| Soy oil | 1012 | 1.38 | 2448 | 1.53 |
| +lysophospholipids | 1031 | 1.36 | 2432 | 1.49 |
| Tallow | 965[a] | 1.46[a] | 2415[a] | 1.57 |
| Soy oil | 1022[b] | 1.37[b] | 2440[b] | 1.51 |
| - lysophospholipids | 989 | 1.44[a] | 2433 | 1.51[a] |
| + lysophospholipids | 997 | 1.39[b] | 2422 | 1.57[b] |

## Summary

Use of supplemental fats and oils in broiler chicken diets as dietary energy-yielding ingredients is a wide spread practice in the feed industry. Dietary fats vary in composition and in their contribution to energy.

The main factor that affects the metabolisable energy value of oils and fats is their digestibility. The age of birds is another important factor affecting the ability to digest fats.

Therefore supplementation of exogenous biosurfactants would be beneficial to enhance fat digestibility.

Results from many research and commercial studies indicate that lysophospholipids supplementation can be used as a feeding strategy in poultry diets in order to improve fat digestibility and growth performance.

In addition, lysophospholipids provides an opportunity to manage feed cost, as expensive fat can be partially substituted in poultry diets. ■