LIPID METABOLISM

1. **General**

A. Lipids:

1) Include a group of substances that are insoluble in water, but soluble in ether, chloroform & benzene.

2) Include fats, waxes, glycolipids, phospholipids, steroids, prostaglandins, etc.

3) .Fats. are by far the most important lipids based on amounts present in the animal
body & its food.

4) But others also play significant roles in nutrition & physiology - e.g., cholesterol is a precursor of vitamin D and sex hormones, and it is infamous component of atheromatous plaques of cardiovascular diseases!

B. Lipids in diets for non ruminant species:

1) Baby pigs diet (milk) consists of 6-8% fat (30-40% on a DM basis). (Others - 80% water, 5-6% protein & 4.5-5% lactose.)

2) Lipid content in grains - Corn, . 3.6%; milo, . 2.8%; barley & wheat, less (< 2%).

3) Soybean & other oilseed meals (solvent extracted) are low in lipids (< 2-3%).

4) Animal protein sources (fish meal, meat meal, etc.) are relatively high (6-10%).

5) Corn-soy-based diets usually contain . 2.5-3% fat.

C. Some reasons for using feed grade lipids in non ruminant diets:

1) To improve growth rate & feed efficiency.

2) To reduce dustiness of feed, and also in confinement buildings.

3) To ↑energy content of sow's milk, ˆ increase the survival rate of baby pigs.

4) To reduce segregation of smaller particles.

5) To facilitate the pelleting process.

6) To reduce wear & tear on mixing and handling equipments .

2. **Classification of Lipids**

A. Based on the No. of carbon atoms and the degree of un saturation:

1) Saturated fatty acid (SFA) - No double bonds.

2) Unsaturated fatty acid (UFA) - One or more double bonds.

3) Polyunsaturated fatty acids - Two or more double bonds.

B. Natural lipids (plant & animal origin):

1) Made up of triglycerides (glycerol + 3 FA).

2) Most FA have 8 to 24 C with 16 to 18 C being common for many feed lipids.

3) Short (< 10 C) or medium chain FA - FA with 14 C or less.

3. **Physical and Chemical Characteristics of Lipids** .

	Corn	Soy	Saf-flower	Coco-nut	Past. grass	Butter	Tallow	Lard	Egg
Saturated acids, %									
Butyric C14:0						3.2			
Caproic C6:0				0.2		1.8			
Caprylic C8:0				8.2		0.8			
Capric C10: 0				7.4		1.4			
Lauric C12:0				47.5		3.8			
Myristic C14:0			0.2	18.0	1.0	8.3	3.0		0.3
Palmitic C16:0	7.0	8.5	12.3	8.0	16.0	27.0	27.0	32.2	22.1
Stearic C18:0	2.4	3.5	1.8	2.8	2.0	12.5	21.0	7.8	7.7
Total	***9.4***	***12.0***	***14.3***	***92.8***	***19.0***	***58.8***	***51.0***	***40.0***	***30.1***
Unsaturated acids, %									
Palmitoleic C16:1					2.0				3.3
Oleic C18:1	45.6	17.0	11.2	5.6	3.0	35.0	40.0	48.0	36.6
Linoleic C18:2	45.0	54.4	74.3	1.6	13.0	3.0	2.0	11.0	11.1
Linolenic C18:3		7.1			61.0	0.8	0.5	0.6	0.3
Arachidonic C20:4									0.8
Total	***90.6***	***78.5***	***85.5***	***7.2***	***79.0***	***38.8***	***42.5***	***59.6***	***52.1***

ESSENTIAL FATTY ACIDS

1. **Dietary Requirements**

A. .Essentiality. of fatty acids:

1) Evans & Burr (1926. Proc. Soc. Exp. Biol. Med. 24:740) indicated that *.a component of fat other than fat-soluble vitamins are dietary essential for rats!*.

2) Burr & Burr (1929. J. Biol. Chem. 82:345):

a) Feeding the diet almost devoid of fat to rats resulted in a poor growth, symptoms of dermatitis, necrosis of tails and death.

b) Also observed adverse effects on reproduction & lactation.

c) Small amounts of PUFA were effective in preventing/curing those conditions.

Thus, they called the PUFA, .Essential Fatty Acids!.

B. Swine & chicks:

1) Demonstration of the essentiality of FA:

a) For chicks by Reiser in 1950 (J. Nutr. 42:319).

b) For swine by Whitz and Beeson in 1951 (J. Anim. Sci. 10:112).

2) Deficiency symptoms:

a) Swine - e.g., poor growth, skin lesions, retarded sexual maturity, underdeveloped GI systems, etc.

b) Birds - e.g., ↓growth & disease resistance, dermal problems, faulty feathering, fatty livers, ↓development of secondary sex characteristics, etc.

2. **Essential Fatty Acid Activity**

A. Essential FA .activity.

1) Interconversion among FA, FA provided in the diet may not be the one that is responsible for alleviating the deficiency symptom .

2) Fatty acids are involved in a wide range of metabolic processes in animals:

a) May exhibit many manifestations of dietary essential FA deficiencies.

b) May respond differently to various FA depending on deficiency symptoms.

B. Fatty acids to be active:

1) Important to have unsaturated bonds between carbons 6-7 and 9-10 from the methyl end of FA chain [. . . known as omega (ω) carbon], which give FA the correct configuration!

2) Activity of various FA:

a) Linoleic acid (US bonds at 6-7 & 9-10 positions) - Has a 100% activity, and animals can synthesize arachidonic acid from linoleic acid.

b) Arachidonic acid (US bonds at 6-7, 9-10, 12-13 & 15-16 positions) has a100% activity.

c) Oleic acid (an US bond at 9-10 position) has no activity because animals cannot unsaturate the 6-7 bond.

d) Linolenic acid (US bonds at 3-4, 6-7 & 9-10 positions) - Not effective because the .3-4. bond destroys a critical configuration, and although animals can saturate this bond, not efficiently, has a limited activity.

3) Essential FA:

a) From a metabolic standpoint, .arachidonic acid. is the essential FA.

b) From a dietary standpoint, .linoleic acid. is the essential FA because of:

(1) Conversion of linoleic to arachidonic acid.

(2) Low arachidonic acid contents in feeds.

C. Metabolic transformation of FA:

1) Conversion by microsomal chain elongation or desaturase system.

2) Competition among series because of the use of the same enzyme systems:

a) w-3- & w-6-family can suppress metabolism of each
other.
b) w-6 family can suppress formation of PUFA from oleic acid.
Affinity for enzymes?
Linolenic (w-3) > linoleic (w-6) > oleic (w-9)!
D. The cat family (e.g., cats & lions) - Unable to desaturate linoleic & linolenic acids
may require specific polyunsaturated FA of animal origin.

3. **Functions of Essential Fatty Acids**
A. Important components of cellular membranes and subcellular structures (e.g.,
mitochondria) - Present as phospholipids & provide .fluidity. to the membrane, which is essential for cellular functions.

B. Involved in the synthesis of arachidonic acid derivatives, which are synthesized and incorporated into the phospholipids of cell membranes - e.g.:
1) Prostaglandins - Involved in vasoconstriction/vasodilation, & reproductive cycles, lipid metabolism, etc.

2) Prostacyclin - Involved in vasodilation, inhibition of platelet aggregation, etc.
3) Thromboxanes - Involved in vasoconstriction, stimulation of platelet aggregation
(clotting), etc.

4) Leukotrienes - Mediators of allergic response & inflammation, also potent vasoconstrictors, etc.

4. **A Source of Linoleic Acid?**

A. Linoleic acid - Sources:

Source	Percent	
Sunflower oil	78	
Sunflower oil	68	
Corn oil	55	(58.0%)
Soybean oil	50	(65.7%)
Cottonseed oil	50	
Peanut oil	27	
Poultry fat	25	(11.8%)
Lard	10	(18.3%)
Fish oil	2.7	
Beef tallow	1.5	(3.1%)
Milk fat	1.5	
Coconut oil	1.5	
Corn	1.8	
Oats	1.5	
Wheat	.6	
Barley .	2	
Soybean meal	3	

B. Animal fats tend to be low in linoleic acid.
C. Plant oils tend to be high in linoleic acid, especially in forage lipids - e.g., pasture grasses contain . 60% of lipids as linolenic acid.
D. The content and(or) type of animal fats can be influenced by the concentration and type of dietary lipids!

5. **Fatty Acid Requirements**

A. Birds (linoleic acid): (NRC, 1994)

1) Poultry (chickens, hens & broilers) - 0.83 (hens with 120 g of feed/day) to 1.25%
(hens with 80 g of feed/day), with 1.00% for all others.

2) Turkeys - 0.8% (8-24 wk & breeders/holding), 1.0% (up to 8 wk), and 1.1% for
laying hens.

B. Swine (linoleic acid):
1) ARC, 1981 - 3 & 1.5% of dietary DE for pigs up to 30 kg & from 30-90 kg,
respectively.
2) 0.10% for all classes of pigs.
These levels are usually present in typical cereal-protein supplement-based diets
(e.g., corn, 1.8% & soy, 0.30%).

C. Fish:
1) Fresh water fish generally require either dietary linoleic acid or linolenic acid, or
both - 0.5 to 2.5% depending on estimates/species.
2) Marine fish require dietary eicosapentaenoic acid [EPA; 20:5 (n-3)] and(or)
docosahexaenoic acid [DHA; 22:6] - 0.5 to 2% of EPA & DHA depending on
estimates/species.
D. Factors that influence the .essential FA deficiency,. ˆ the requirement:
1) Age & carryover effects (e.g., from the egg to chick).
2) Growth rate.
3) Sex - % may need more (e.g. in rats, 10-20 mg for & vs > 50 mg/d for %).
4) Humidity & water balance - Related to dermal conditions.