The Balance of Fatty Acids and Its Impact on Sows and Piglets

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CONTENTS

1. Concept

- Fatty acids are a class of compounds composed of the three elements: carbon, hydrogen, and oxygen. They constitute the primary components of neutral fats, phospholipids, and glycolipids.
- More than 40 different types of fatty acids have been discovered in the natural world.
- Fatty acid synthesis enzymes are present in the cytoplasm of various tissues in the body, including the liver, kidneys, brain, lungs, mammary glands, and adipose tissue. These enzymes facilitate the synthesis of fatty acids, with the liver exhibiting the highest enzymatic activity in fatty acid synthesis. Therefore, hepatocytes are the primary site for fatty acid synthesis.
- Animals are unable to synthesize polyunsaturated fatty acids with more than one double bond internally. These essential fatty acids include linoleic acid and alpha-linolenic acid.

The Classification of Fatty Acids

● **Fatty Acid Classification Based on Carbon Chain Length**

➢ Short-Chain Fatty Acids (SCFAs) refer to fatty acids with a carbon atom count of ≤ 6, primarily including acetic acid, propionic acid, and butyric acid.

➢ Medium-Chain Fatty Acids (MCFAs) are fatty acids with a carbon atom count ranging from 6 to 12, primarily including caproic acid, caprylic acid, capric acid, and lauric acid, among others.

➢ Long-Chain Fatty Acids (LCFAs) are defined as fatty acids with a carbon atom count of 13 or higher. Examples include palmitic acid, oleic acid, linoleic acid, and alpha-linolenic acid.

The Classification of Fatty Acids

- Fatty Acid Classification Based on the Degree of Saturation of Carbon-Hydrogen Chains

➢ Saturated Fatty Acids: Fatty acids with fully saturated carbon-hydrogen chains, such as stearic acid.

➢ Monounsaturated Fatty Acids: Fatty acids with one unsaturated bond in their carbon-hydrogen chain, such as oleic acid.

➢ Polyunsaturated Fatty Acids: Fatty acids with two or more unsaturated bonds in their carbon-hydrogen chain, such as linoleic acid and alpha-linolenic acid. Polyunsaturated fatty acids are mostly of particular physiological significance.

The Classification of Fatty Acids

- Classification Based on the Position of the First Double Bond in Unsaturated Fatty Acids

➢ω-3 Fatty Acids: The first double bond is located at the third carbon atom from the methyl end, as seen in alpha-linolenic acid.

➢ω-6 Fatty Acids: The first double bond is located at the sixth carbon atom from the methyl end, as observed in linoleic acid.

➢ω-7 Fatty Acids, ω-9 Fatty Acids, ω-12 Fatty Acids ----

➢ω-3 and ω-6 fatty acids are essential and important in the body.

The Nutritional Functions of Fatty Acids

1.Providing energy, serving as a source of metabolic fuel for the body.

2.Maintaining the normal physiological function of cell membranes.

3.Serving as a precursor for the synthesis of other compounds.

4.Esterifying cholesterol, reducing blood cholesterol and triglyceride levels.

5.Enhancing brain cell activity, improving memory and cognitive function.

6.Preserving the integrity of the intestinal mucosal barrier.

7.Exhibiting anti-inflammatory, antibacterial, and antiviral properties.

The Functions of Essential Fatty Acids

1. Serve as the primary components of lipids in biological membranes, including cell membranes, mitochondrial membranes, and myelin sheaths.

2. Act as precursors for the synthesis of biologically active compounds, such as prostaglandins.

3. Maintain the impermeability of the skin and other tissues to water.

4. Lower blood cholesterol levels, exhibit anti-thrombotic properties, and provide resistance against atherosclerosis.

The deficiency of the essential fatty acids can result in impaired biosynthesis of biological membranes, reduced immunity, damage to the reproductive system, decreased reproductive function, and a susceptibility to atherosclerosis.

2. Fatty Acid Balance

- Unsaturated/Saturated Fatty Acid Balance
- Short/Medium/Long-Chain Fatty Acid Balance
- ω-6/ω-3 Fatty Acid Balance

Unsaturated/Saturated Fatty Acid Balance (U/S)

- unsaturated fatty acids are generally more easily digested and absorbed than saturated fatty acids.
- The digestibility of fat is dependent on the ratio of unsaturated to saturated fatty acids in the overall diet.
- When the U/S (Unsaturated/Saturated) ratio in feed is greater than 1.5, the digestibility of fat is quite high, averaging between 85% to 92%. However, if the U/S ratio falls below 1.0 to 1.3, digestibility drops to a range of 35% to 75%.
- Excessively high levels of unsaturated fatty acids can also impact the body's immune function and lead to a decline in meat quality.
- To ensure optimal fat digestibility, the minimum U/S ratio required for laying hens is 2.25, while broiler chickens require a minimum U/S ratio of 2.75, and for pigs, the minimum U/S ratio is 2.91.

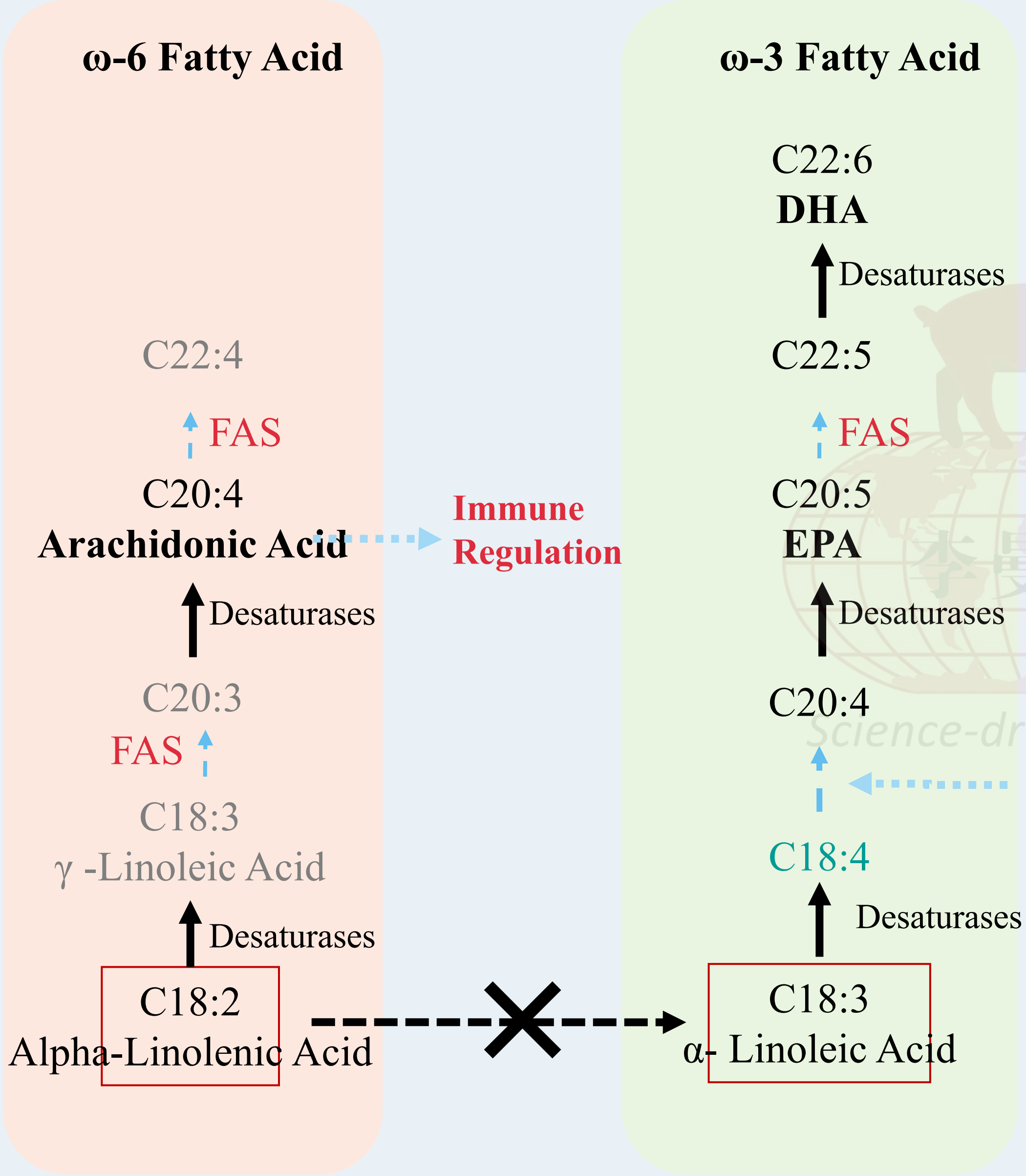
Short/Medium/Long-Chain Fatty Acid Balance

- Piglet trials indicating: short-chain fatty acids (sodium butyrate) are most effective in improving piglet survival rates. Medium-chain fatty acids are more effective in reducing the weaning-to-estrus interval in sows, while long-chain fatty acids (PUFA) are better at enhancing colostrum quality (Chen, 2019).
- Piglet trials: butyric acid can improve the feed-to-meat ratio during the 15-28 day period after weaning. Lauric acid and stearic acid had no significant effect on the growth performance of weaned piglets. Fatty acids of different carbon chain lengths can promote the renewal of piglet ileal epithelial cells (Yang Yuan, 2020).
- Dairy cow trials: the ratio of short- to long-chain fatty acids (SMCFA to LCFA) had no impact on feed intake, milk production, or rumen fermentation. However, as the dose of SMCFA additives in the diet increased, there was a linear increase in milk fat content and SMCFA concentration in milk, which altered the composition of milk fat and blood lipid metabolism (Sun Yan, 2012).
- The addition of a mixture of medium-chain and long-chain fatty acids to the diet can enhance the immune performance of dairy cows, but the effectiveness varies depending on the ratio (Xu Xiaoyan, 2012).

ω-6/ω-3 Fatty Acid Balance

- The ω-6 and ω-3 series are two essential sources of fatty acids in the body.
- Due to the lack of ω-3 desaturase enzymes in the body, these two series of fatty acids cannot be converted into each other internally and must be obtained from dietary sources.
- ω-3 fatty acids inside the body can form anti-inflammatory substances, such as ω-3 oxylipins, while ω-6 fatty acid derivatives, including prostaglandins, have pro-inflammatory effects. The ratio of ω-3 to ω-6 in the diet impacts immune and anti-inflammatory functions.
- When ω-3 and ω-6 fatty acids coexist, they compete for the same enzymes required in their metabolic pathways.

ω-6/ω-3 Fatty Acid Balance



- **Immune Balance Regulation**
- **Lipid Metabolism Regulation**
- **Lipid Transport Regulation**
- **Reproductive Efficiency**

ω-6/ω-3Fatty Acid Balance（Human)

- FAO recommends a ratio of 5～10:1.
- The International Society for the Study of Fatty Acids and Lipids recommends a ratio of 4～6:1.
- The European Food Safety Authority (EFSA)recommends a ratio of 4～4.5:1.
- The United States recommends a ratio of 2.3:1.
- Japan recommends a ratio of 4:1.
- Canada recommends a ratio of 5～6:1.
- The Chinese Nutrition Society recommends a ratio of 4～6:1.
- The typical ratio in human diets is generally around 25～30:1.

The Impact of ω-6/ω-3 Fatty Acid Balance on Animals

(1) Impact on Immunity

(2) Impact on Physiological Functions

(3) Impact on Growth Performance

(4) Impact on Livestock and Poultry Product Quality

The Impact of ω-6/ω-3 Fatty Acid Balance on Animals

(1) Impact on Immunity

Research suggests that an appropriate ω-6/ω-3 ratio can regulate the body to maintain an optimal immune level.

- ✓ Studies have found that a lower ω-6/ω-3 ratio can enhance the levels of serum total protein, albumin, IgA, IgG, IgM, and other immune antibodies in Yangzhou geese after 56 days of age (Song Zhigang, 2011).
- ✓ Dietary differences in PUFA ratios may impact the immune function of laying hens by altering the expression of cytokine genes and the composition of fatty acids in immune cells (Xia Zhaogang, 2004).
- ✓ Modifying the ω-6/ω-3 fatty acid ratio in the feed of weaned piglets can improve their response to immune stress. When the ω-6/ω-3 ratio is maintained at around 5:1, it can promote the release of pro-inflammatory cytokines and enhance the body's immune response (Yu Pingping, 2013).
- ✓ An ω-6/ω-3 ratio of 10 has been found to optimize the immune response in weaned piglets (Zuo Lei, 2010).

The Impact of ω-6/ω-3 Fatty Acid Balance on Animals

(2) Impact on Physiological Functions

✓- Wang Mengzhi (2011) found that a ω-6/ω-3 ratio of 6:1 has a favorable effect on lipid-lowering in geese.

✓- Ding Luoyang (2012) discovered that a ω-6/ω-1 ratio of 3:1 reduces damage to the membrane structure of goose liver cells.

✓- Liu Xianjun (2012) observed that ω-6/ω-3 ratios of 8, 12, and 19:1 enhance the antioxidative capacity of fattening pigs.

✓- Guo Zhiyou found that an appropriate ω-6/ω-3 ratio benefits the improvement of villus damage in piglets and promotes intestinal morphological development.

✓- Qi Keke (2009) research indicated that as the dietary ω-6/ω-3PUFA ratio decreases, there is a significant reduction in total blood cholesterol in broiler chickens.

✓- Yang Zaibin (2011) demonstrated that the addition of different gradients of PUFA in broiler feed can lower the pH in the digestive tract, increase the activity of fat enzymes, pancreatic enzymes, and amylase in various sections of the intestine, thereby improving the gut environment.

The Impact of ω-6/ω-3 Fatty Acid Balance on Animals

(3) Impact on Growth Performance

✓- When the ω-3/ω-6 ratio in feed is approximately 1.238, fish exhibit higher growth rates, improved protein efficiency, and lower feed conversion ratios. When the ratio of oleic acid to linoleic acid in the feed is between 7 to 8, the yellow catfish exhibit the fastest growth and the highest feed utilization efficiency (Tang Li, 2010).

✓- Guo Zhiyou discovered that a ω-6/ω-3 ratio of 10:1 can significantly reduce the diarrhea rate in weaned piglets.

✓- When weaned piglets at 21 days of age have a ω-6/ω-3PUFA ratio of 10, their daily weight gain is significantly higher compared to piglets with ratios of 2.5 and 20. This ratio also improves the feed conversion rate from day 0 to 21. The levels of IL-1β, IL-6, and TNF-α exhibit a quadratic trend with increasing ω-6/ω-3 ratios. The optimal ω-6/ω-3PUFA ratio for weaned piglets is found to be 10 (Zuo Lei, 2010).

✓- It has also been reported that reducing the values of ω-6/ω-3 fatty acids in the diet has no significant impact on the production performance of animals.

The Impact of ω-6/ω-3 Fatty Acid Balance on Animals

(4) Impact on Livestock and Poultry Product Quality

✓- Liu Xianjun (2012) discovered that when the ω-6/ω-3 ratio in pig feed is 3:1, the ratio of ω-6/ω-3 in the longest dorsal muscle of pigs reaches the recommended dietary ω-6/ω-3PUFA ratio by the Chinese Nutrition Society (4-6:1).

✓- Cui Hongze (2020) found that as the values of ω-6/ω-3 fatty acids in the diet decrease, the content of ω-3 fatty acids in fattening pig muscles significantly increases. The levels of ω-6 fatty acids decrease noticeably, and the content of ω-3 fatty acids in subcutaneous fat tissue significantly increases. The ω-6/ω-3 fatty acid ratio within the fat is significantly reduced.

✓- Nong (2020) discovered that a low ω-6/ω-3 ratio significantly increases the content of ω-3 fatty acids in subcutaneous fat tissue of local Chinese pigs and significantly reduces the ω-6/ω-3 ratio in subcutaneous fat tissue.

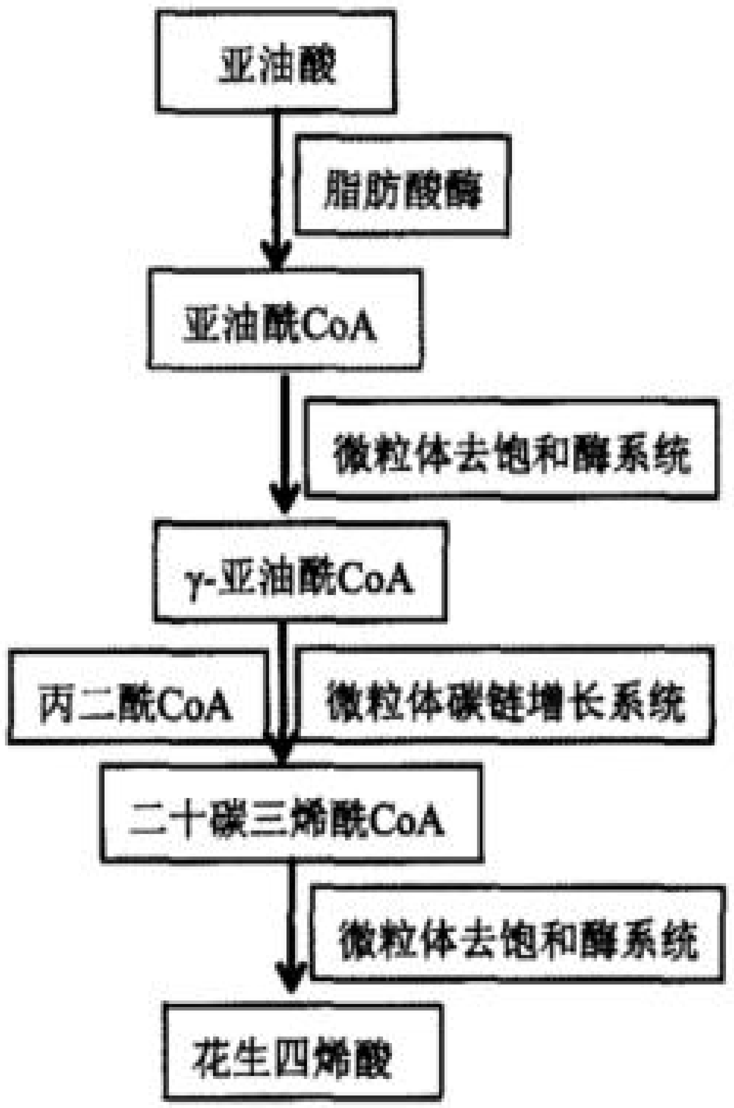
✓- Song (2020) found that adding flaxseed oil to pig feed increases the proportion of unsaturated fatty acids in pork and reduces the ω-6/ω-3 ratio.

3. Linoleic Acid and Linolenic Acid Balance

- ω-6 and ω-3 fatty acids belong to the category of polyunsaturated fatty acids and are crucial dietary nutrients. These two series of fatty acids cannot be converted into one another within the body and must be acquired from our diet. Therefore, maintaining the proper balance of ω-6/ω-3 PUFAs in our food is of utmost significance.
- Linoleic acid serves as the precursor to the ω-6 series of fatty acids
- Linolenic acid serves as the precursor to the ω-3 series of fatty acids
- The balance of ω-6/ω-3 fatty acids primarily revolves around the equilibrium between linoleic acid and linolenic acid.

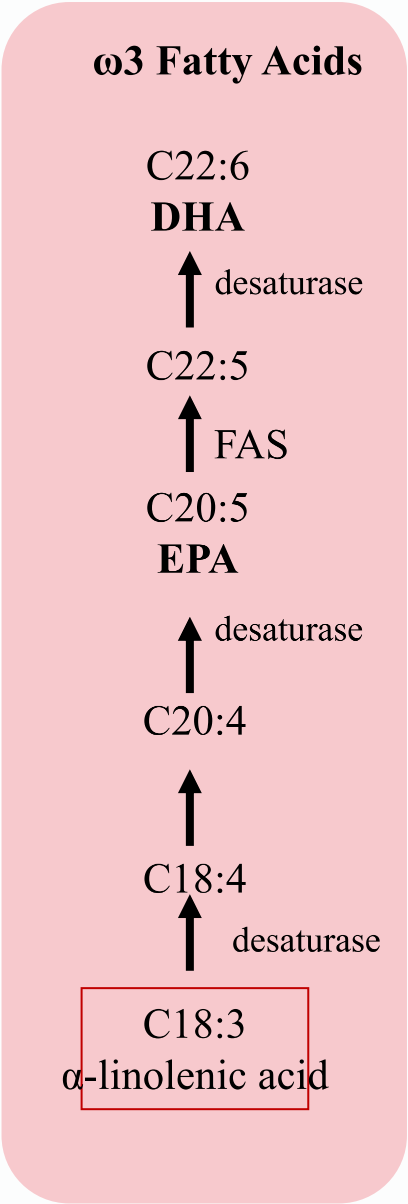
3. Linoleic Acid

- Linoleic acid is one of the essential unsaturated fatty acids in the body;
- It belongs to the ω-6 series of polyunsaturated fatty acids. It serves as the precursor to all ω-6 polyunsaturated fatty acids;
- It can be converted into arachidonic acid, a precursor for prostaglandin synthesis;
- It has various benefits, such as protecting cardiovascular and cerebral health, lowering blood cholesterol and triglycerides, and preventing atherosclerosis.

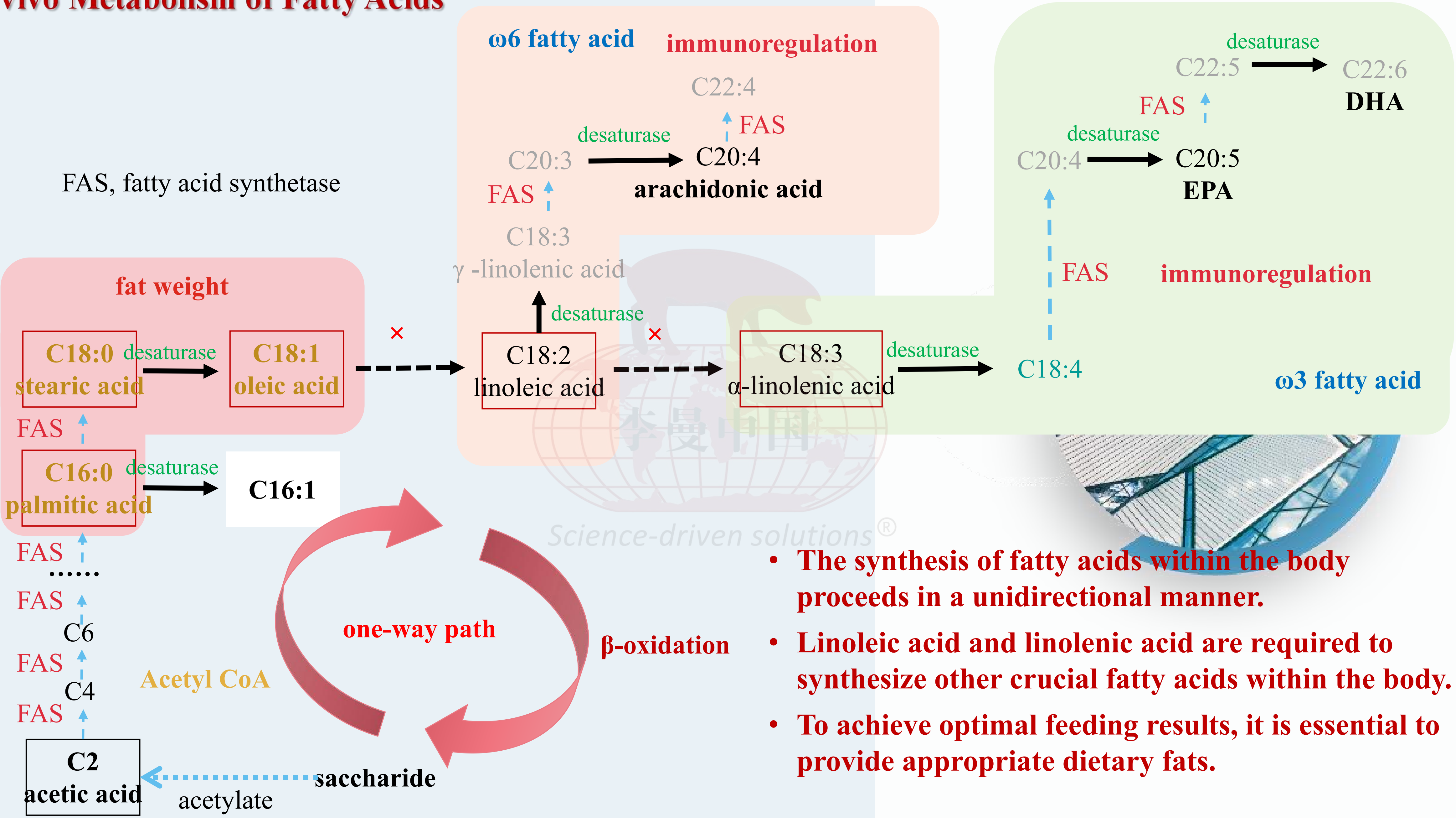


3. Linolenic Acid

- Linolenic acid is one of the essential unsaturated fatty acids in the body, belonging to the ω-3 series of polyunsaturated fatty acids.
- It serves as the precursor to all ω-3 polyunsaturated fatty acids
- It can be synthesized in the body to produce EPA and DHA, with EPA being a precursor for intracellular triene prostaglandins and DHA being a primary component of nerve system phospholipids in the brain and retina.
- In the human body, approximately 8% to 20% of linolenic acid can be converted into EPA, while about 0.5% to 9% is converted into DHA.
- It possesses key physiological functions, including regulating blood lipids, lowering blood pressure and blood sugar, preventing cardiovascular and cerebrovascular diseases, enhancing the immune system, reducing inflammation, inhibiting the occurrence and spread of cancer, protecting vision, improving memory, providing antioxidant effects, and slowing down the aging process.



In vivo Metabolism of Fatty Acids



- The synthesis of fatty acids within the body proceeds in a unidirectional manner.
- Linoleic acid and linolenic acid are required to synthesize other crucial fatty acids within the body.
- To achieve optimal feeding results, it is essential to provide appropriate dietary fats.

Linoleic Acid and Linolenic Acid Metabolism Share Common Enzymes

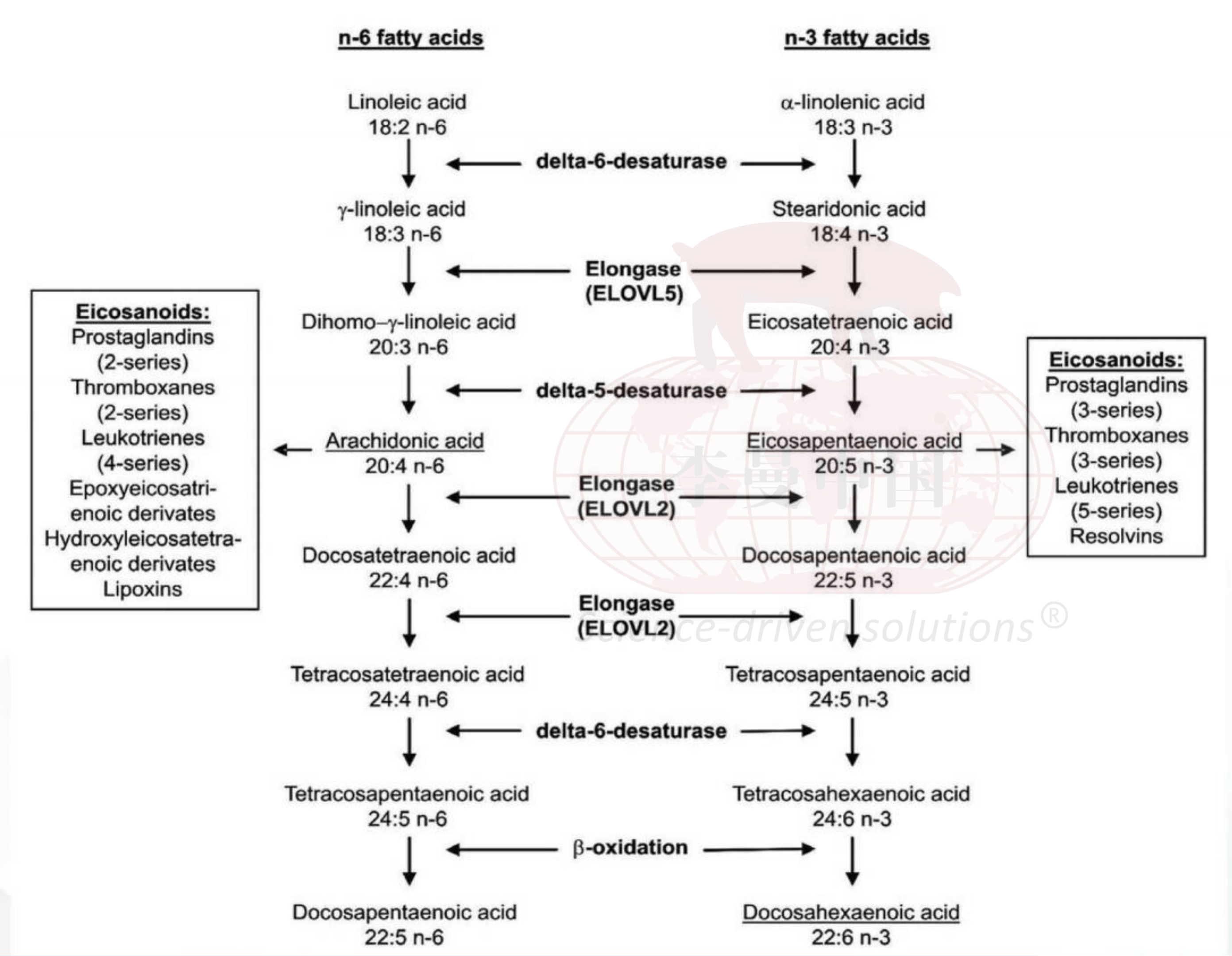


Figure 1: Synthesis and Conversion Pathways of n-3 and n-6 PUFA [1]

Linoleic Acid and Linolenic Acid Balance

- In rodent experiments, a high level of linoleic acid in the diet can partially inhibit the efficiency of α-linolenic acid from the diet in converting to EPA and DHA in the body.
- As the ratio of linoleic acid to linolenic acid decreases, there is a significant increase in omega-3 fatty acids in chicken breast muscles. A diet with a ratio of 10 significantly increases subcutaneous fat thickness and intramuscular fat content, resulting in the reddest breast muscle color (Qi, 2010).
- When 3.4% flaxseed oil is added to the feed of laying hens, the ω-6/ω-3 PUFA ratio in the egg yolks of hens decreases (Oliveira, 2010).
- Different LA/LNA ratios do not significantly impact the growth of the Misgurnus anguillicaudatus (pond loach). However, a ratio within the range of 1 to 4 is beneficial for the fish's antioxidant capacity (Tian Jingjing, 2015)

The appropriate ratio of linolenic acid to linoleic acid for grass carp fry is 1.08.

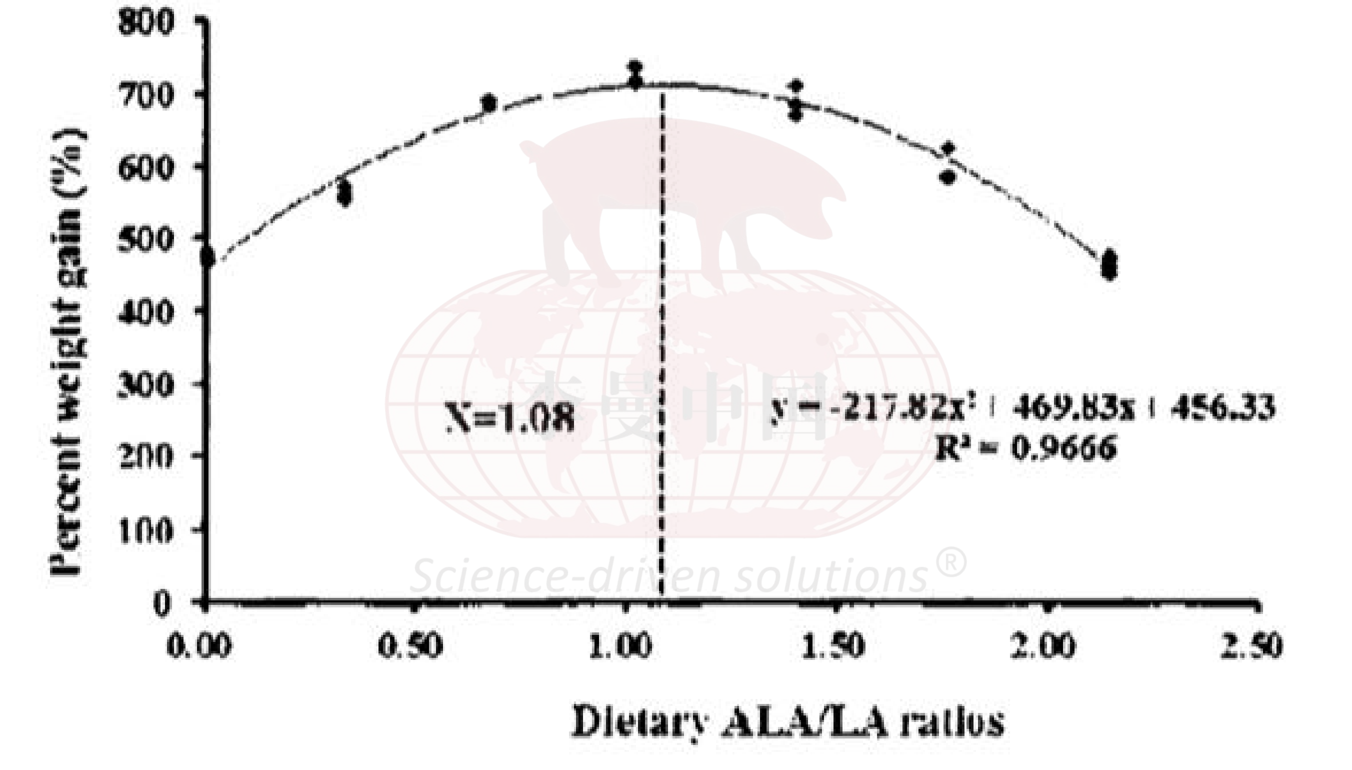


Figure 14: Determining the Optimal ALA/LNA Ratio for Grass Carp Fry Based on Weight Gain Percentage

Zeng Yunyun， 2015

Linoleic Acid and Linolenic Acid Balance

- ADG and ADFI for fattening pigs are maximized at a dietary LA/ALA ratio of 13:1 and 9:1, while F/G is minimized in the 6:1 group (Chen, Jing, 2019).
- Replacing soybean oil with flaxseed oil to increase the dietary ALA content has improved the ADG and feed efficiency of fattening pigs. Furthermore, the improvement in LA/ALA ratios ranging from 1:1 to 5:1 is better than that of the 10:1 group (Li, 2015).
- Replacing soybean oil with 3% flaxseed oil, resulting in an LA/ALA ratio of 1:1, can suppress the expression of IL-6, IL-1β, and TNF-α (Duan, 2014).
- Adding flaxseed to the feed for fattening pigs significantly increases the content of back fat and ω-3 PUFA, linolenic acid, and EPA in the abdominal region (Romans, 1995).

Fatty Acid Content in Different Oils

	reference price	Capry-lic acid C8:0	capric acid C10:0	lauric acid C12:0	Myristic acid C14:0	pentadecanoic acid C15:0	palmitic acid C16:0	palmitoleic acid C16:1	heptadecanoic acid C17:0	stearic acid C18:0	oleic acid C18:1	linoleic acid C18:2	linolenic acid C18:3	arachidic acid C20:0	eicosenoic acid C20:1	Arachidonic acid C20:2	arachidonic acid C20:4	EPA C20:5	behenic acid C22:0	Docosaenoic acid C22:1	DPA C22:5	DHA C22:6	tetracosanoic acid C24:0	iodine number	saponification value	U/S
Kanora Oil							3.9	0.2		1.9	64.1	**18.7**	**9.2**	0.6	1				0.2				0.2	110～115		13.71
Chicken oil	5800			0.2	1.3		23.2	6.5	0.3	6.4	41.6	**18.9**	**1.3**											76～80	194～204	2.20
Cocoa butter	8000				0.1		25.8	0.3		34.5	35.3	**2.9**		1.1										32～40	190～200	0.63
Coconut oil	11000	8	6.4	48.5	17.6		8.4			2.5	6.5	**1.5**		0.1										7～13	248～264	0.28
Corn oil	9800						12.2	0.1		2.2	27.5	**57**	**0.9**	0.1										110～128	186～196	5.90
Cottonseed oil	6300				0.9		24.7	0.7	0.1	2.3	17.6	**53.3**	**0.3**	0.1										99～121	189～199	2.56
Lard oil	6500		0.1	0.1	1.5	0.2	24.8	3.1	0.5	12.3	45.1	**9.9**	**0.1**	0.2	1.3	0.1	0.4							53～68	192～203	1.52
Linseed oil	14000						4.8			4.7	19.9	**15.9**	**52.7**													9.32
Olive Oil	11300						13.7	1.2		2.5	71.1	**10**	**0.6**	0.9										76～90	188～196	4.85
Palm Oil	5800			0.3	1.1		45.1	0.1		4.7	38.8	**9.4**	**0.3**	0.2										45～56	195～205	0.95
Palm kernel oil	11000	3.9	4	49.6	16		8			2.4	13.7	**2**		0.1										14～24	243～255	0.59
Peanut oil	19000				0.1		11.6	0.2	0.1	3.1	46.5	**31.4**		1.5	1.4	0.1			3				1	84～102	188～196	3.88
Rapeseed oil	9100				0.1		2.8	0.2		1.3	23.8	**14.6**	**7.3**	0.7	12.1	0.6			0.4	34.8			1	97～110	168～183	13.45
Rice bran oil	5800				0.5		16.4	0.3		2.1	43.8	**34**	**1.1**	0.5	0.4				0.2				0.1	92～109	181～195	4.02
Sesame oil	29500						9.9	0.3		5.2	41.2	**43.3**	**0.2**											104～118	187～196	5.63
Soybean oil	6900				0.1		11	0.1		4	23.4	**53.2**	**7.8**	0.3					0.1					125～138	188～195	5.45
Sunflower seed oil	10300			0.5	0.2		6.8	0.1		4.7	18.6	68.2	**0.5**	0.4										122～139	186～196	7.22
Cow fat			0.1	0.1	3.3	1.3	25.5	3.4	1.5	21.6	38.7	**2.2**	**0.6**	0.1			0.4							33～50	190～202	0.86
Sheep fat			0.2	0.3	5.2	0.8	23.6	2.5	2	24.5	33.3	**4**	**1.3**				0.4							35～46	192～198	0.74
Tuna oil					8.09		27.09	10.03		3.39	18.8	**2.99**	**0.5**		2.4		0.42	9.32		2.3	1.16	18.76	0.84	150～192		1.79
Schizochytrium oil					0.57	1.59	27.34		1.54	1.2	0.45		**0.27**	0.34			0.52	0.42	0.21		13.7	49.84				2.0

Research has shown that appropriate essential fatty acids (EFAs) and balanced ratios are of significant importance during pregnancy, lactation, and piglet growth.

What are Linoleic Acid/Linolenic Acid Ratio

Effects on Sow Feeding???

Impact on Piglets???

4. The Impact of the Linoleic Acid to Linolenic Acid Ratio on Sows and Piglets

- Experimental Animals: Pregnant Sows of a Duroc × Landrace Crossbreed
- Using soybean oil and flaxseed oil as fat sources, four groups of isonitrogenous and isoenergetic compound feeds were prepared, adjusting the linoleic acid to linolenic acid ratio.
- The experiment was conducted from day 91 of pregnancy in the sows until day 28 of piglet weaning.

group		group 1	group 2	group 3	group 4
la/lna ratio	calculated value	3.00	5.00	7.00	8.00
	measured value	2.90	5.06	7.03	7.98

The Effects of Different LA/LNA Ratios on Late Pregnancy and Lactation Sows

Indicator	3.00	5.00	7.00	8.00	p v.
Late Pregnancy ADFI	3.11	3.11	3.05	3.14	0.823
Lactation ADFI	4.53	4.75	5.13	4.91	0.200
3-day postpartum BW	243.50	244.00	246.83	238.83	0.952
Weaning BW	221.33	223.67	229.17	220.67	0.917
Lactation Weight Loss	22.17	20.33	17.67	18.17	0.564
Total Milk Yield	246.15	255.59	282.65	273.98	0.091

The Effects of Different LA/LNA Ratios on Late Pregnancy and Lactation Sows

Indicator	3.00	5.00	7.00	8.00	p v.
3rd-day Postpartum Backfat	22.00	23.33	22.00	21.17	0.394
28th-day Postpartum Backfat	18.33	20.17	19.17	18.17	0.214
Backfat Loss	3.67	3.17	2.83	3.00	0.268
Insemination Interval After Weaning	5.33	5.00	4.25	5.00	0.349

The Effects of Different LA/LNA Ratios on Reproduction in Sows and Growth in Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Total Born	11.83	11.67	13.50	14.00	0.358
Liveborn per litter	10.67	10.83	11.50	11.83	0.759
Piglets Birth Weight	1.67	1.70	1.59	1.60	0.745
Weaned Piglets	11.00	10.67	10.67	11.33	0.141

The Effects of Different LA/LNA Ratios on Reproduction in Sows and Growth in Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Survival Rate of 28-Day-Old Piglets	95.83	95.67	98.67	98.67	0.548
Weaning Litter Weight	78.22	82.28	88.54	85.52	0.051
Weaning Litter Weight Gain	61.54	63.90	70.66	68.49	0.091
Piglet Daily Weight Gain	204.27	212.17	238.91	215.08	0.225

The Effects of Different LA/LNA Ratios on Serum Biochemical Indices in Sows

Indicator	3.00	5.00	7.00	8.00	P v.
Glutamic Pyruvic Transaminase	49.13	56.07	40.80	42.43	0.259
Glutamic-Oxalacetic Transaminase	51.63	45.13	40.90	42.03	0.756
Total Protein	72.10	72.80	76.63	77.40	0.761
Albumin	37.23	37.50	39.63	38.07	0.728
Globulin	34.87	35.30	37.00	39.33	0.817

The Effects of Different LA/LNA Ratios on Serum Biochemical Indices in Sows

Indicator	3.00	5.00	7.00	8.00	P v.
Glucose	2.37	2.59	2.70	2.75	0.815
Total Cholesterol	3.03[a]	2.57[ab]	1.99[b]	2.46[ab]	0.028
Triglyceride	0.21	0.27	0.18	0.22	0.486
High Density Lipoprotein	1.47[a]	1.03[b]	0.98[b]	1.13[b]	0.004
Low Density Lipoprotein	1.17[a]	0.99[ab]	0.75[b]	0.90[ab]	0.040

The Effects of Different LA/LNA Ratios on Serum Biochemical Indices in Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Glutamic Pyruvic Transaminase	36.67	37.23	43.00	42.80	0.697
Glutamic-Oxalacetic Transaminase	52.57[b]	60.07[b]	74.50[a]	59.40[b]	0.041
Total Protein	43.47	50.10	51.20	47.70	0.375
Albumin	27.47	29.07	33.83	32.00	0.088
Globulin	16.00	17.84	17.37	15.70	0.735

The Effects of Different LA/LNA Ratios on Serum Biochemical Indices in Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Glucose	5.43	5.76	6.23	5.41	0.455
Total Cholesterol	3.21	3.09	2.57	3.09	0.729
Triglyceride	1.11	0.99	0.73	0.78	0.677
High Density Lipoprotein	1.58	1.20	1.03	1.45	0.093
Low Density Lipoprotein	1.74	1.39	1.30	1.43	0.528

The Effects of Different LA/LNA Ratios on the Immune Function of Sows

Indicator	3.00	5.00	7.00	8.00	P v.
Sow Serum IgA	0.04	0.04	0.04	0.05	0.941
Sow Serum IgG	4.96	5.10	6.61	5.54	0.079
Sow Serum IgM	0.74	0.91	1.25	0.71	0.096
Colostrum IgG	5.67	6.23	6.16	6.45	0.300
Colostrum IgM	0.67	0.69	0.62	0.77	0.889

The Effects of Different LA/LNA Ratios on the Immune Function of Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Piglet Serum IgA	**0.05**	**0.05**	**0.04**	**0.04**	**0.460**
Piglet Serum IgG	**1.67**	**2.70**	**3.18**	**1.05**	**0.078**
Piglet Serum IgM	**0.23**	**0.22**	**0.24**	**0.21**	**0.987**

The Effects of Different LA/LNA Ratios on Serum Antioxidant Function in Sows

Indicator	3.00	5.00	7.00	8.00	P v.
Sow MDA	4.57	4.35	3.37	5.87	0.408
Sow SOD	49.71^{b}	50.80^{b}	61.86^{a}	57.27^{ab}	0.016
Sow GSH-Px	938.98^{b}	977.97^{ab}	1106.55^{a}	1030.51^{ab}	0.047
Sow T-AOC	6.01^{b}	6.48^{ab}	8.43^{a}	7.57^{ab}	0.037

The Effects of Different LA/LNA Ratios on Antioxidant Function in Sow Colostrum

Indicator	3.00	5.00	7.00	8.00	P v.
Colostrum MDA	10.26	8.48	7.76	8.08	0.239
Colostrum SOD	73.51[b]	76.16[b]	84.51[a]	74.24[b]	0.041
Colostrum GSH-Px	44.07	48.59	53.54	50.28	0.091
Colostrum T-AOC	5.99[b]	6.38[ab]	7.92[a]	7.59[ab]	0.035

The Effects of Different LA/LNA Ratios on Antioxidant Function in Sow's Milk

Indicator	3.00	5.00	7.00	8.00	P v.
Milk MDA	7.82	6.01	5.34	7.45	0.127
Milk SOD	71.48	75.66	70.47	65.41	0.939
Milk GSH-Px	147.04[b]	185.17[ab]	205.08[a]	172.46[ab]	0.046
Milk T-AOC	6.34 [b]	7.24[ab]	8.86[a]	7.60[ab]	0.049

The Effects of Different LA/LNA Ratios on Serum Antioxidant Function in Piglets

Indicator	3.00	5.00	7.00	8.00	P v.
Piglet MDA	6.05	5.44	3.92	5.90	0.087
Piglet SOD	68.17	68.23	76.56	70.22	0.064
Piglet GSH-Px	517.37[b]	644.49[ab]	686.19[a]	615.26[ab]	0.048
Piglet T-AOC	5.98	6.22	6.50	6.13	0.946

The Effects of Different LA/LNA Ratios on the Composition of Sow Colostrum

Indicator	3.00	5.00	7.00	8.00	P v.
Milk Fat	4.19	4.38	4.60	4.56	0.816
Lactoproteid	16.75^{b}	17.73^{a}	17.87^{a}	17.27^{ab}	0.037
Lactose	3.10	3.14	3.24	3.04	0.190
Total Solids	23.51	23.96	24.08	23.26	0.144

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow Blood Plasma

Indicator	3.00	5.00	7.00	8.00	P v.
C14:0	0.02	0.02	0.02	0.02	0.285
C16:0	0.07^{c}	0.09^{b}	0.12^{a}	0.07^{c}	0.000
C18:0	0.05^{c}	0.07^{b}	0.10^{a}	0.06^{c}	0.000
SFA	0.14^{c}	0.18^{b}	0.24^{a}	0.15^{c}	0.000

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow Blood Plasma

Indicator	3.00	5.00	7.00	8.00	P v.
C18:1n-9	0.05[c]	0.06[b]	0.09[a]	0.05[c]	0.000
C20:1n-9	0.02	0.02	0.02	0.02	0.109
MUFA	0.07[c]	0.09[b]	0.11[a]	0.07[c]	0.000
C18:2n-6	0.09[c]	0.14[b]	0.19[a]	0.10[c]	0.000
C18:3n-3	0.01	0.01	0.01	0.01	0.838
C22:6n-3	0.02	0.02	0.02	0.02	0.178
n-6/n3	2.52[c]	3.79[b]	5.26[a]	2.90[c]	0.000

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow Colostrum Blood Plasma

Indicator	3.00	5.00	7.00	8.00	P v.
C14:0	0.10^{d}	0.11^{c}	0.24^{a}	0.21^{b}	0.000
C16:0	1.75^{c}	2.11^{b}	3.87^{a}	3.78^{a}	0.000
C18:0	0.42^{d}	0.57^{c}	0.99^{a}	0.87^{b}	0.000
SFA	0.10^{d}	0.11^{c}	0.24^{a}	0.21^{b}	0.000

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow Colostrum

Indicator	3.00	5.00	7.00	8.00	P v.
C16:1n-7	0.15^{d}	0.19^{c}	0.33^{b}	0.35^{a}	0.000
C18:1n-9	2.35^{d}	3.17^{c}	5.69^{a}	5.42^{b}	0.000
C20:1n-9	0.3^{d}	0.18^{c}	0.49^{a}	0.47^{b}	0.000
MUFA	2.81^{d}	3.54^{c}	6.51^{a}	6.25^{b}	0.000
C18:3n-3	1.05^{a}	1.05^{a}	1.02^{c}	1.03^{b}	0.000
C22:6n-3	0.09^{a}	0.06^{b}	0.02^{d}	0.04^{c}	0.000
C18:2n-6	3.15^{c}	2.64^{d}	7.42^{a}	7.07^{b}	0.000
n-6/n-3	2.50^{c}	2.16^{d}	6.72^{a}	6.21^{b}	0.000

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow's Milk

Indicator	3.00	5.00	7.00	8.00	P v.
C14:0	1.65^{a}	1.49^{b}	1.34^{c}	1.47^{b}	0.003
C16:0	15.50^{a}	16.23^{a}	12.60^{c}	13.90^{b}	0.001
C18:0	2.02^{b}	2.08^{b}	2.41^{a}	1.81^{c}	0.000
SFA	19.41^{a}	19.96^{a}	15.96^{b}	17.18^{b}	0.001

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Sow's Milk

Indicator	3.00	5.00	7.00	8.00	P v.
C16:1n-7	3.82^{a}	3.22^{b}	2.73^{c}	3.47^{b}	0.000
C18:1n-9	12.53^{c}	13.03^{bc}	14.50^{a}	13.83^{ab}	0.015
C20:1n-9	0.67^{d}	0.80^{c}	1.18^{a}	1.08^{b}	0.000
MUFA	16.42^{b}	17.65^{ab}	18.41^{a}	18.38^{a}	0.020
C18:3n-3	1.15^{a}	1.14^{a}	1.12^{b}	1.15^{a}	0.001
C22:6n-3	0.09^{a}	0.09^{a}	0.08^{b}	0.08^{b}	0.014
C18:2n-6	10.07^{b}	11.27^{a}	11.93^{a}	11.07^{a}	0.010
n-6/n-3	8.65^{a}	8.49^{a}	8.61^{a}	7.61^{b}	0.012

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Piglet Blood Plasma

Indicator	3.00	5.00	7.00	8.00	P v.
C14:0	0.03	0.03	0.03	0.03	0.481
C16:0	0.29^{a}	0.28^{ab}	0.18^{c}	0.27^{b}	0.000
C18:0	0.10^{b}	0.10^{b}	0.14^{a}	0.09^{b}	0.002
SFA	0.42^{a}	0.41^{a}	0.36^{b}	0.39^{a}	0.004

The Effects of Different LA/LNA Ratios on Fatty Acid Composition in Piglet Blood Plasma

Indicator	3.00	5.00	7.00	8.00	P v.
C16:1n-7	0.01[d]	0.03[b]	0.04[a]	0.03[c]	0.000
C18:1n-9	0.08[c]	0.13[a]	0.14[a]	0.11[b]	0.000
C20:1n-9	0.03	0.03	0.03	0.03	0.701
MUFA	0.10[d]	0.17[b]	0.18[a]	0.14[c]	0.000
C18:3n-3	0.02	0.02	0.02	0.02	0.841
C22:6n-3	0.03	0.03	0.03	0.03	0.731
C18:2n-6	0.17[c]	0.22[b]	0.26[a]	0.24[a]	0.000
n-6/n-3	3.34[c]	4.17[b]	4.95[a]	4.64[a]	0.000

5. Conclusion

1. Different LA/LNA ratios show no significant effects on the reproductive performance of sows and the growth performance of piglets. However, an appropriate ratio exhibits a certain trend in improving sow lactation, piglet weaning litter weight, and piglet weight gain.

2. An appropriate LA/LNA ratio, by regulating the content of cholesterol, HDL, LDL, and other components in the serum, promotes nutritional metabolism, enhances sow milk quality, and improves the body's immune and antioxidant functions.

3. Different LA/LNA ratios significantly affect the fatty acid content and the ω-6/ω-3 PUFA ratio in the blood plasma of sows, as well as in the colostrum and regular milk of sows, and in the blood plasma of piglets. This may be the reason for the impact on piglets through sows.

4. Under the conditions of this experiment, a LA/LNA ratio of 7.0 in the diet of sows exhibits better feeding results.

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Thank you!