SESSION 8

MEAT AND HUMAN HEALTH

45th ICoMST
YOKOHAMA
JAPAN '99
Meat Joins Countries Around the World

8-L1

NEEDS TO MODIFY THE FATTY ACID COMPOSITION OF MEATS FOR HUMAN HEALTH

Harumi Okuyama and **Atsusi Ikemoto**

Faculty of Pharmaceutical Sciences, Nagoya City University, Mizuhoku, Nagoya 467-8603, Japan

Keywords: meat, polyunsaturated fatty acid, food chain, dietary manipulation, human health

Abstract

Linoleic acid (LA, 18:2n-6) and a-linolenic acid (aLNA, n-3) are synthesized in plants but not higher animals. When ingested, LA is desaturated and elongated to form dihomo-g-linolenic acid and arachidonic acid (AA) while aLNA is metabolized to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); no interconversion occurs in animals between the n-6 and n-3 series. Different food materials for cattle contain significantly different proportions of n-6 and n-3 fatty acids; e.g., grasses are relatively enriched with aLNA while grains are enriched with LA. Therefore, tissue polyunsaturated fatty acid composition (n-6/n-3 ratio) varies greatly depending on the choice of food materials for cattle. The n-6/n-3 ratio of tissue lipids affects many aspects of animal physiology including behavioral performance and health status. The causal relationship among the food materials, tissue n-6/n-3 balance and tissue physiology also applies to humans. Evidence has been accumulated that "increased intake of LA(n-6) and associated relative n-3 deficiency" observed in the past several decades in the industrialized countries, but not cholesterol, is the major risk factor for cancers of western type, coronary heart disease (CHD), cerebrovascular disease (CVD) and allergic hyper-reactivity, which are expected to prevail in the early 21st century. Therefore, it is important to lower the n-6/n-3 ratios of cattle tissues (meats and milk) as low as possible by selecting food materials.

Introduction- Major fatty acids in meats can be classified into 3 series

Major fatty acids in meats are classified mainly into 3 series depending on their metabolism in animals.

1. *Saturated and monounsaturated fatty acid series:*

Carbohydrates and proteins → Saturated Fatty Acids (16:0,18:0) → Monounsaturated Fatty Acids (16:1,18:1)

Animal fats — Animal fats, Olive oil, Rapeseed oil

2. *Linoleic acid (n-6) series:*

Linoleic acid(LA,18:2n-6) → γ-Linolenic acid(18:3n-6)→ Dihomo- γ-linolenic acid(20:3n-6) → Arachidonic acid (AA,20:4n-6)

(Enriched in grains; soybean, corn..)

3. *α-Linolenic acid (n-3) series:*

α-Linolenic acid (αLNA,18:3n-3) → Eicosapentaenoic acid (EPA, 20:5n-3) → → Docosahexaenoic acid (DHA,22:6n-3)

(Enriched in grasses & phytoplanktons) — (Enriched in seafood)

Saturated and monounsaturated fatty acids are synthesized in animal body from carbohydrates and proteins; excess energy is converted to these fatty acids. LA and αLNA are synthesized in plants but not in animal body; they must be supplied to animals as foods. LA is essential for the maintenance of growth and reproductive physiology but the essential amount is relatively small; 1 en % is more than enough. α-LNA is also essential for the maintenance of brain and retinal functions, and the essential amount is recognized to be in the order of 1 en %. The LA is desaturated and elongated to form highly unsaturated fatty acids such as AA while αLNA is converted to EPA and DHA. In animal tissues, depot fats (neutral lipids) consisted of mainly saturated and monounsaturated fatty acids, and to a lesser extent of LA, but not much of AA, EPA and DHA. The accumulability (depositability) appears to be cpntrolled by melting points of the respective fatty acids. Although LA has a relatively low melting point (-5° C) as compared with saturated fatty acid (e.g., 18:0, mp. 63° C) and monounsaturated fatty acid (18:1n-9, mp. 13° C), it can be accumulated in significant amounts as mixed-acid triacylglycerol; αLNA with a melting point of -15° C is deposited much less effectively. On the other hand, highly unsaturated fatty acids such as AA, EPA and DHA are incorporated into complex lipids (phospholipids) and exist as invisible lipids in tissues.

Preferential β-oxidation of highly unsaturated fatty acids in animal tissues

Various fatty acids are β-oxidized differently in animal tissues; saturated and monounsaturated fatty acids are effectively deposited as neutral lipids while αLNA, EPA and DHA are preferentially β-oxidized. This is probably because the fatty acids with lower melting points cannot form stable lipid droplets surrounded by phospholipid membranes in cells. Those fatty acids with lower melting points suppress fatty acid synthesis from carbohydrates and proteins, and induce β-oxidation enzymes in mitochondria and peroxisomes. These mechanisms would probably enable highly unsaturated fatty acids to be β-oxidized preferentially to saturated and monounsaturated fatty aids. In fact, αLNA, EPA and DHA do not accumulate much in the depot fats even when supplied in significant amounts.

Variability of the lipid contents and the fatty acid compositions of meats - Importance of food chain

Palatability has been the major criterion for the quality of meats in market, and is positively associated with the contents of fats (consisted mainly of saturated and monounsaturated fatty acids and of less proportions of LA). Marbled beef is a typical example, and the means to increase fat contents in meats to produce marbled beef-type meats have been well developed. However, the number of health-oriented people is increasing toward the next century, in which not only the palatability but also the health effect would be another major criterion in selecting human foods of animal origin. Then, the means must be developed to produce meats with less fats, more health effects and with comparable palatability.

As emphasized above, the supply of LA and αLNA depends entirely on foods in animals and no interconversion occurs among the n-6 and n-3 series described above. Therefore, the n-6/n-3 balance of tissue lipids changes significantly depending on the n-6/n-3 balance of food materials. For example, the n-6/n-3 ratio of beef from grass-fed cows (produced in Australia) was 2 while that of grain-fed cows (produced in Japan) was 15, reflecting the LA/αLNA balance of fed materials. Although the palatability of the latter appears to be estimated by majority of people to be superior but health effects are not, which will be described below. This kind of food chain has been proved in fish, birds and mammals as well as in humans.

Fall of classical recommendation in lipid nutrition for the prevention of diseases in the elderly

Previously, animal fats enriched with saturated and monounsaturated fatty acids were considered hypercholesterolemic while high-LA vegetable oils were hypocholesterolemic. However, this difference was found to be transient; no significant difference was found between animal fats and high-LA vegetable oils in aged animals after long-term feeding; both were hypercholesterolemic as compared with oils enriched with n-3 fatty acids (1). Furthermore, "excessive intake of LA and relative n-3 deficiency" has been found to increase the incidence of CHD and CVD by changing the eicosanoid balance and hemodynamic properties (2). Beneficial effects of lowering the n-6/n-3 ratio of foods has been shown clinically for cancers of western type , CVD, and allergic hyper-reactivity (atopic dermatitis and asthma) (2-5).

N-6/n-3 ratio but not cholesterol in foods is the major risk factor for atherosclerosis and coronary heart disease (CHD)

Dietary cholesterol is not reflected directly in plasma cholesterol, and the major risk factor for CHD has been proved not to be hypercholesterolemia but is the high n-6/n-3 ratio of foods (2). Furthermore, longevity was negatively correlated with plasma cholesterol level; people with higher plasma cholesterol level lived longer in older generations (6). Classical medical care aimed at decreasing plasma cholesterol appears to be applicable to a limited number of populations; those with familial hypercholesterolemia and related genetic factor. Hypocholesterolemic drugs (HMG-CoA reductase inhibitor) reduced the risk for CHD by 30% (7) while decreasing the n-6/n-3 ratio by dietary means reduced it by 70% in clinical studies (4). Thus, the major risk factor for atherosclerosis and CHD was found to be the high n-6/n-3 ratio of foods rather than high intake of cholesterol and hypercholesterolemia.

Differential effectiveness in dietary modification of fatty acid composition of beef, poultry and pork

For the prevention of diseases expected to prevail in the early 21st century, it is recommended to decrease the n-6/n-3 ratio of human foods to as low as 2 (8). Because currently available meats from grain-fed cattle have n-6/n-3 ratios of above 10, the food materials for cattle must be changed in order to lower the n-6/n-3 ratios of human foods as low as possible. The n-6/n-3 ratio of 1 is in a safe range because hunters and gatherers were estimated to have had foods with n-6/n-3 ratios of roughly 1 (9).

Among major grains for cattle, rapeseed, soybean and corn contain oils with n-6/n-3 ratios of 2, 7 and >10, respectively. Although, rapeseed has a relatively low n-6/n-3 ratio, there is a limitation in increasing its content in cattle's food materials because of it's safety problem (10). Various soybean varieties contain oils with different n-6/n-3 ratios, and the one with the ratio of as low as 2 is available. Selecting such a variety of soybean would improve human health by lowering the n-6/n-3 ratios of both soybean oil and meats for human use. On the other hand, linseed and seeds from beefsteak plant (*Perilla frutescens*) are the two major grains with n-6/n-3 ratios of as low as 0.2. Utilizing meals from these grains as cattle's food materials would greatly improve the nutritional status of meats in terms of n-6/n-3 ratio.

The effectiveness of changing dietary n-6/n-3 ratio on meats' fatty acid composition differs significantly among the three major meats consumed in Japan, beef, poultry and pork. In cows, ruminant bacteria hydrogenate LA and αLNA to form saturated, monounsaturated and trans-monounsaturated fatty acids. Consequently, cows' milk and beef contain relatively smaller amounts of LA; the major fatty acids being saturated and monounsaturated fatty acids. In contrast, fatty acids of eggs and meats reflect relatively more directly the n-6/n-3 balance of food materials in the case of hens (chicken) and pigs. Therefore, grains and meals with high LA contents could be directed to raising cows while those with lower n-6/n-3 ratios could be directed to hens (chicken) and pigs to produce eggs and meats with lower n-6/n-3 ratios. Such attempts have been made successfully to modify the fatty acid compositions of our foods of animal origin.

References

1. Ishihara,A.,Ito,A.,Sakai,K.,Watanabe,S.,Kobayashi,T. and Okuyama,H. (1995) Dietary high-linoleate safflower oil is not hypocholesterolemic in aged mice after a long-term feeding- Comparison with lard, perilla oil and fish oil. Biol.Pharm.Bull. 18: 485-490
2. Okuyama,H.,Kobayashi,T. and Watanabe,S. (1997) Dietary fatty acids. The n-6/n-3 balance and chronic, elderly diseases. Excess linoleic acid and relative n-3 deficiency syndrome seen in Japan. Prog.Lipid Res. 35: 409-457
3. Dolechek,T.A. and Grandis,G. (1991) Dietary polyunsaturated fatty acids and morality in the multiple risk factor intervention trial (MRFIT) in Health Effects of ω3 Polyunsaturated Fatty Acids in Seafood (Simopoulos,A.P. et al eds.), Karger
4. de Lorgeril,M.,Renaud,S.,Mamelle,N.,Salen,P.,Martin,J-L.,Monjaud,I.,Guidollet,J.,Touboul,P. and Delaye,J. (1994) Meiterranean alpha-linolenic acid-rich diet in secondary prevention of coronary heart disease. Lancet 343: 1454-1459
5. Strandberg,T.E.,Salooma,.V.,Naukkarinen,V.A.,Vanhanen,H.T.,Sarna,S.J. and Miettinen,T.A. (1991) Long-term mortality after 5-year multifactorial primary prevention of cardiovascular diseases in middle aged men. J.Am.Med.Assoc. 266: 1225-1229
6. Shibata,H.,Kumagai,S.,Watanabe,S.,Suzuki,T. and Suyama,Y. (1995) Relationship of serum lipids to 10-year deaths from all causes and cancer in Japanese urban dwellers aged 40 years and over. J.Epidemiol. 5: 87-94
7. Sandinavian Simbastatin Survial Study Group (1994) Randomized trial of cholesterol lowering in 4444 patients with coronary heart disease; the Scandinavian Simbastatin Survival Study (4S). Lancet 344: 1383-1389
8. Okuyama,H. (1997) Recommended lipid intake-President's summary from the Japan Society for Lipid Nutrition. J.Lipid Nutr. 6: 5-42 (in Japanese)
9. Leaf,A.and Weber,P. (1987) A new era for science in nutrition. Am.J.Clin.Nutr. 45:1048-1053
10. Miyazaki,M.,Huang,M-Z.,Takemura,N.,Watanabe,S. and Okuyama,H (1998) Free fatty acid fractions from some vegetable oils exhibit reduced survival time-shortening activity in stroke-prone spontaneously hypertensive rats. Lipids 33: 655-661

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