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The Return of ω3 Fatty Acids into the Food Supply

I. Land-Based Animal Food Products and Their Health Effects

Editor
A.P. Simopoulos

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International Conference on the Return of ω3 Fatty Acids into the Food Supply
I. Land-Based Animal Food Products. Bethesda, Md., September 18–19, 1997

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The Center for Genetics, Nutrition and Health, Washington, D.C.

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Preface

Studies on the evolutionary aspects of diet suggest that major changes have taken place in our food supply since the agricultural revolution 10,000 years ago. The change in animal feeds that came along with the domestication of animals changed the composition of meats, particularly the content of essential fatty acids (ω6 and ω3 fatty acids). The meat of animals in the wild has less total fat, less saturated fat and more polyunsaturated fat with a ratio of ω6 to ω3 fatty acids of less than 2/1. The change became even greater with the advent of modern agricultural practices and agribusiness. Using grains to feed cattle instead of grazing and eating grass has led to increases in the ω6 fatty acids and decreases in the ω3 fatty acid content of meat. Similar changes have occurred in the composition of eggs, poultry, and in fish from aquaculture. Because wild plants have a ratio of linoleic acid to α-linolenic acid of less than 1, the overall ratio of ω6 to ω3 was less than 2/1 prior to the agricultural revolution.

These changes have been widely reported in the scientific literature. Industry has recognized the need to alter animal feeds in order to reverse this change. Today one can find products consistent with the evolutionary aspects of diet in the American market, such as ω3-enriched eggs with the ω6/ω3 ratio closer to eggs under completely natural conditions. The ω3 enrichment was accomplished by adding to chicken feed ω3 fatty acids in the form of fish meal, or flaxseed or docosahexaenoic acid (DHA) produced from algae. This change is not limited to the US market. ω3-enriched eggs can be found in various parts of the world, in Canada, Brazil, Australia, Israel, Greece, Germany, and other European countries.

As a result of the above developments, and the recognition of the important role of ω3 fatty acids in growth and development and in health and disease, it was thought timely to hold the 1st International Conference on the Return of ω3 Fatty Acids into the Food Supply: I. Land-Based Animal Food

Products and Their Health Effects, at the Natcher Conference Center, National Institutes of Health in Bethesda, Md., Sept 18–19, 1997.

The conference, organized by the Center for Genetics, Nutrition and Health, was sponsored by the Center for Genetics, Nutrition and Health, the National Institute on Alcohol Abuse and Alcoholism-NIH, the National Institute on Child Health and Human Development-NIH, Designer Egg Producers' Association International, ENRECO, Inc. (Essential Nutrient Research Company), F. Hoffmann-La Roche AG, Flax Council of Canada, Martek Biosciences Corporation, OmegaTech, Inc., Pilgrim's Pride – Eggs Plus, Roche Vitamins Inc., the Iams Company, and the NutraSweet Kelco Company.

The conference, limited to 100 persons, was attended by scientists from Argentina, Australia, Belgium, Canada, France, Greece, Israel, Mexico and the US.

The first session was on the relationship of ω3 fatty acids in health and selected disease states. It began with presentations on the evolutionary aspects of diet with emphasis on the ω3 fatty acids. Dr. Simopoulos gave an overview of the evolutionary aspects of diet and pointed out that the ω3 fatty acids are found in every meal of the traditional Greek diet, as it was during the Paleolithic period when our genetic profile was established, which may account for the lowest rates of cardiovascular disease and cancer in the Greek population as noted in the Seven Countries Study. Dr. Eaton reviewed the evidence and the need to take into consideration the findings of the Paleolithic diet in the development of dietary recommendations. Dr. Leaf presented a thorough review of the role of ω3 fatty acids in cardiovascular disease, and Dr. Bruce Watkins presented rather provocative but persuasive data on the effects of polyunsaturated fatty acids on bone modeling and cartilage function. His work has important implications in the prevention of osteoporosis since ω6 fatty acids increase the production of prostaglandin E_2 which in turn increases osteoclastic activity. A number of diseases are due to inborn errors of essential fatty acid metabolism. Retinitis pigmentosa is such a genetic disorder. Dr. Hoffman reviewed the data and described the ongoing intervention trials with DHA.

The second session consisted of presentations on the development of ω3-enriched products and the sources of ω3 fatty acids for animal feeds. Dr. Barclay discussed the production of DHA from microalgae and pointed out its beneficial use in animal feeds. He was followed by Dr. Abril who described the production of DHA-enriched poultry eggs and meat using the algae-based feed ingredient. Dr. Sim reviewed his studies in which poultry products are enriched in ω3 fatty acids by using flaxseed. Dr. Sim gave an extensive presentation of his clinical studies with ω3-enriched eggs and their beneficial effects in human subjects. This theme was continued by Dr. Van Elswyk who spoke on poultry-based alternatives for enhancing the ω3 fatty acid content of American diets. Dr. Kyle reviewed his experience with the production of DHA from single cell oil sources of DHA and the clinical studies with DHA-enriched infant formula.

Dr. Howe reviewed his data on ω3-enriched pork and emphasized the need to balance ω3 enrichment without adversely affecting the taste of pork. He presented data indicating that feeds containing ω3 fatty acids can be withdrawn 4 weeks prior to slaughter without compromising the ω3 enrichment, yet preventing alterations in the taste of pork or its physical characteristics.

Dr. Mandel discussed the studies leading to the enrichment of beef with ω3 fatty acids, and Dr. Holub spoke on the natural enrichment of cow's milk with DHA. This session ended with a presentation by Mr. Born, who discussed the issues involved in ω3-enriched products as they move from research to retail.

ω3 fatty acid-enriched products are not limited to human consumption. Therefore, two papers discussed the status of ω3-enriched products in companion animal nutrition. Dr. Hayek presented studies with ω3-enriched products showing improvement in various disease states, and Mr. Stitt presented data on the rapid absorption and elongation of α-linolenic acid in dogs.

The fourth session was on the Scientific and Policy Aspects. Mr. Newton gave an overview on the status of Global Food Fortification Perspectives of Long Chain ω3 Fatty Acids. Dr. Holub discussed the ω3 fatty acid status in Canada. Canada has specific recommendations for ω3 fatty acids. Dr. Howe discussed the situation in Australia and Dr. Lee discussed the situation in the US. The US does not have dietary recommendations for ω3 fatty acids and the nutrition label does not separately list the ω6 and ω3 polyunsaturated fatty acids.

There was an extensive discussion on these issues. Particularly the need to include ω3 fatty acids in infant formula.

Dr. Simopoulos addressed two issues: (1) dietary recommendations and genetic variation, and (2) the need to redefine food safety to include food composition. Dr. Simopoulos spoke on the need to redefine the dietary reference values by taking into consideration not only the evolutionary aspects of diet, but also genetic variation. She used as an example the folate data. The dietary reference values for folate, as for other nutrients, are targeted to the general and supposedly normal population, and do not take into consideration consumers with special needs, such as those with genetic abnormalities or diseases. In the case of folate, 5–15% of the general population are homozygous for a thermolabile variant of 5,10-methylenetetrahydrofolate reductase

(C677T) which causes mild hyperhomocysteinemia and is positively associated with the development of vascular disease and the risk of neural tube defects. Individuals with C677T have lower red cell folate concentrations and the current reference daily intake is not adequate since they have increased needs. It is possible that other genetic variants interact with particular nutrients, which casts doubt on the validity of assuming 'normality' for nutrient requirements in any population.

There is a need to redefine food safety. Food safety should not be limited to avoiding contamination with bacteria, viruses, protozoa, and toxins. Food safety must take into consideration changes in food composition. This principle is even more important when we have a food supply, such as the current Western diet, that has an imbalance in the ω6 and ω3 essential fatty acids and is high in trans fatty acids, increasing the risk for chronic diseases. Furthermore, when new nutrients are introduced into the food supply whose structure has been altered, i.e. trans fatty acids, or the ratio of esential nutrients has changed as is currently the case with the ω6 and ω3 fatty acid imbalance, the short- and long-term effects and safety need to be establushed.

The adverse effects of trans fatty acids on lipid metabolism and the lack of ω3 fatty acids in infant formulas highlight the importance of taking into consideration nutritional effects on both growth and neurological development and on chronic disease processes when designing new food products. Just as we are required to develop Environmental Impact Statements whenever environmental changes are contemplated, we should be required to develop Nutritional Impact Statements for novel foods relative to their safety in growth and development and in health and disease, particularly chronic diseases.

This conference was the first to bring together scientists from academia, government and industry to discuss the return of ω3 fatty acids into the food supply. The published proceedings cannot capture the thoughtful discussions and the excitement of active participation that took place within the scientific sessions and during the social events, but the interested reader will find the papers stimulating, groundbreaking, and useful.

These proceedings should be of interest to physicians, veterinarians, nutritionists, dieticians, food technologists, agriculturalists, food policy-makers, consumer advocates, lawyers and entrepreneurs.

Artemis P. Simopoulos

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Overview of Evolutionary Aspects of ω3 Fatty Acids in the Diet

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Introduction

The health of the individual and the population in general is the result of interactions between genetics and the environment. This concept was originally articulated by Hippocrates in 480 B.C. as follows:

> 'Positive health requires a knowledge of man's primary constitution (which today we call genetics) and of the powers of various foods, both those natural to them and those resulting from human skill (today's processed food). But eating alone is not enough for health. There must also be exercise, of which the effects must likewise be known. The combination of these two things makes regimen, when proper attention is given to the season of the year, the changes of the winds, the age of the individual and the situation of his home. If there is any deficiency in food or exercise the body will fall sick'.

Whereas our genetic profile has not changed over the past 40,000 years, major changes have taken place in our food supply and in energy expenditure/physical activity. Our current diet (Western diet) is characterized by an increase in total fat, saturated fat, trans fatty acids and the ω6 essential fatty acids (EFA), but a decrease in the ω3 EFA [1, 2]. The ratio of ω6 to ω3 fatty acids is 10–20/1, whereas during evolution it was 1/1 (table 1; fig. 1) [1–4].

Furthermore, table 2 indicates that vitamin C, calcium and potassium intakes were higher than today's recommended allowances [5]. Wild plants provide higher amounts of both vitamins C and E (fig. 1) [5, 6]. Western societies and other developed countries are characterized by sedentary life-styles. At the turn of the century, 30% of energy came from muscular work, whereas today it is about 1% [7]. It is evident that today we have an imbalance in ω6 and ω3 EFA and practically a deficiency in ω3 fatty acid intake, as well as a deficiency in energy expenditure/physical activity.

Table 1. Characteristics of hunter-gatherer and Western diet and lifestyles

Characteristic	Diet and lifestyle	
	Hunter-gatherer	Western
Physical Activity Level	high	low
Diet		
Energy-density	low	high
Energy intake	moderate	high
Protein	high	low-moderate
Animal	high	low-moderate
Vegetable	very low	low-moderate
Carbohydrate	low-moderate (slowly absorbed)	moderate (rapidly absorbed)
Fiber	high	low
Fat	low	high
Vegetable	very low	moderate to high
Animal	low	high
	polyunsaturated	saturated
ω6/ω3 ratio	low (2.4)	high (12)
Linolenic and linoleic acids, g fatty acid/person/day	low (3.3)	high (12.3)
Long chain ω6 and ω3 PUFA	high (2.3)	low (0.2)
Vitamins	Paleolithic period	Current US intake
Riboflavin, mg/day	6.49	1.34–2.08
Folate, mg/day	0.357	0.149–0.205
Thiamin, mg/day	3.91	1.08–1.75
Ascorbate, mg/day	604.00	77–109
Carotene, mg/day	5.56	2.05–2.57
(retinol equivalent)	(927.00)	–
Vitamin A, mg/day	17.2	7.02–8.48
(retinol equivalent)	(2,870.00)	(1,170–429)
Vitamin E, mg/day	32.8	7–10

Modified from Simopoulos [4].

The change in the EFA came about because of the indiscriminate recommendation to substitute vegetable oils, i.e. corn oil, safflower, sunflower and cottonseed oil, for saturated fat. These vegetable oils are very high in ω6 fatty acids and very low in ω3 fatty acids. Corn oil has a ratio of ω6/ω3 of 60/1, and safflower oil 77/1. In addition, because animals are grain fed, their carcass

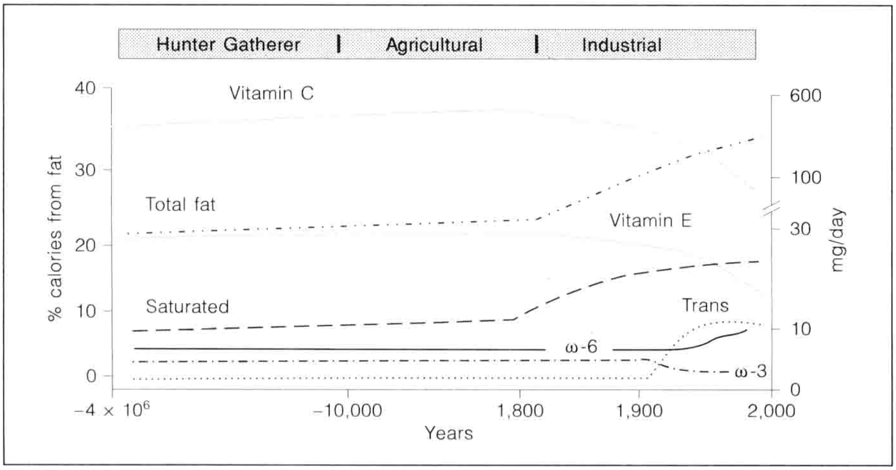

Fig. 1. Hypothetical scheme of fat, fatty acid (ω3, ω6, trans and total) intake (as percent of calories from fat) and intake of vitamins E and C (mg/day). Data were extrapolated from cross-sectional analyses of contemporary hunter-gatherer populations and from longitudinal observations and their putative changes during the preceding 100 years [3].

contains small amounts of ω3 fatty acids but it is high in saturated fats and ω6 fatty acids [8]. Eggs and poultry in agriculture, fish in aquaculture and cultivated plants contain lower amounts of ω3 fatty acids than eggs from chickens that fetch their own food (table 3) [9, 10], fish in the wild [11], and wild plants [1, 5, 12, 13] (table 4). Because of agribusiness and food technology, not only is there an enormous increase in ω6 fatty acids in the food supply, but the hydrogenation process has led to major increases in trans fatty acids. Under natural conditions less than 2% of energy comes from trans fatty acids, whereas today in the US and Canada, 10% of energy comes from trans fatty acids [14]. Trans fatty acids are found in margarines, hydrogenated oils in salad dressings and frying oils, and in ready-made (baking) mixes, crackers, potato chips, pretzels, and other processed foods [15, 16]. The adverse effects of trans fatty acids have been described elsewhere [14].

During evolution, ω3 fatty acids were found in meat, fish and wild plants [2, 6, 8, 11–13, 17]. Recent studies by Cordain et al. [18] on wild animals confirm the original observations of Sinclair et al. [19] (fig. 1).

Over the past 15 years a number of animal experiments, epidemiological investigations and double-blind controlled clinical trials have confirmed the essentiality of ω3 fatty acids, particularly docosahexaenoic acid (DHA) for the normal retina and brain development of the premature infant and the hypotriglyceridemic and inflammatory and antithrombotic aspects of ω3 fatty

Table 2. Late Paleolithic and currently recommended nutrient composition for Americans

	Late Paleolithic	Current recommendations
Total dietary energy, %		
Protein	33	12
Carbohydrate	46	58
Fat	21	30
Alcohol	~0	–
P:S ratio	1.41	1.00
Cholesterol, mg	520	300
Fiber, g	100–150	30–60
Sodium, mg	690	1,100–3,300
Calcium, mg	1,500–2,000	800–1,600
Ascorbic acid, mg	440	60

Modified from Eaton et al. [5].
P:S = Polyunsaturated-to-saturated fat.

acids [20–25]. It therefore became important to investigate the ω3 fatty acid composition of diets that have been shown to be associated with a decreased rate of cardiovascular disease and cancer. Such an opportunity presented itself in the diet of Crete [26].

The population of Crete was one of the populations participating in the Seven Countries Study [27]. The others were the populations of the former Yugoslavia, Italy, Holland (Zutphen), Finland, USA and Japan. The results of the Seven Countries Study are interesting because they showed that the population of Crete had the lowest rate of cardiovascular disease and cancer, followed by the population of Japan. The investigators concluded that the reason must be the high olive oil intake and the low saturated fat intake of the 'Mediterranean diet'. The fact that Crete had a high fat diet, 37% from fat, and Japan had a low fat diet, 11% from fat, was not very much discussed nor were any other fatty acids considered, despite the fact that the people of Crete ate 30 times more fish than the US population. In addition, the people of Crete ate lots of vegetables, fruits, nuts and legumes, all rich sources of folate, calcium, vitamins and minerals.

The traditional Greek diet, including the diet of Crete, includes wild plants. Wild plants are rich sources of ω3 fatty acids and antioxidants [6, 12, 13]. A commonly eaten plant is purslane (table 4). Purslane is rich in α-linolenic