Health Benefits and Functional Advantages of Soybean Oil

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Commodity soybean oil

Polyunsaturated fatty acids
(e.g., linoleic acid)

High oleic soybean oil

Monounsaturated fatty acids
(e.g., oleic acid)

2

Leading Causes of Death (2023)

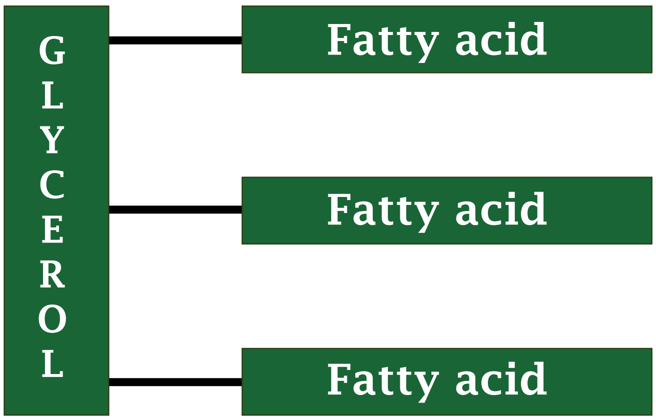
1) Cancer
2) Heart disease
3) Pneumonia
4) Cerebrovascular disease
5) Diabetes

3

Understanding fat and fatty acids

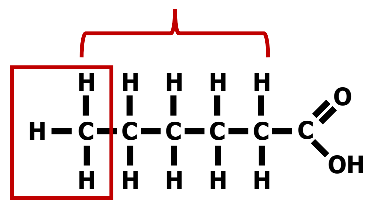
4

Triglycerides



Most fat in food and stored in our body is present as triglycerides

Fatty acid structure



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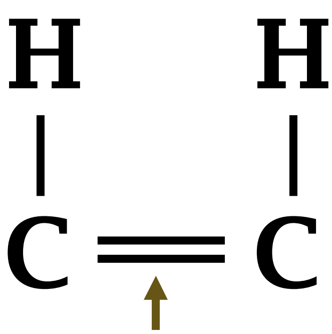
Fatty Acid Nomenclature



C = Carbon
H = Hydrogen

- Chain length (number of carbons)
- Number of double bonds
- Position of double bonds

Saturated fatty acids: No double bonds

Unsaturated fatty acids: Contain at ≥1 double bond

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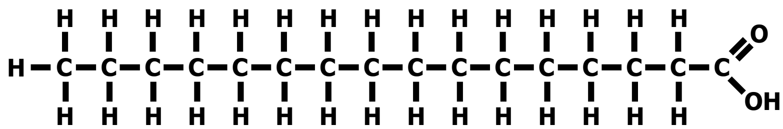
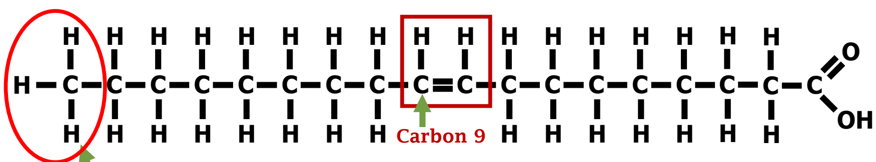
Saturated fatty acid



Palmitic acid

16 carbons
No double bonds
Source: Palm oil

Monounsaturated fatty acid



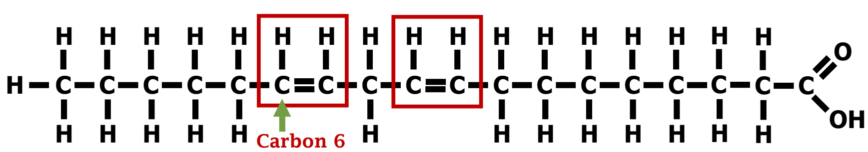
Omega end

Oleic acid

18 carbons
1 double bond
omega-9 fatty acid
Source: Olive oil,
High oleic soybean oil

7

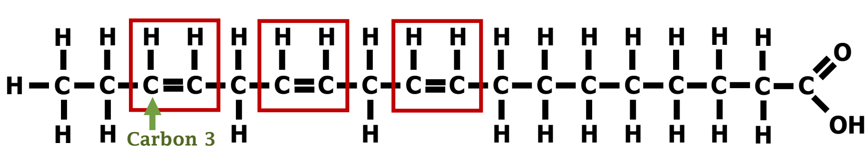
Polyunsaturated fatty acid



Linoleic acid

18 carbons
2 double bonds
omega-6 fatty acid
Essential
Source: Soybean oil
Corn oil

Polyunsaturated fatty acid



alpha-linolenic acid

18 carbons
3 double bonds
omega-3 fatty acid
Essential
Source: Soybean oil
Flaxseed oil
Walnut oil
Canola oil

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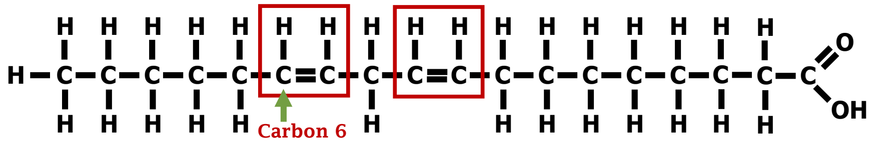
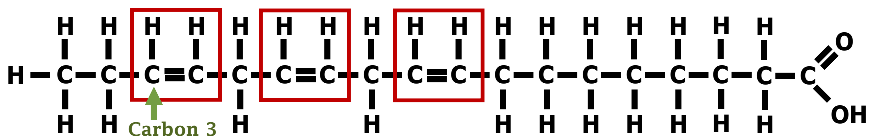
Polyunsaturated fatty acid



Linoleic acid

The predominant omega-6 PUFA in the diet

Polyunsaturated fatty acid



alpha-linolenic acid

The predominant omega-3 PUFA in the diet

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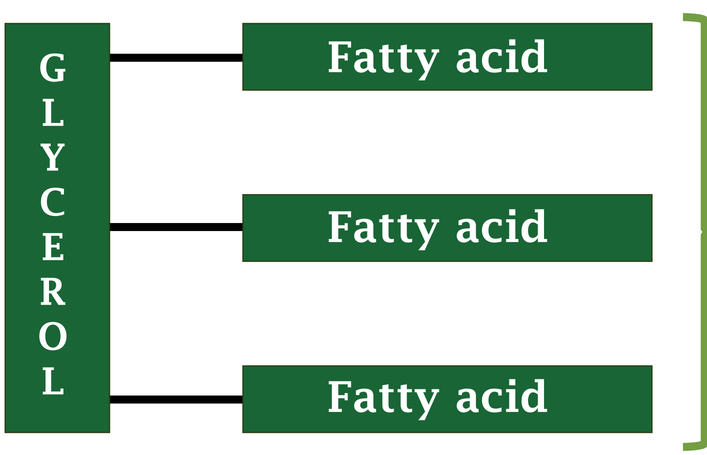
Triglycerides



Mixture of different types of fatty acids

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All oils (liquids) and fats (solids) are a mix of different fatty acids

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Fat or oil	Poly-unsaturated	Mono-unsaturated	Saturated
Sunflower	65.7	19.5	10.3
Corn	54.7	27.6	12.9
Soybean	57.7	22.8	15.6
Sesame	41.7	39.7	14.2
Canola	28.1	63.3	7.4
Lard	11.2	45.1	39.2
Olive	10.5	73.0	13.8
Palm	9.3	37.0	49.3
Tallow	4.0	41.8	49.8
Butter	3.0	23.4	50.5
Coconut	1.7	6.3	82.5

Fatty Acid Content of Selected Fats (g/100 g)

USDA United States Department of Agriculture

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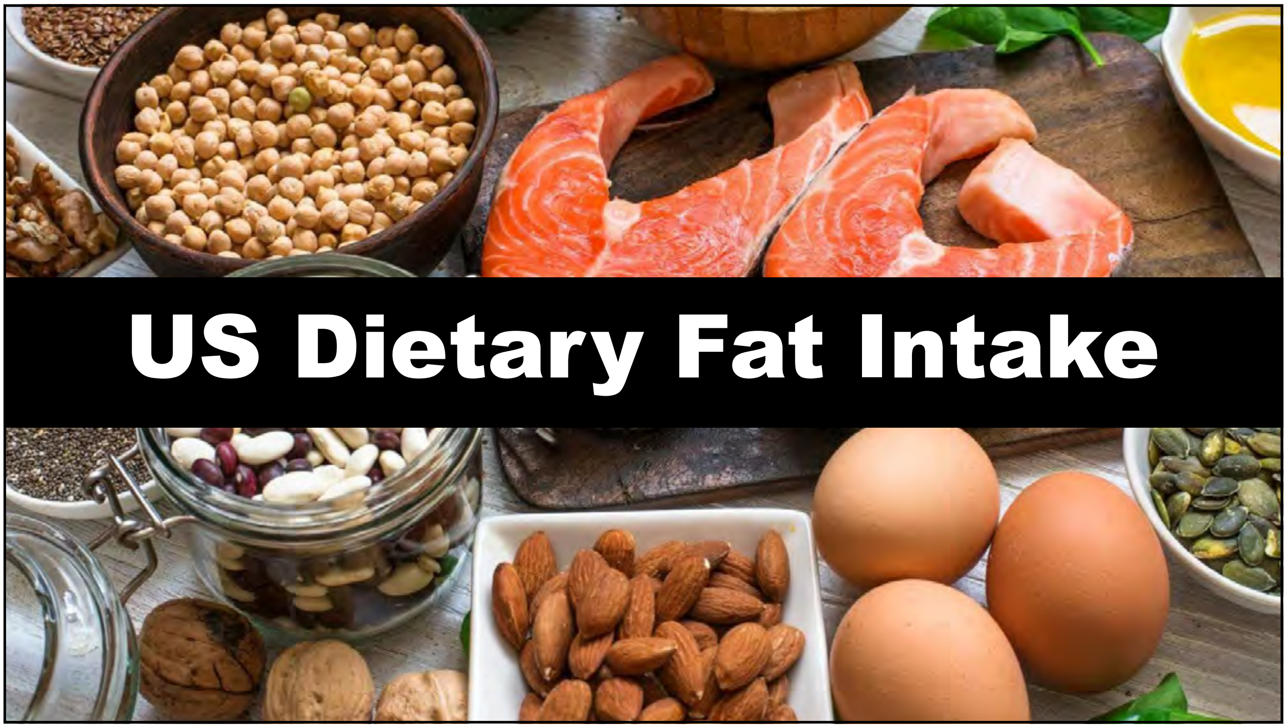
US Dietary Fat Intake

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The types of fat consumed in the United States has changed markedly over the past 60 years

14

Major sources of fat prior to the 1960s

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Changes in consumption of omega-3 and omega-6 fatty acids in the United States during the 20th century[1–3]

Tanya L Blasbalg, Joseph R Hibbeln, Christopher E Ramsden, Sharon F Majchrzak, and Robert R Rawlings

ABSTRACT

Background: The consumption of omega-3 (n–3) and omega-6 (n–6) essential fatty acids in Western diets is thought to have changed markedly during the 20th century.

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Results: The estimated per capita consumption of soybean oil increased >1000-fold from 1909 to 1999. The availability of linoleic acid (LA) increased from 2.79% to 7.21% of energy ($P < 0.000001$), whereas the availability of α-linolenic acid (ALA) increased from 0.39% to 0.72% of energy by using 1909-C modeling. By using 1909-T modeling, L[illegible] 0.35% of energy. The ratio o[illegible] 1909 to 10.0 in 1999. The 1909-T but not the 1909-C data showed substantial declines in dietary availability (percentage of energy) of n–6 arachidonic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Predicted net effects of these dietary changes included declines in tissue n-3 highly unsaturated fatty acid status (36.81%, 1909-T; 31.28%, 1909-C; 22.95%, 1999) and declines in the estimate omega-3 index (8.28, 1909-T; 6.51, 1909).

Conclusion: The apparent increased consumption of LA, which was primarily from soybean oil, has likely decreased tissue concentrations of EPA and DHA during the 20th century. *Am J Clin Nutr* doi: 10.3945/ajcn.110.006643.

Am J Clinical Nutr 93: 950, 2011

INTRODUCTION

There has been much speculation about changes in the consumption of essential fatty acids throughout the 20th century; however, to our knowledge, detailed quantitative analyses have not been reported. It has been suggested that n–3 fatty acids [α-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA n–3), and docosahexaenoic acid (DHA)] have become less abundant in American diets, and the average ratio of n–6 to n–3 fatty acids has increased from as little as 1:1 to as much as 30:1 (1).

Dietary intakes of n–3 and n–6 fatty acids are critical determinates of the proportions of bioactive 20- and 22-carbon n–6 and n–3 highly unsaturated fatty acids (HUFAs) in tissue phospholipids (2). Tissue HUFAs, in turn, have been shown to affect multiple disease states (3–7) ranging from psychiatric (8, 9) and cardiovascular disease (10) to neurodevelopmental deficits (11). The omega-3 index, which is a direct measure of erythrocyte EPA + DHA as a percentage of total fatty acids, has been proposed as a risk biomarker for cardiovascular disease (10). However, there is no method for estimating the omega-3 index from dietary intakes of n–3 and n–6 fatty acids. In contrast, the percentage of n–3 in HUFAs is a biomarker that can be predicted by dietary intake data for all relevant n–3 and n–6 fatty acids in humans by using an empirical equation developed by Lands et al (2). The percentage of n–3 in HUFAs can be used alone as an indicator of disease risk or to estimate the omega-3 index in the absence of direct erythrocyte sampling (12). To our knowledge, no estimate of changes in the n–3 or n–6 tissue status of Americans throughout the 20th century has previously been published.

We used the standardized methods of the Center for Nutrition [illegible] for analyzing US Department [illegible] ability data to evaluate the essential fatty acid content of the US food supply from 1909 to 1999 (all years available for the 20th century). Because the essential fatty acid composition of foods produced in the early 20th century were likely to be different from those produced by modern practices (14–16), the essential fatty acid content for 1909 was modeled twice: 1909-C designating modeling with foods with current fatty acid compositions and 1909-T designating modeling using nutrient composition data from the direct analysis of foods produced via practices that were common in the early 20th century (1909-T) (**Table 1**). In addition, we derived the omega-3 index and percentage of n–3 in HUFAs to estimate the consequent changes in tissue status.

[1] From the Section on Nutritional Neuroscience, Laboratory of Membrane Biochemistry and Biophysics, National Institute on Alcohol Abuse and Alcoholism (TLB, CER, SFM, and JRH) and the Laboratory of Clinical Translation Studies, National Institute on Alcohol Abuse and Alcoholism (RRR), National Institutes of Health, Bethesda, MD.

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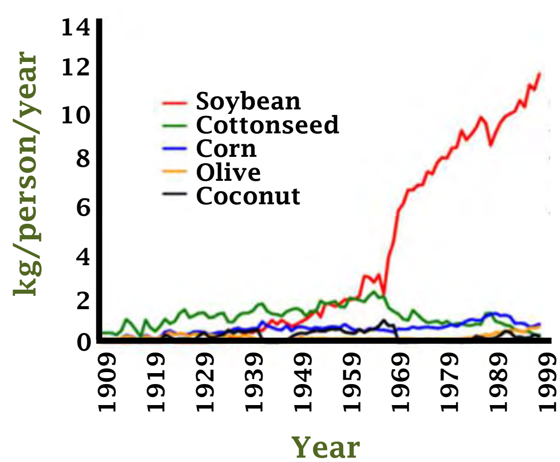
Estimated US Vegetable and Seed Oil Consumption Based on Availability



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Estimated annual per capita consumption (kg) of foods

Food	1909	1999	Percent difference
Oils	0.7	14.7	2051
Soybean	0.01	11.6	116,300
Canola	0.01	0.8	16,700
Peanut	0.01	0.7	7000
Fats	17.9	18.2	85
Margarine	0.3	3.6	25
Tallow	0.5	2.1	371
Shortening	3.3	9.0	170
Butter	8.1	2.2	-73
Lard	5.8	1.3	-77

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Dietary Fat Intake Recommendations

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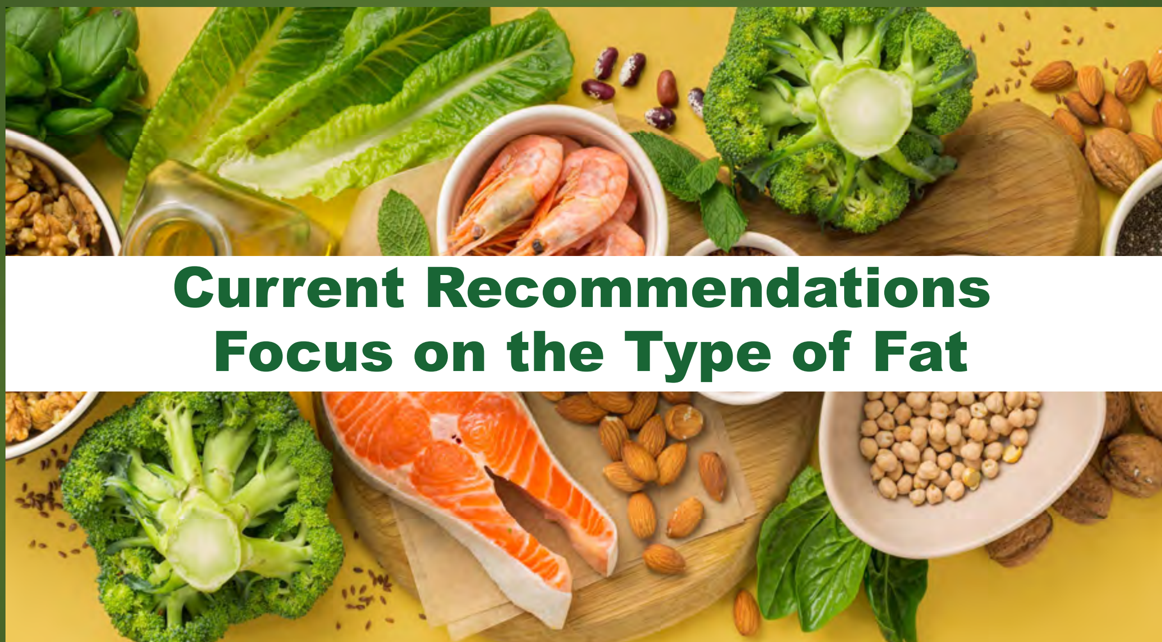

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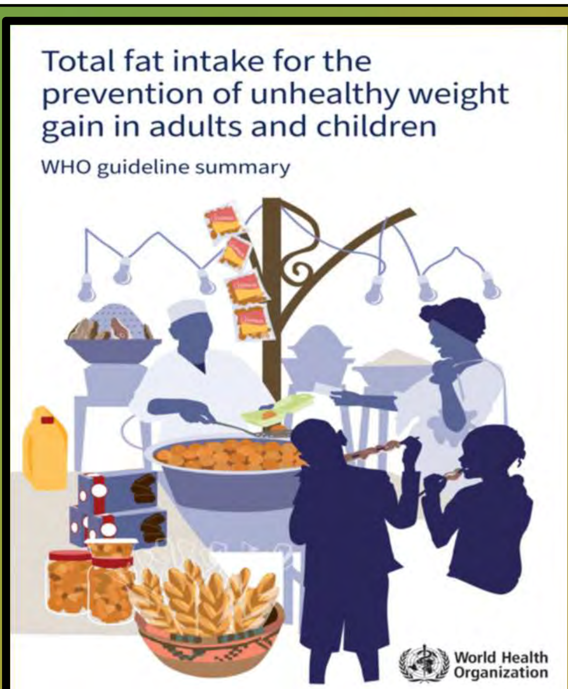

To reduce risk of heart disease, limit saturated fat intake to 10% of total energy intake

World Health Organization

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"... intake of saturated fat should be limited to less than 10 percent of calories per day by replacing them with unsaturated fats, particularly polyunsaturated fats."

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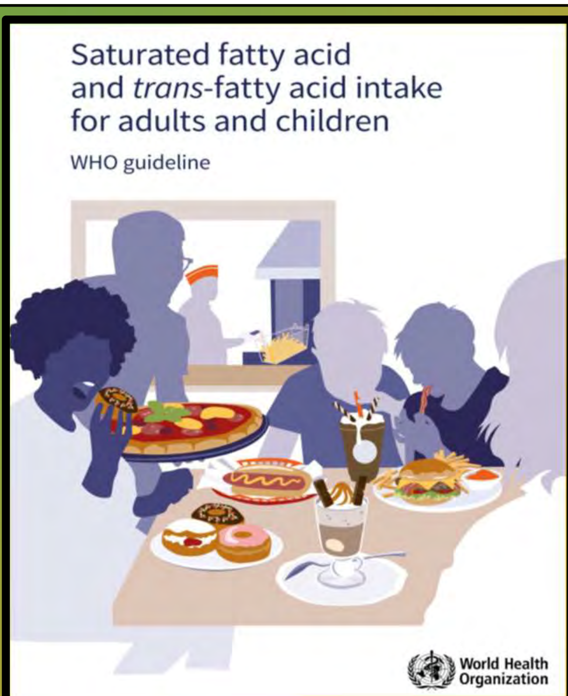

Replace saturated fat with:

- **Polyunsaturated fat √√√**
- **Monounsaturated fat√√**
- **Carbohydrates from √ whole grains, pulses, fruits and vegetables**

√ Indicates strength of evidence

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What is the basis for emphasizing polyunsaturated fat?

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Saturated Fats Compared With Unsaturated Fats and Sources of Carbohydrates in Relation to Risk of Coronary Heart Disease

A Prospective Cohort Study

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J Am Coll Cardiol 66: 1538, 2015

ABSTRACT

BACKGROUND The associations between dietary saturated fats and the risk of coronary heart disease (CHD) remain controversial, but few studies have compared saturated with unsaturated fats and sources of carbohydrates in relation to CHD risk.

OBJECTIVES This study sought to investigate associations of saturated fats compared with unsaturated fats and different sources of carbohydrates in relation to CHD risk.

METHODS We followed 84,628 women (Nurses' Health Study, 1980 to 2010), and 42,908 men (Health Professionals Follow-up Study, 1986 to 2010) who were free of diabetes, cardiovascular disease, and cancer at baseline. Diet was assessed by a semiquantitative food frequency questionnaire every 4 years.

RESULTS During 24 to 30 years of follow-up, we documented 7,667 incident cases of CHD. Higher intakes of polyun-

"... the macronutrient substituted for SFAs [saturated fatty acids] is critically important."

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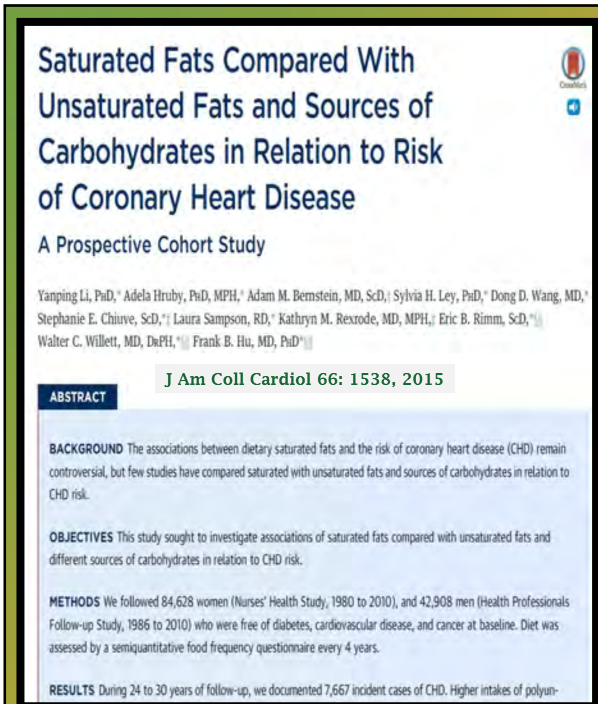

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Nurses' Health Study and Health Professional Follow up Study

- 84,628 US women
- 42,908 US men
- Diet assessed every 4 years
- Follow up: 24–30 years
- 7,667 heart attacks or coronary heart disease deaths

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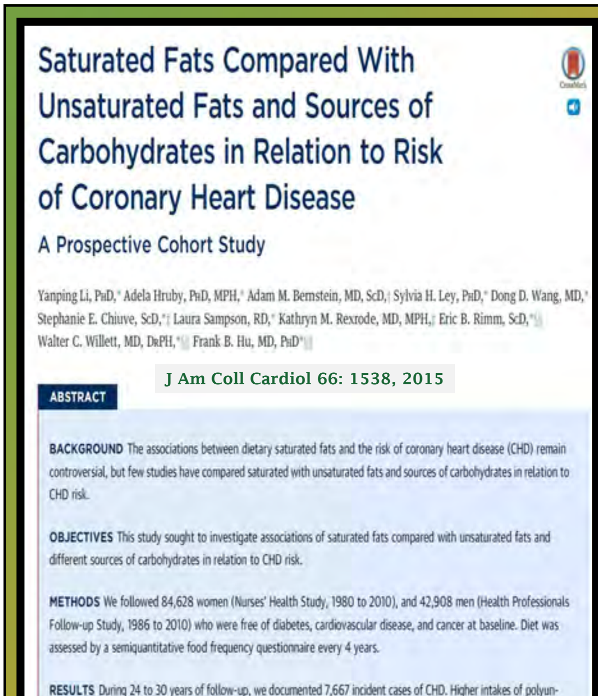

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Effect on CHD risk of replacing 5% of energy from saturated fat with 5% of energy from:

Dietary component	Risk
Refined carbohydrate	
Carbohydrate (whole grains)	
Monounsaturated fat	
Polyunsaturated fat	

Adjusted for energy, protein, cholesterol intake, alcohol, smoking, BMI, physical activity, use of vitamins and aspirin, family history of MI and diabetes and baseline hypercholesterolemia & hypertension

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Sugar or carbohydrate from refined grains

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Effect on CHD risk of replacing 5% of energy from saturated fat with 5% of energy from:

Dietary component	Risk
Refined carbohydrate	↑ 2%
Carbohydrate (whole grains)	
Monounsaturated fat	
Polyunsaturated fat	

Adjusted for energy, protein, cholesterol intake, alcohol, smoking, BMI, physical activity, use of vitamins and aspirin, family history of MI and diabetes and baseline hypercholesterolemia & hypertension

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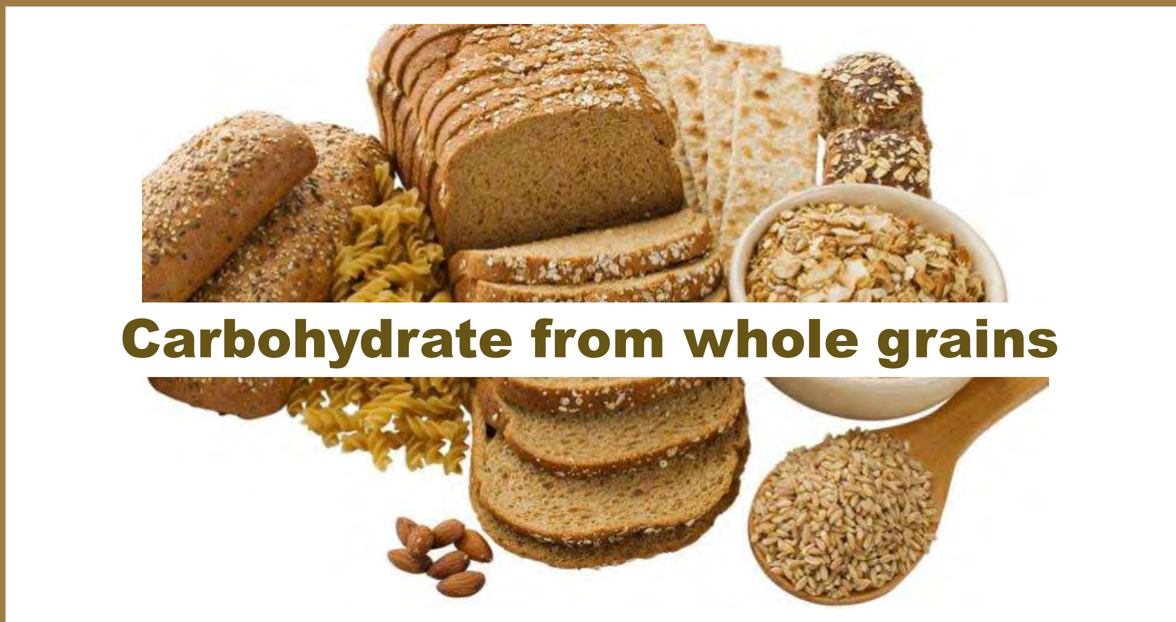

Carbohydrate from whole grains

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Refined carbohydrate	↑ 2%
Carbohydrate (whole grains)	↓ 9%
Monounsaturated fat	
Polyunsaturated fat	

Adjusted for energy, protein, cholesterol intake, alcohol, smoking, BMI, physical activity, use of vitamins and aspirin, family history of MI and diabetes and baseline hypercholesterolemia & hypertension

30

Monounsaturated fat


31

Monounsaturated fat

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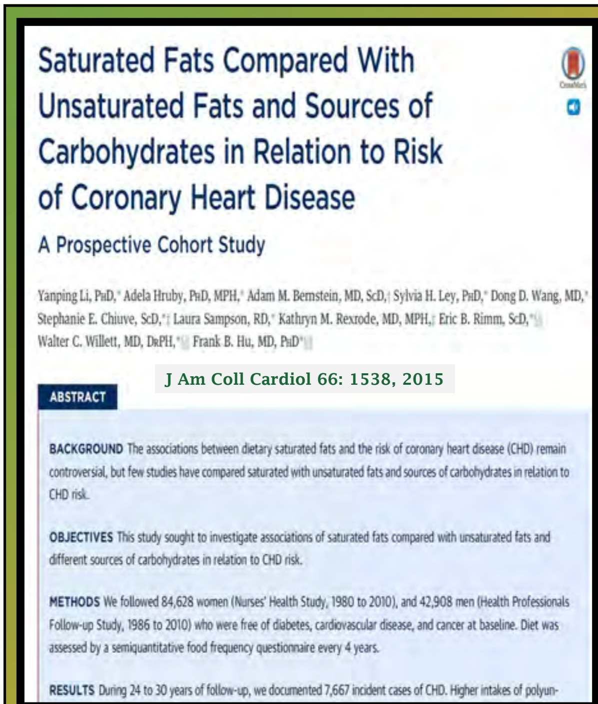

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METHODS We followed 84,628 women (Nurses' Health Study, 1980 to 2010), and 42,908 men (Health Professionals Follow-up Study, 1986 to 2010) who were free of diabetes, cardiovascular disease, and cancer at baseline. Diet was assessed by a semiquantitative food frequency questionnaire every 4 years.

RESULTS During 24 to 30 years of follow-up, we documented 7,667 incident cases of CHD. Higher intakes of polyun-

Effect on CHD risk of replacing 5% of energy from saturated fat with 5% of energy from:

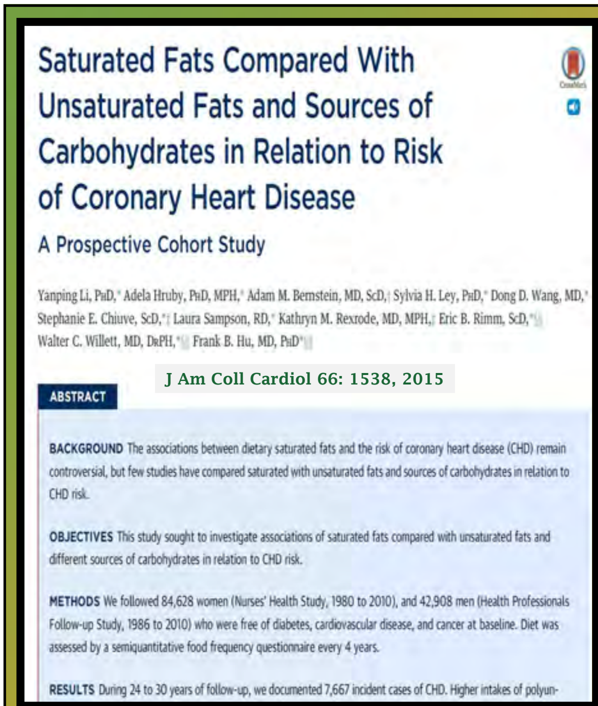
Dietary component	Risk
Refined carbohydrate	↑ 2%
Carbohydrate (whole grains)	↓ 9%
Monounsaturated fat	↓ 15%
Polyunsaturated fat	

Adjusted for energy, protein, cholesterol intake, alcohol, smoking, BMI, physical activity, use of vitamins and aspirin, family history of MI and diabetes and baseline hypercholesterolemia & hypertension

33

Polyunsaturated fat

34



Saturated Fats Compared With Unsaturated Fats and Sources of Carbohydrates in Relation to Risk of Coronary Heart Disease

A Prospective Cohort Study

Yanping Li, PhD, Adela Hruby, PhD, MPH, Adam M. Bernstein, MD, ScD, Sylvia H. Ley, PhD, Dong D. Wang, MD, Stephanie E. Chiuve, ScD, Laura Sampson, RD, Kathryn M. Rexrode, MD, MPH, Eric B. Rimm, ScD, Walter C. Willett, MD, DrPH, Frank B. Hu, MD, PhD

J Am Coll Cardiol 66: 1538, 2015

ABSTRACT

BACKGROUND The associations between dietary saturated fats and the risk of coronary heart disease (CHD) remain controversial, but few studies have compared saturated with unsaturated fats and sources of carbohydrates in relation to CHD risk.

OBJECTIVES This study sought to investigate associations of saturated fats compared with unsaturated fats and different sources of carbohydrates in relation to CHD risk.

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RESULTS During 24 to 30 years of follow-up, we documented 7,667 incident cases of CHD. Higher intakes of polyun-

Effect on CHD risk of replacing 5% of energy from saturated fat with 5% of energy from:

Dietary component	Risk
Refined carbohydrate	↑ 2%
Carbohydrate (whole grains)	↓ 9%
Monounsaturated fat	↓ 15%
Polyunsaturated fat	↓ 25%

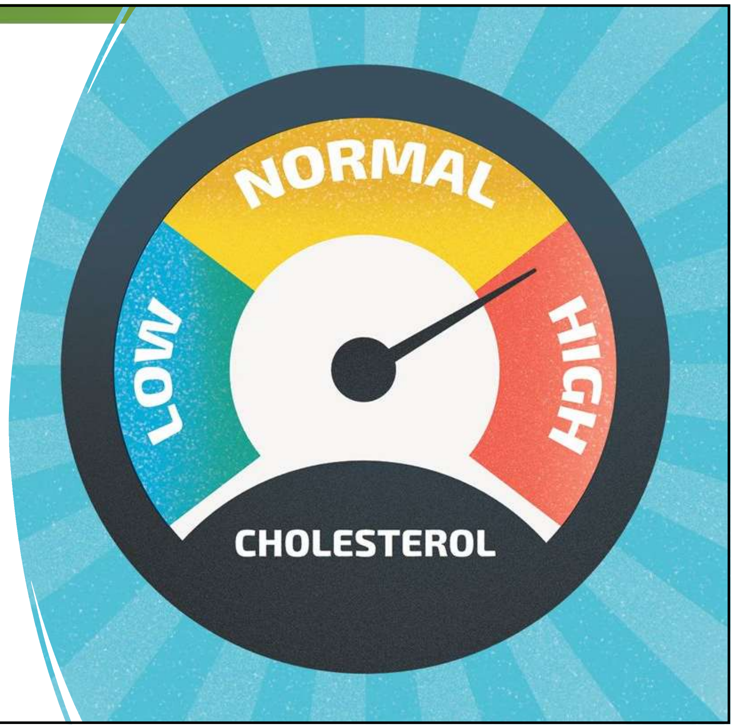
Adjusted for energy, protein, cholesterol intake, alcohol, smoking, BMI, physical activity, use of vitamins and aspirin, family history of MI and diabetes and baseline hypercholesterolemia & hypertension

35

Simply reducing saturated fat is not sufficient to lower risk of heart disease

36

Replacing saturated fat with unsaturated fat lowers blood cholesterol levels



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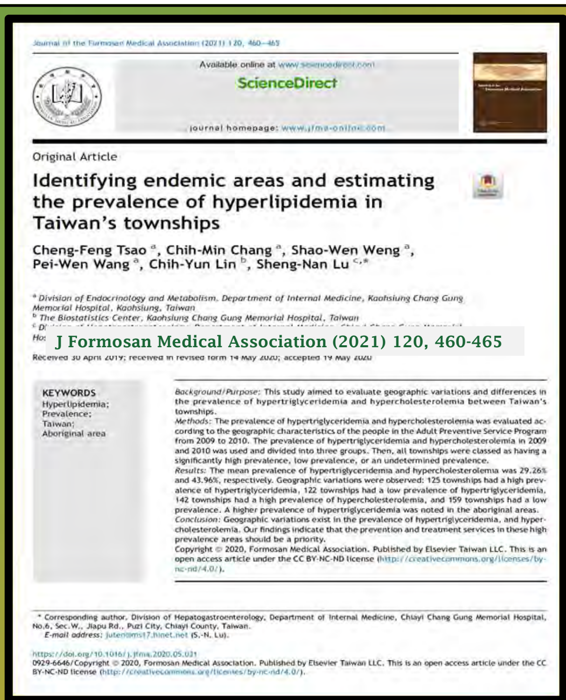

Journal of the Formosan Medical Association (2021) 120, 460–465

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.jfma-online.com

Original Article

Identifying endemic areas and estimating the prevalence of hyperlipidemia in Taiwan's townships

Cheng-Feng Tsao [a], Chih-Min Chang [a], Shao-Wen Weng [a], Pei-Wen Wang [a], Chih-Yun Lin [b], Sheng-Nan Lu [c,*]

[a] Division of Endocrinology and Metabolism, Department of Internal Medicine, Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan
[b] The Biostatistics Center, Kaohsiung Chang Gung Memorial Hospital, Taiwan

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Received 30 April 2019; received in revised form 14 May 2020; accepted 19 May 2020

KEYWORDS
Hyperlipidemia;
Prevalence;
Taiwan;
Aboriginal area

Background/Purpose: This study aimed to evaluate geographic variations and differences in the prevalence of hypertriglyceridemia and hypercholesterolemia between Taiwan's townships.
Methods: The prevalence of hypertriglyceridemia and hypercholesterolemia was evaluated according to the geographic characteristics of the people in the Adult Preventive Service Program from 2009 to 2010. The prevalence of hypertriglyceridemia and hypercholesterolemia in 2009 and 2010 was used and divided into three groups. Then, all townships were classed as having a significantly high prevalence, low prevalence, or an undetermined prevalence.
Results: The mean prevalence of hypertriglyceridemia and hypercholesterolemia was 29.26% and 43.96%, respectively. Geographic variations were observed: 125 townships had a high prevalence of hypertriglyceridemia, 122 townships had a low prevalence of hypertriglyceridemia, 142 townships had a high prevalence of hypercholesterolemia, and 159 townships had a low prevalence. A higher prevalence of hypertriglyceridemia was noted in the aboriginal areas.
Conclusion: Geographic variations exist in the prevalence of hypertriglyceridemia, and hypercholesterolemia. Our findings indicate that the prevention and treatment services in these high prevalence areas should be a priority.
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E-mail address: juten@ms17.hinet.net (S.-N. Lu).

https://doi.org/10.1016/j.jfma.2020.05.031
0929-6646/Copyright © 2020, Formosan Medical Association. Published by Elsevier Taiwan LLC. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Prevalence of high cholesterol

43.96%

39

Oil	Strength of Evidence
Soybean	Supportive
Corn	Limited
Canola	
Olive	Very limited and preliminary

Qualified Health Claims for Reducing Risk of Coronary Artery Disease

FDA U.S. FOOD & DRUG ADMINISTRATION

40

FDA Completes Review of Qualified Health Claim Petition for Oleic Acid and the Risk of Coronary Heart Disease

“The U.S. Food and Drug Administration (FDA) has determined that there is credible evidence to support a qualified health claim that consuming oleic acid in edible oils … may reduce the risk of coronary heart disease.”

FDA U.S. FOOD & DRUG ADMINISTRATION

*Oils must contain ≥70% oleic acid

41

High-oleic acid oils qualify for a health claim

42

Saturated fat increases risk of cardiovascular disease

43

Impact of Nonoptimal Intakes of Saturated, Polyunsaturated, and Trans Fat on Global Burdens of Coronary Heart Disease

Qianyi Wang, ScD; Ashkan Afshin, ScD, MD; Mohammad Yawar Yakoob, ScD, MD; Gitanjali M. Singh, PhD; Colin D. Rehm, PhD, MPH; Shahab Khatibzadeh, MD; Renata Micha, PhD; Peilin Shi, PhD; Dariush Mozaffarian, MD, DrPH; on behalf of the Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE)*

Background—Saturated fat (SFA), ω-6 (n-6) polyunsaturated fat (PUFA), and trans fat (TFA) influence risk of coronary heart disease (CHD), but attributable CHD mortalities by country, age, sex, and time are unclear.

Methods and Results—National intakes of SFA, n-6 PUFA, and TFA were estimated using a Bayesian hierarchical model based on country-specific dietary surveys; food availability data; and, for TFA, industry reports on fats/oils and packaged foods. Etiologic effects of dietary fats on CHD mortality were derived from meta-analyses of prospective cohorts and CHD mortality rates from the 2010 Global Burden of Diseases study. Absolute and proportional attributable CHD mortality were computed using a comparative risk assessment framework. In 2010, nonoptimal intakes of n-6 PUFA, SFA, and TFA were estimated to result in 711 800 (95% uncertainty interval [UI] 680 700–745 000), 250 900 (95% UI 236 900–265 800), and 537 200 (95% UI 517 600–557 000) CHD deaths per year worldwide, accounting for 10.3% (95% UI 9.9%–10.6%), 3.6%, (95% UI 3.5%–3.6%) and 7.7% (95% UI 7.6%–7.9%) of global CHD mortality. Tropical oil–consuming countries were estimated to have the highest proportional n-6 PUFA– and SFA-attributable CHD mortality, whereas Egypt, Pakistan, and Canada were estimated to have the highest proportional TFA-attributable CHD mortality. From 1990 to 2010 globally, the estimated proportional CHD mortality decreased by 9% for insufficient n-6 PUFA and by 21% for higher SFA, whereas it increased by 4% for higher TFA, with the latter driven by increases in low- and middle-income countries.

Conclusions—Nonoptimal intakes of n-6 PUFA, TFA, and SFA each contribute to significant estimated CHD mortality, with important heterogeneity across countries that informs nation-specific clinical, public health, and policy priorities. (*J Am Heart Assoc.* 2016;5:e00289

J Am Heart Assoc. 2016;5:e002891

Key Words: cardiovasc … saturated fat • trans fat

Coronary heart disease (CHD) is the leading cause of death worldwide and accounted for 7 million deaths in 2010.[1] The types of dietary fats consumed play an important role in CHD risk, representing key modifiable risk factors.[2] In particular, higher intakes of trans fat (TFA)[3] and of saturated fat (SFA) replacing ω-6 (n-6) polyunsaturated fat (PUFA) are associated with increased CHD,[4,5] whereas higher intake of PUFA replacing either SFA or carbohydrate is associated with lower risk.[6]

Considerable heterogeneity is evident in intakes of these dietary fats[7] and in CHD mortality rates[1] globally; however, differences in CHD mortality attributable to nonoptimal intakes of SFA, n-6 PUFA, and TFA by country, age, and sex are not well established. Furthermore, whereas dietary intakes and CHD rates have changed substantially in recent decades, the regional and country-level trends in these burdens have not been evaluated in detail. This may be especially relevant for dietary linoleic acid, the predominant n-6 PUFA, which appears to have similar CHD benefits whether replacing SFA or carbohydrates.[8] No prior study has investigated global CHD deaths attributable to higher SFA, insufficient n-6 PUFA, and higher TFA consumption.

To address these gaps, we used a comparative risk assessment framework to quantify CHD mortality due to nonoptimal intakes of n-6 PUFA, SFA, and TFA in 186 countries in 1990 and 2010 by age and sex.

From the Harvard T.H. Chan School of Public Health (Q.W., M.Y.Y., S.K.) and Friedman School of Nutrition Science & Policy, Tufts University (A.A., G.M.S., C.D.R., R.M., P.S., D.M.), Boston, MA.

Accompanying Tables S1 and S2 are available at http://jaha.ahajournals.org/content/5/1/e002891/suppl/DC1

*Individual members of the Nutrition and Chronic Diseases Expert Group (NutriCoDE) are listed in the Appendix.

Correspondence to: Qianyi Wang, ScD, 16 Parker Hill Avenue, Boston, MA 02120.

Received November 10, 2015; accepted November 18, 2015.

Journal of the American Heart Association 1

Globally, 3 times more people diet of coronary heart disease mortality from consuming too little polyunsaturated fat than too much saturated fat.

44

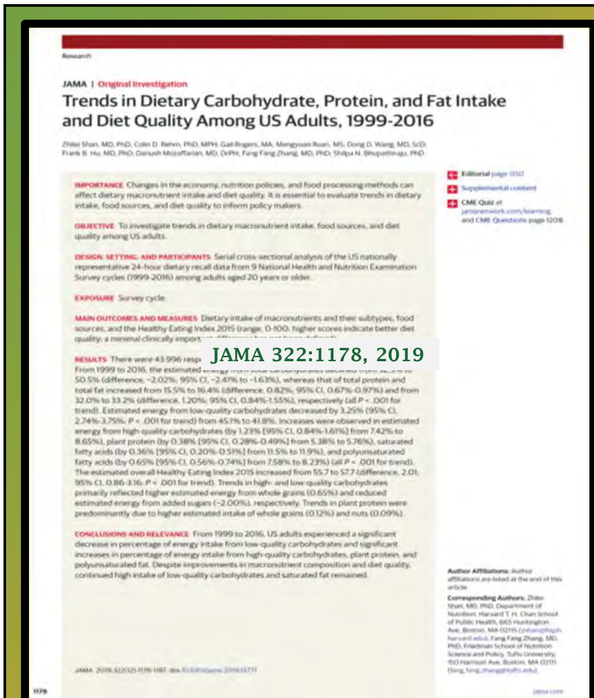

Impact of Nonoptimal Intakes of Saturated, Polyunsaturated, and Trans Fat on Global Burdens of Coronary Heart Disease

J Am Heart Assoc. 2016;5:e002891

Expert Group

Optimal intake of linoleic acid (polyunsaturated fat): **12% of energy**

45


JAMA | Original Investigation

Trends in Dietary Carbohydrate, Protein, and Fat Intake and Diet Quality Among US Adults, 1999-2016

JAMA 322:1178, 2019

Percentage of Calories Derived from Different Types of Fat by US Adults

Fat type	Survey years 1999-2000	2007-2008	2015-2016
Sample size	4237	5420	5017
Saturated	11.5	11.6	11.9
Polyunsaturated	**7.6**	**7.7**	**8.2**
Monounsaturated	12.9	12.9	13.1

*~90% of dietary PUFA intake from linoleic acid

nhanes
National Health and Nutrition Examination Survey

46


OPEN ACCESS

Effect of diet low in omega-6 polyunsaturated fatty acids on the global burden of cardiovascular diseases and future trends: evidence from the Global Burden of Disease 2021

Qingsong Mao[1] and Yuzhe Kong[1*]

Background: This research analyzes the worldwide impact of cardiovascular diseases (CVD) associated with low consumption of omega-6 polyunsaturated fatty acids, utilizing data from the 2021 Global Burden of Disease Study.

Method: The study explored the influence of diets deficient in omega-6 polyunsaturated fatty acids on CVD across global, regional, and national levels. … enders and analyzed … -demographic index … the future prevalence of CVD linked to insufficient omega-6 intake until 2050.

Result: In 2021, insufficient omega-6 intake was linked to roughly 737.88 thousand deaths and 17.87 million disability-adjusted life years (DALYs) due to CVD, showing a decreasing trend in this health burden throughout the study period. The most significant effects were seen in individuals aged 75 and older, with a higher disease burden noted in males. Forecasts suggest likely declines in disease prevalence in regions with high SDI. On a national level, regions like Russia and various countries in North Africa and the Middle East might experience increasing challenges related to CVD due to low omega-6 intake by 2030 and 2050.

Conclusion: These results highlight the critical need for preventive strategies for CVD and stress the importance of managing dietary patterns to mitigate health risks.

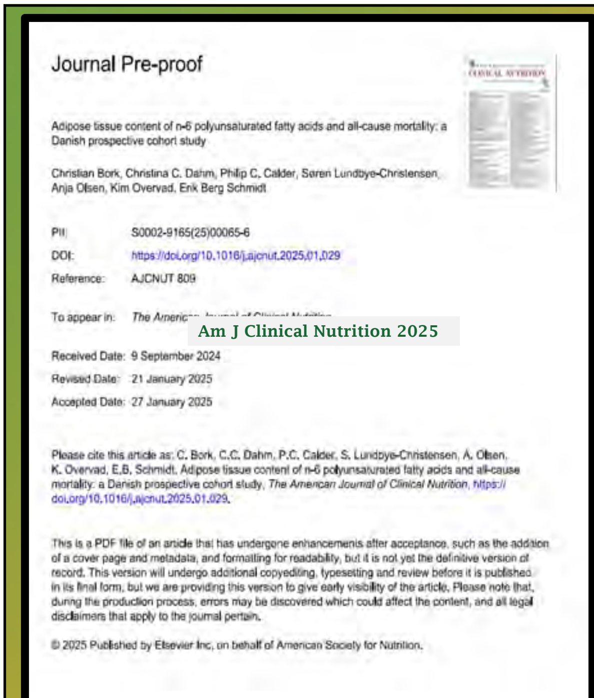
1 Introduction

Cardiovascular diseases (CVD) are the primary cause of mortality worldwide (1). Numerous risk factors including smoking, dyslipidemia, hypertension, obesity, lack of physical activity, and ethnicity are closely associated with CVD (1). It is noteworthy that behavioral risk factors could prevent up to 90% of CVD incidents (2). Additionally, dietary habits and specific dietary components significantly influence CVD (3). LA, a crucial fatty acid that must be ingested

Front. Med. 11:1485695. 2025

In 2021, insufficient (<9-10% of energy) omega-6 intake was linked to roughly 738,000 deaths due to cardiovascular disease.

47


Journal Pre-proof

Adipose tissue content of n-6 polyunsaturated fatty acids and all-cause mortality: a Danish prospective cohort study

Christian Bork, Christina C. Dahm, Philip C. Calder, Søren Lundbye-Christensen, Anja Olsen, Kim Overvad, Erik Berg Schmidt

PII: S0002-9165(25)00065-6
DOI: https://doi.org/10.1016/j.ajcnut.2025.01.029
Reference: AJCNUT 809

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Received Date: 9 September 2024
Revised Date: 21 January 2025
Accepted Date: 27 January 2025

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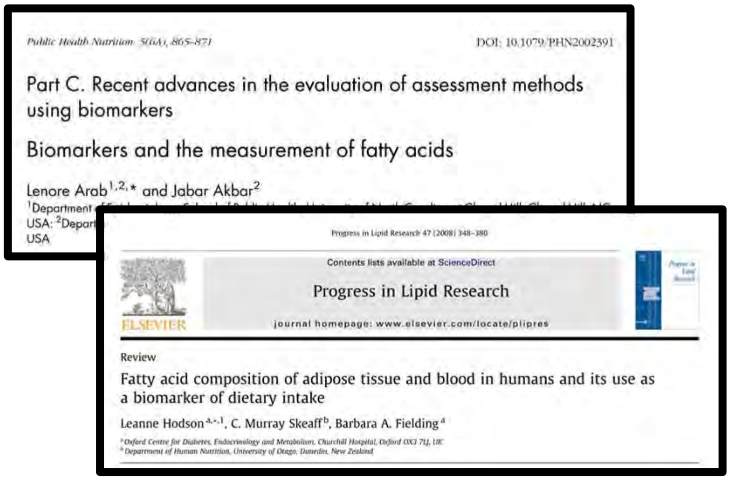
Am J Clinical Nutrition 2025

"Adipose [fat] tissue content of linoleic acid was inversely associated with all-cause mortality …"

48

Omega-6 polyunsaturated fatty acids in adipose tissue have a slow turnover reflecting long-term exposure during 1-2 years or even longer


Public Health Nutrition: 5(6A), 865–871 DOI: 10.1079/PHN2002391

Part C. Recent advances in the evaluation of assessment methods using biomarkers

Biomarkers and the measurement of fatty acids

Lenore Arab[1,2,*] and Jabar Akbar[2]

Progress in Lipid Research 47 (2008) 348–380

Contents lists available at ScienceDirect

Progress in Lipid Research

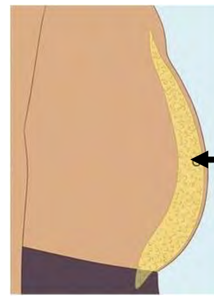
journal homepage: www.elsevier.com/locate/plipres

Review

Fatty acid composition of adipose tissue and blood in humans and its use as a biomarker of dietary intake

Leanne Hodson[a,*,1], C. Murray Skeaff[b], Barbara A. Fielding[a]

[a] Oxford Centre for Diabetes, Endocrinology and Metabolism, Churchill Hospital, Oxford OX3 7LJ, UK
[b] Department of Human Nutrition, University of Otago, Dunedin, New Zealand



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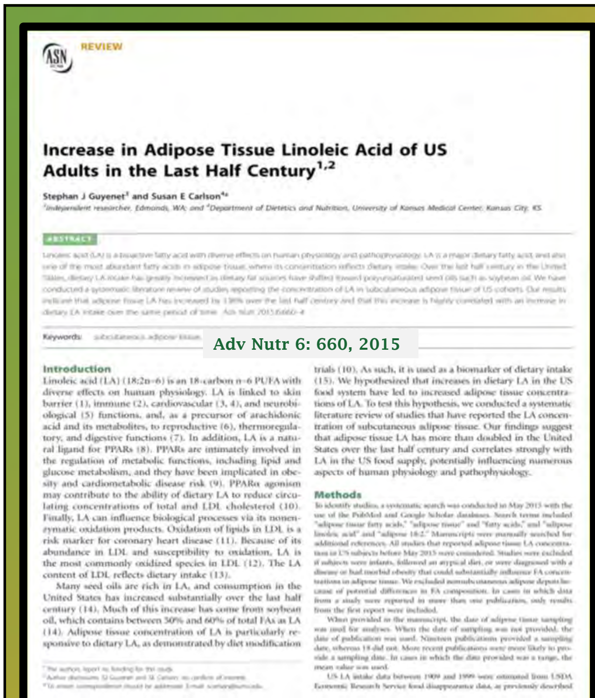

REVIEW

Increase in Adipose Tissue Linoleic Acid of US Adults in the Last Half Century[1,2]

Stephan J Guyenet[3] and Susan E Carlson[4*]

[3] Independent researcher, Edmonds, WA; and [4] Department of Dietetics and Nutrition, University of Kansas Medical Center, Kansas City, KS

ABSTRACT

Linoleic acid (LA) is a bioactive fatty acid with diverse effects on human physiology and pathophysiology. LA is a major dietary fatty acid, and also one of the most abundant fatty acids in adipose tissue, where its concentration reflects dietary intake. Over the last half century in the United States, dietary LA intake has greatly increased as dietary fat sources have shifted toward polyunsaturated seed oils such as soybean oil. We have conducted a systematic literature review of studies reporting the concentration of LA in subcutaneous adipose tissue of US cohorts. Our results indicate that adipose tissue LA has increased by 136% over the last half century and that this increase is highly correlated with an increase in dietary LA intake over the same period of time.

Keywords: subcutaneous adipose tissue

Adv Nutr 6: 660, 2015

Introduction

Linoleic acid (LA) (18:2n-6) is an 18-carbon n-6 PUFA with diverse effects on human physiology. LA is linked to skin barrier (1), immune (2), cardiovascular (3, 4), and neurobiological (5) functions, and, as a precursor of arachidonic acid and its metabolites, to reproductive (6), thermoregulatory, and digestive functions (7). In addition, LA is a natural ligand for PPARs (8). PPARs are intimately involved in the regulation of metabolic functions, including lipid and glucose metabolism, and they have been implicated in obesity and cardiometabolic disease risk (9). PPARα agonism may contribute to the ability of dietary LA to reduce circulating concentrations of total and LDL cholesterol (10). Finally, LA can influence biological processes via its nonenzymatic oxidation products. Oxidation of lipids in LDL is a risk marker for coronary heart disease (11). Because of its abundance in LDL and susceptibility to oxidation, LA is the most commonly oxidized species in LDL (12). The LA content of LDL reflects dietary intake (13).

Many seed oils are rich in LA, and consumption in the United States has increased substantially over the last half century (14). Much of this increase has come from soybean oil, which contains between 50% and 60% of total FAs as LA (14). Adipose tissue concentration of LA is particularly responsive to dietary LA, as demonstrated by diet modification trials (10). As such, it is used as a biomarker of dietary intake (15). We hypothesized that increases in dietary LA in the US food system have led to increased adipose tissue concentrations of LA. To test this hypothesis, we conducted a systematic literature review of studies that have reported the LA concentration of subcutaneous adipose tissue. Our findings suggest that adipose tissue LA has more than doubled in the United States over the last half century and correlates strongly with LA in the US food supply, potentially influencing numerous aspects of human physiology and pathophysiology.

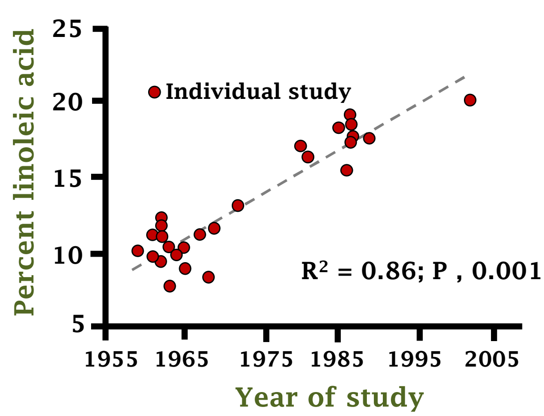
Methods

To identify studies, a systematic search was conducted in May 2015 with the use of the PubMed and Google Scholar databases. Search terms included "adipose tissue fatty acids," "adipose tissue" and "fatty acids," and "adipose linoleic acid" and "adipose 18:2." Manuscripts were manually searched for additional references. All studies that reported adipose tissue LA concentrations in US subjects before May 2015 were considered. Studies were excluded if subjects were infants, followed an atypical diet, or were diagnosed with a disease or had morbid obesity that could substantially influence FA concentrations in adipose tissue. We excluded nonsubcutaneous adipose depots because of potential differences in FA composition. In cases in which data from a study were reported in more than one publication, only results from the first report were included.

When provided in the manuscript, the date of adipose tissue sampling was used for analyses. When the date of sampling was not provided, the date of publication was used. Nineteen publications provided a sampling date, whereas 18 did not. More recent publications were more likely to provide a sampling date. In cases in which the data provided was a range, the mean value was used.

US LA intake data between 1909 and 1999 were estimated from USDA Economic Research Service food disappearance data, as previously described

Increase over time in adipose tissue (buttocks and abdominal area) linoleic acid concentration



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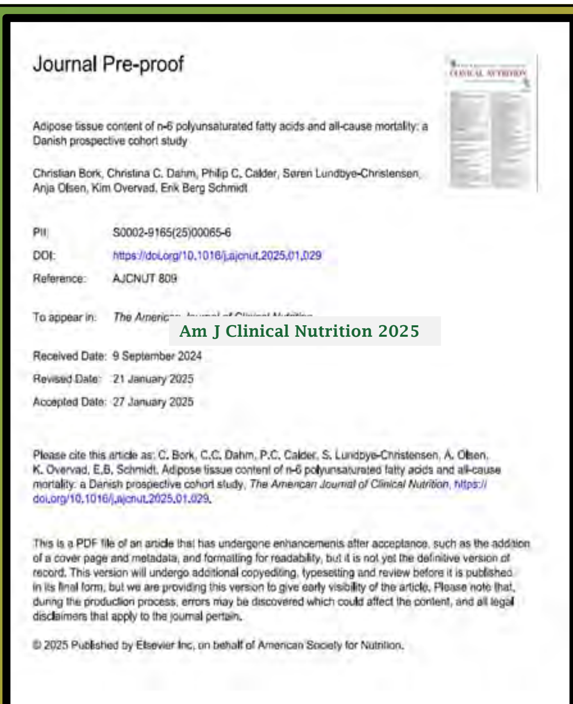

Journal Pre-proof

Adipose tissue content of n-6 polyunsaturated fatty acids and all-cause mortality: a Danish prospective cohort study

Christian Bork, Christina C. Dahm, Philip C. Calder, Søren Lundbye-Christensen, Anja Olsen, Kim Overvad, Erik Berg Schmidt

PII: S0002-9165(25)00065-6
DOI: https://doi.org/10.1016/j.ajcnut.2025.01.029
Reference: AJCNUT 809

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Accepted Date: 27 January 2025

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Relationship between buttock adipose tissue linoleic acid (LA) content and risk of mortality

Percent LA	Cases	% decrease
4.75-9.59	403	----
9.60-10.60	265	21
10.61-11.70	252	20
11.71-29.41	240	26

4,663 Danish adults enrolled in 1993-1997, 21 year follow up. 1,160 deaths. All values statistically significant. Adjusted for age, education, smoking, physical activity, BMI, waist circumference and aloohol intake

51

52

Mean Fatty Acid Composition of Soybean Oil (633 varieties)

Fatty acid	Percent		Fatty acid type
Palmitic	12.1	16.0	Saturated
Stearic	3.9		
Oleic	21.6	21.6	Monounsaturated
Linoleic[1]	54.4	62.3	Polyunsaturated
α-linolenic[2]	7.9		

Abdelghany et al. Agronomy 2020, 10, 24
[1]Essential omega-6 FA [2]Essential omega-6 FA

53

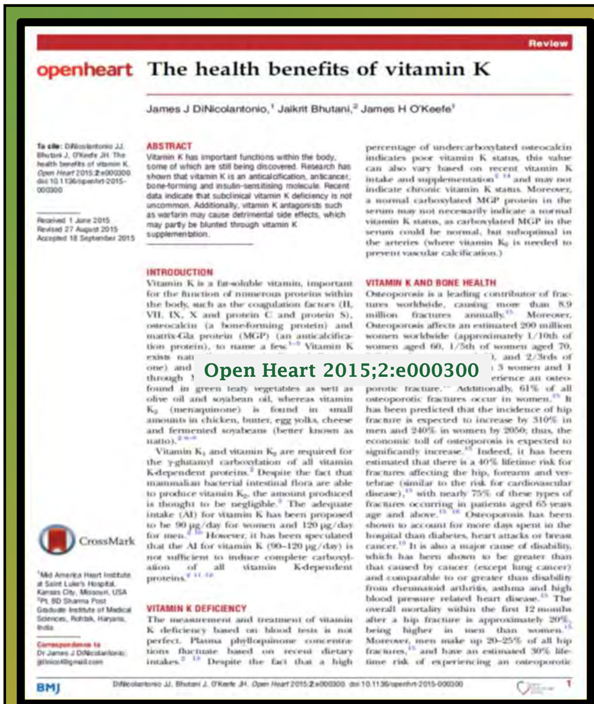
Contribution to US intake

- ~7% of caloric intake
- >40% of linoleic acid
- >40% of alpha-linolenic acid

54

55

56


Review

openheart The health benefits of vitamin K

James J DiNicolantonio,[1] Jaikrit Bhutani,[2] James H O'Keefe[1]

Open Heart 2015;2:e000300

Proposed Benefits

- Bone health (fractures)
- Cardiovascular disease
- Cancer (liver)
- Diabetes (insulin sensitivity)

57

Type of oil	Vitamin K1
Soybean oil	25.0
Canola	10.0
Olive oil	8.1
Walnut	2.0
Sesame oil	1.8
Flaxseed	1.3
Palm	1.1
Safflower	1.0
Sunflower	0.8
Corn	0.3
Peanut oil	0.1
Coconut	0.1

Vitamin K Content of Plant Oils

(ug/tablespoon, ~14 g)

58

Fat-soluble vitamin that acts as an antioxidant, helping to protect cells from the damage caused by free radicals.

59

NUTRITION AND CANCER
2020, VOL. 72, NO. 5, 808–825

Taylor & Francis

The Potential Physiological Role of γ-Tocopherol in Human Health: A Qualitative Review

Mika D. Thompson and Robert V. Cooney

Office of Public Health Studies, University of Hawai'i at Mānoa, Honolulu, HI, USA

ABSTRACT
Chronic aging-related diseases result in the greatest burden to the health care system, yet there is little agreement on optimal levels of vitamins or the functional significance of many other dietary molecules in disease prevention. This review presents accumulated information regarding the role of γ-tocopherol in the prevention of nitrogen oxide-mediated damage and its impact on aging-related diseases. γ-Tocopherol is ubiquitous in the diet and levels appear to be physiologically regulated such that levels rise in response to inflammation and deficiencies in certain key vitamins. The unique antioxidant properties of γ-tocopherol, whereby DNA-damaging nitrogen dioxide is rapidly converted to nitric oxide, suggest a mechanistic justification for a functional role in the prevention of DNA damage over time. Data from cell, animal, and human studies indicate that γ-tocopherol appears to have significant beneficial effects, protecting cells from inflammatory damage; however, interpretation of epidemiologic studies is complex due to the paradoxical rise in levels of γ-tocopherol in response to [...] dant mechanism of action, ap[...] atic pathways suggests γ-to[...] health. Its utility as a biomarker and the consequences of its deficiency deserve further study.

ARTICLE HISTORY
Received 11 March 2019
Accepted 31 July 2019

Nutr Cancer 72: 808, 2020

Introduction

Since the discovery of Vitamin E nearly 100 years ago, numerous experimental and observational studies using animal models, cell cultures, and humans have contributed to our current understanding of its role in human health and nutrition. Vitamin E is recognized as a well-established biological antioxidant, preventing oxidative damage to membrane lipids from highly reactive oxygen radicals. Via this mechanism and potentially others, Vitamin E is known to play important roles in reproduction, muscle function, red blood cell maintenance, and immune function (1). Most of these findings have stemmed from prior research focusing almost exclusively on α-tocopherol, the form of Vitamin E thought to be the most potent in terms of bioavailability and bioactivity with respect to acute effects of deficiency. Consequently, the Institute of Medicine has deemed only α-tocopherol as "Vitamin E" (1). However, an expanding body of literature on the less studied tocopherols suggests that γ-tocopherol, the predominant form of tocopherol in the American diet, may have a role of equal or greater importance with respect to the prevention of many aging-related conditions, including cancer, cardiovascular disease, and Alzheimer's disease (2, 3). Thus, the aim of the current review is to examine the literature on γ-tocopherol, focusing on the most recent developments in these fields, and discuss the implications for public health and nutrition.

Methods

We conducted a qualitative, electronic literature review of γ-tocopherol's role in human health utilizing PubMed, Google Scholar, and Web of Science up to 2019 with no restrictions. The following search terms were used for the search: gamma-tocopherol, γ-tocopherol, tocopherol, vitamin E, inflammation, chronic inflammation, nitrogen oxide, nitric oxide, nitrosative, oxidative, antioxidants, supplementation, immune, aging, age-related, cancer, and cardiovascular disease. The two authors independently reviewed article titles and abstracts, and chose studies based on their cross-referenced relevance to the role γ-tocopherol has in

"Data from cell, animal, and human studies indicate that gamma-tocopherol appears to have significant beneficial effects ..."

60

Vitamin E (Tocopherol) Content of Selected Oils

	Tocopherol (mg/g)	
Food	Gamma	Delta
Soybean	64.26	21.30
Corn	--	--
Olive	0.83	0.00
Canola	27.34	0.99
Sunflower	--	--
Sesame	--	--
Peanut	15.91	1.37
Walnut	--	--
Palm	0.00	0.00
Coconut	0.00	0.10

61

- Lowers blood LDL-cholesterol when replacing saturated fat
- Source of both essential fatty acids
- Source of vitamin K
- Source of vitamin E

62


Nutritional Epidemiology

The Type of Oil Used for Cooking Is Associated with the Risk of Nonfatal Acute Myocardial Infarction in Costa Rica[1,2]

Edmond K. Kabagambe,* Ana Baylin,* Alberto Ascherio,*† and Hannia Campos*,**3

Departments of *Nutrition and †Epidemiology, Harvard School of Public Health, Boston MA 02115 and **Centro Centroamericano de Población, Universidad de Costa Rica, San Pedro de Montes de Oca, Costa Rica

ABSTRACT Palm oil and soybean oil are the 2 most widely used cooking oils in the world. Palm oil is consumed mainly in developing countries, where morbidity and mortality due to cardiovascular disease (CVD) are on the rise. Although claims about adverse or protective effects of these oils are commonly made, there are no epidemiologic studies assessing the association between these oils and cardiovascular disease endpoints. We examined whether consumption of palm oil relative to soybean oil and other unsaturated oils (predominantly sunflower) is associated with myocardial infarction (MI) in Costa Rica. The cases (n = 2111) were survivors of a first acute MI and were matched to randomly selected population controls (n = 2111). Dietary intake was assessed with a validated semiquantitative FFQ. Adipose tissue profiles of essential fatty acids were assessed to validate cooking oil intake and found to be consistent with self-reported major oils used for cooking. The data were analyzed using conditional logistic regression. Palm oil users were more likely to have an MI than users of soybean oil [odds ratio (OR) = 1.33; 95% CI: 1.08–1.63] or other cooking oils (OR = 1.23; CI: 0.99–1.52), but they did not differ from users of soybean oil with a high *trans*-fatty acid content (OR = 1.14; CI: 0.84–1.56). These data suggest that as currently used in Costa Rica, and most likely in many other developing countries, the replacement of palm oil with a polyunsaturated nonhydrogenated vegetable oil ... 79, 2005.

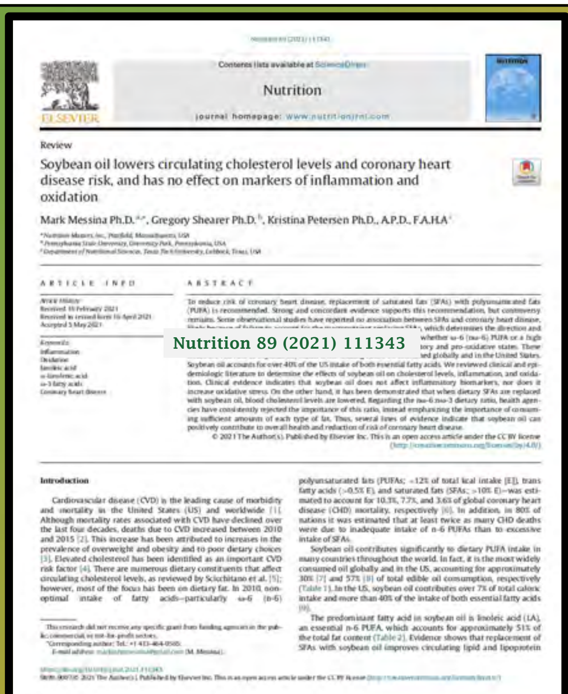
KEY WORDS: • fatty acids • ... cardiovascular disease

J Nutr 135: 2674, 2005

Palm oil users were 3 times more likely to have a myocardial infarction [heart attack] than users of soybean oil.

Costa Rico

63


Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Review

Soybean oil lowers circulating cholesterol levels and coronary heart disease risk, and has no effect on markers of inflammation and oxidation

Mark Messina Ph.D., Gregory Shearer Ph.D., Kristina Petersen Ph.D., A.P.D., F.A.H.A

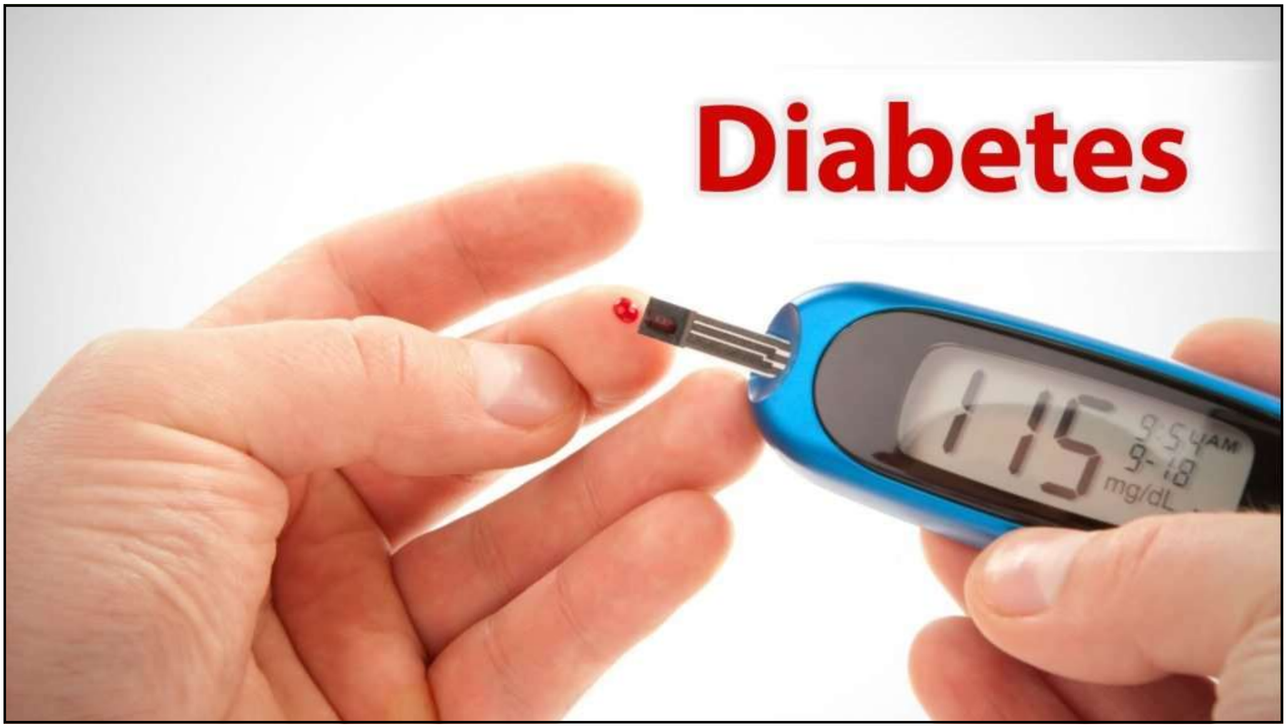
ARTICLE INFO

ABSTRACT

Nutrition 89 (2021) 111343

" ... several lines of evidence indicate that soybean oil can positively contribute to overall health and reduction of risk of coronary heart disease."

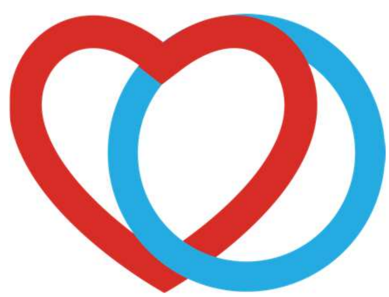
64



65

Diabetes and Cardiovascular Disease

- >500 million diabetics worldwide
- Two-thirds die from CVD
  - Ischemic heart disease
  - Congestive heart failure
  - Stroke
- Risk of CHD 2-3 times higher
- CVD occurs 14.6 years earlier in diabetics versus non-diabetics



Circulation 133: 2459, 2016

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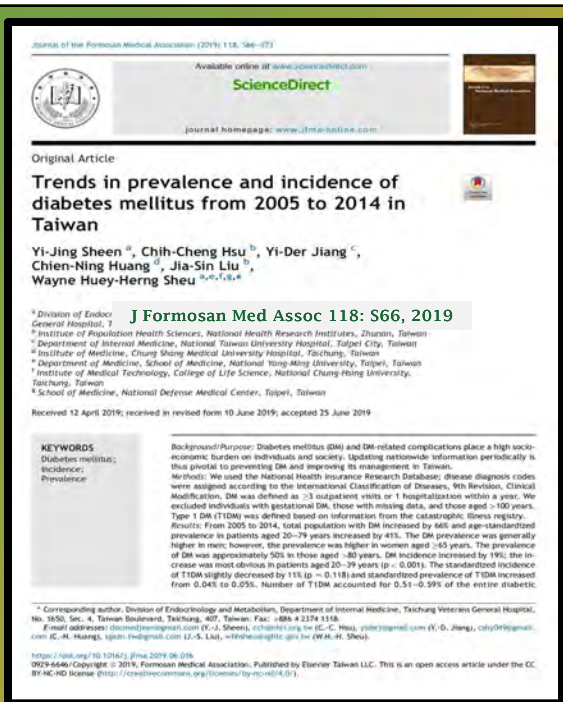
Journal of the Formosan Medical Association (2019) 118, S66–S73

Available online at www.sciencedirect.com

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journal homepage: www.jfma-online.com

Original Article

Trends in prevalence and incidence of diabetes mellitus from 2005 to 2014 in Taiwan

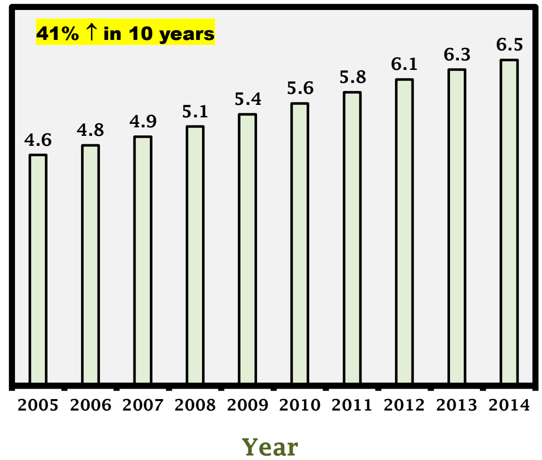
Yi-Jing Sheen [a], Chih-Cheng Hsu [b], Yi-Der Jiang [c], Chien-Ning Huang [d], Jia-Sin Liu [b], Wayne Huey-Herng Sheu [a,e,f,g,*]

J Formosan Med Assoc 118: S66, 2019

Received 12 April 2019; received in revised form 10 June 2019; accepted 25 June 2019

KEYWORDS
Diabetes mellitus;
Incidence;
Prevalence

Increasing prevalence (%) of diabetes in Taiwan (2005-2014)



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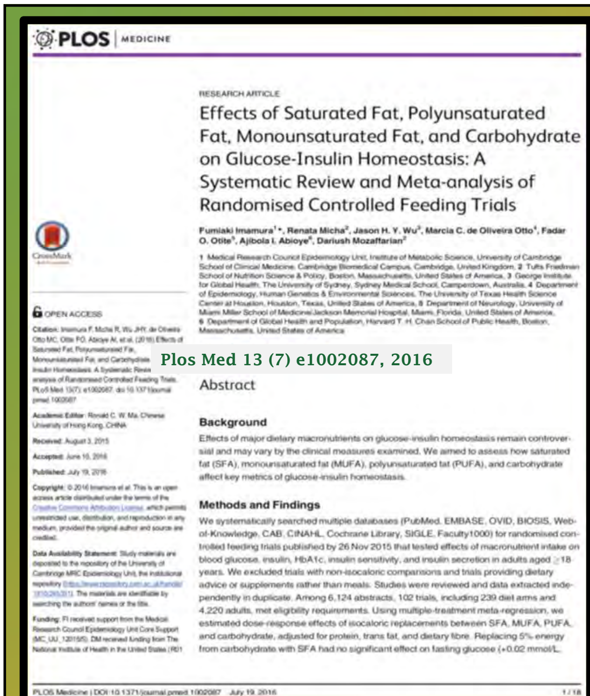

PLOS | MEDICINE

RESEARCH ARTICLE

Effects of Saturated Fat, Polyunsaturated Fat, Monounsaturated Fat, and Carbohydrate on Glucose-Insulin Homeostasis: A Systematic Review and Meta-analysis of Randomised Controlled Feeding Trials

Fumiaki Imamura[1*], Renata Micha[2], Jason H. Y. Wu[3], Marcia C. de Oliveira Otto[4], Fadar O. Otite[5], Ajibola I. Abioye[6], Dariush Mozaffarian[2]

OPEN ACCESS

Plos Med 13 (7) e1002087, 2016

Abstract

Background

Methods and Findings

PLOS Medicine | DOI:10.1371/journal.pmed.1002087 July 19, 2016 1 / 18

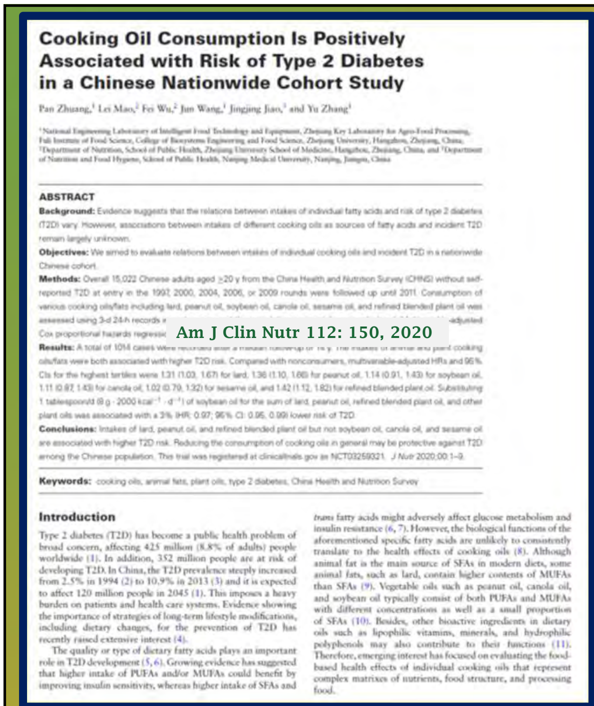
Replacing 5% of energy from saturated fat with equivalent energy from polyunsaturated fat lowers:

- Blood glucose
- Glycosylated hemoglobin (HbA1c)
- Fasting insulin
- C-peptide
- Insulin resistance

Meta-analysis

102 trials, 239 diet arms, 4220 adults

68



Cooking Oil Consumption Is Positively Associated with Risk of Type 2 Diabetes in a Chinese Nationwide Cohort Study

Pan Zhuang,[1] Lei Mao,[1] Fei Wu,[2] Jun Wang,[1] Jingjing Jiao,[3] and Yu Zhang[1]

[1]National Engineering Laboratory of Intelligent Food Technology and Equipment, Zhejiang Key Laboratory for Agro-Food Processing, Fuli Institute of Food Science, College of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou, Zhejiang, China; [2]Department of Nutrition, School of Public Health, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China; and [3]Department of Nutrition and Food Hygiene, School of Public Health, Nanjing Medical University, Nanjing, Jiangsu, China

ABSTRACT

Background: Evidence suggests that the relations between intakes of individual fatty acids and risk of type 2 diabetes (T2D) vary. However, associations between intakes of different cooking oils as sources of fatty acids and incident T2D remain largely unknown.

Objectives: We aimed to evaluate relations between intakes of individual cooking oils and incident T2D in a nationwide Chinese cohort.

Methods: Overall 15,022 Chinese adults aged ≥20 y from the China Health and Nutrition Survey (CHNS) without self-reported T2D at entry in the 1997, 2000, 2004, 2006, or 2009 rounds were followed up until 2011. Consumption of various cooking oils/fats including lard, peanut oil, soybean oil, canola oil, sesame oil, and refined blended plant oil was assessed using 3-d 24-h records … -adjusted Cox proportional hazards regressi…

Am J Clin Nutr 112: 150, 2020

Results: A total of 1014 cases were … The intakes of animal and plant cooking oils/fats were both associated with higher T2D risk. Compared with nonconsumers, multivariable-adjusted HRs and 95% CIs for the highest tertiles were 1.31 (1.03, 1.67) for lard, 1.36 (1.10, 1.68) for peanut oil, 1.14 (0.91, 1.43) for soybean oil, 1.11 (0.87, 1.43) for canola oil, 1.02 (0.79, 1.32) for sesame oil, and 1.42 (1.12, 1.82) for refined blended plant oil. Substituting 1 tablespoon/d (9 g · 2000 kcal^{-1} · d^{-1}) of soybean oil for the sum of lard, peanut oil, refined blended plant oil, and other plant oils was associated with a 3% (HR: 0.97; 95% CI: 0.95, 0.99) lower risk of T2D.

Conclusions: Intakes of lard, peanut oil, and refined blended plant oil but not soybean oil, canola oil, and sesame oil are associated with higher T2D risk. Reducing the consumption of cooking oils in general may be protective against T2D among the Chinese population. This trial was registered at clinicaltrials.gov as NCT03259321. *J Nutr* 2020;00:1–9.

Keywords: cooking oils, animal fats, plant oils, type 2 diabetes, China Health and Nutrition Survey

Introduction

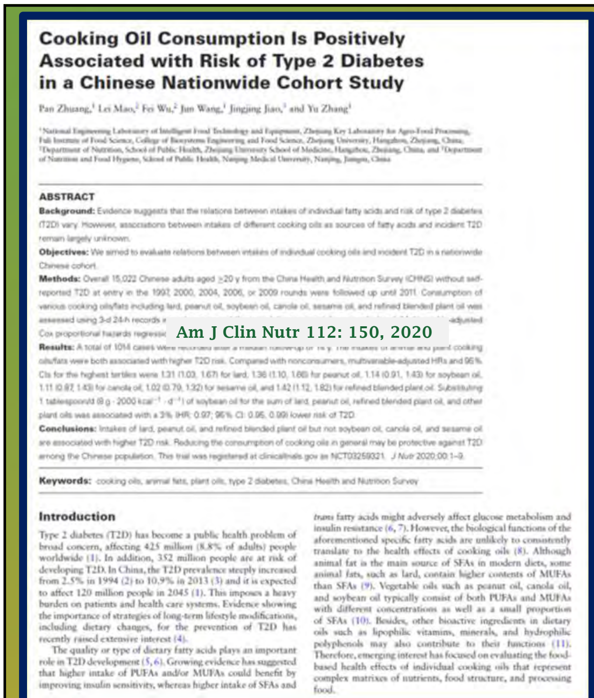
Type 2 diabetes (T2D) has become a public health problem of broad concern, affecting 425 million (8.8% of adults) people worldwide (1). In addition, 352 million people are at risk of developing T2D. In China, the T2D prevalence steeply increased from 2.5% in 1994 (2) to 10.9% in 2013 (3) and it is expected to affect 120 million people in 2045 (1). This imposes a heavy burden on patients and health care systems. Evidence showing the importance of strategies of long-term lifestyle modifications, including dietary changes, for the prevention of T2D has recently raised extensive interest (4).

The quality or type of dietary fatty acids plays an important role in T2D development (5, 6). Growing evidence has suggested that higher intake of PUFAs and/or MUFAs could benefit by improving insulin sensitivity, whereas higher intake of SFAs and *trans* fatty acids might adversely affect glucose metabolism and insulin resistance (6, 7). However, the biological functions of the aforementioned specific fatty acids are unlikely to consistently translate to the health effects of cooking oils (8). Although animal fat is the main source of SFAs in modern diets, some animal fats, such as lard, contain higher contents of MUFAs than SFAs (9). Vegetable oils such as peanut oil, canola oil, and soybean oil typically consist of both PUFAs and MUFAs with different concentrations as well as a small proportion of SFAs (10). Besides, other bioactive ingredients in dietary oils such as lipophilic vitamins, minerals, and hydrophilic polyphenols may also contribute to their functions (11). Therefore, emerging interest has focused on evaluating the food-based health effects of individual cooking oils that represent complex matrixes of nutrients, food structure, and processing food.

Impact of soybean oil intake on risk of developing type 2 diabetes (T2D)

"Increasing consumption of soybean oil in replacement of lard, peanut oil, refined blended plant oil, and other plant cooking oils was associated with lower T2D risk."

69



Cooking Oil Consumption Is Positively Associated with Risk of Type 2 Diabetes in a Chinese Nationwide Cohort Study

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[1]National Engineering Laboratory of Intelligent Food Technology and Equipment, Zhejiang Key Laboratory for Agro-Food Processing, Fuli Institute of Food Science, College of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou, Zhejiang, China; [2]Department of Nutrition, School of Public Health, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China; and [3]Department of Nutrition and Food Hygiene, School of Public Health, Nanjing Medical University, Nanjing, Jiangsu, China

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Impact of soybean oil intake on risk of developing type 2 diabetes (T2D)

- **15,022 Chinese adults**
- **Consumption cooking oil/fat assessed using 3, 24-h records**
- **Median follow-up, 14 years**
- **1,014 cases of diabetes**
- **Substituting 1 tablespoon soybean oil for the sum of lard, peanut oil, and other plant oils, lowered risk by 3%**

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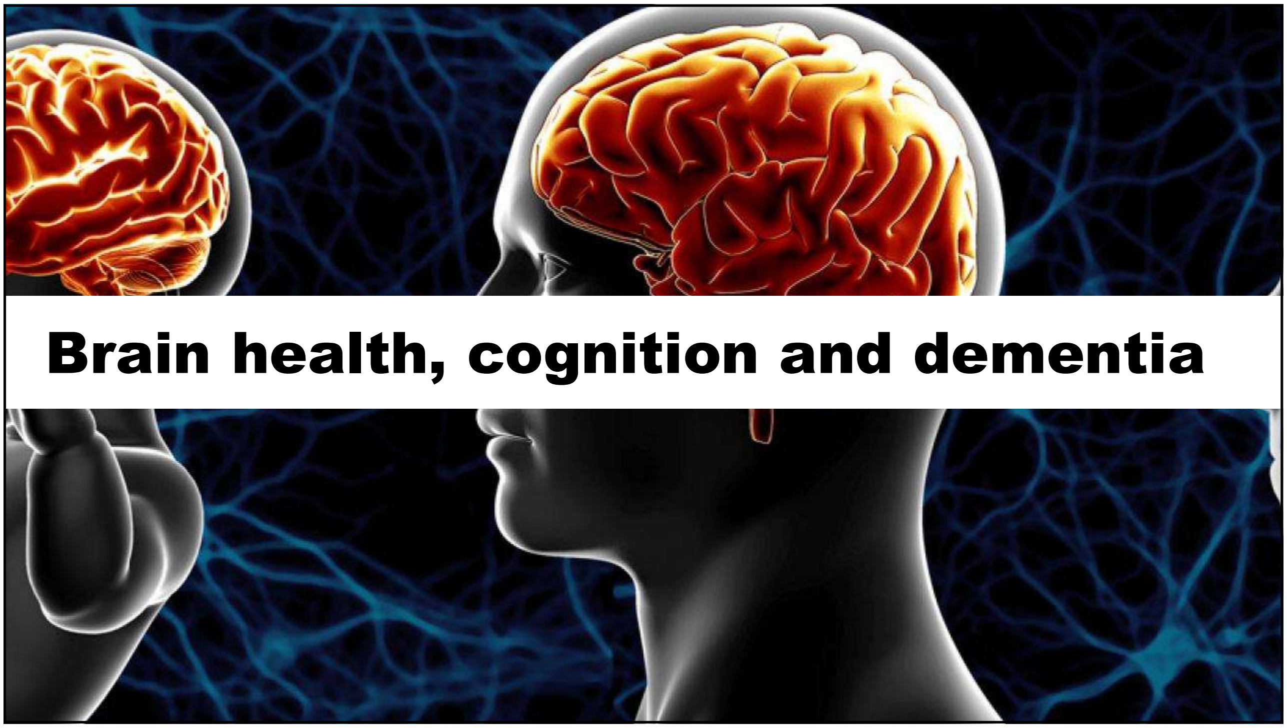


Brain health, cognition and dementia

71

nutrients MDPI

Article

Dietary N-6 Polyunsaturated Fatty Acid Intake and Brain Health in Middle-Aged and Elderly Adults

Jiawei Gu [1,†], Yujia Bao [1,†], Yongxuan Li [1], Li Hua [1], Xiaobei Deng [1], Yuzheng Zhang [2], Xiaojun Zhu [3,*] and Jinjun Ran [1,*]

[1] School of Public Health, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China
[2] National Center for Mental Health, Beijing 100121, China
[3] School of Mathematics and Physics, Xi'an Jiaotong-Liverpool University, Suzhou 215123, China
[*] Correspondence
[†] These authors contributed equally to this work.

Abstract: Background: Dietary intake of polyunsaturated fatty acids (PUFA) plays a significant role in the onset and progression of neurodegenerative diseases. Since the neuroprotective effects of n-3 PUFA have been widely validated, the role of n-6 PUFA remains debated, with their underlying mechanisms still not fully understood. Methods: In this study, 169,295 participants from the UK Biobank were included to analyze the associations between dietary n-6 PUFA intake and neurodegenerative diseases using Cox regression models with full adjustments for potential confounders. In addition, multiple linear regression models were utilized to estimate the impact of n-6 PUFA intake on brain imaging phenotypes. Results: Results indicated that low dietary n-6 PUFA intake was associated with increa... interval] = 1.30 [1.13, 1.49]), Parkinson's ... 2.65]). Moreover, the low intake was linked to diminished volumes of various brain structures, including the hippocampus (β [95% confidence interval] = −0.061 [−0.098, −0.025]), thalamus (−0.071 [−0.105, −0.037]), and others. White matter integrity was also found to be compromised in individuals with low n-6 PUFA intake. Conclusions: These findings enhanced our understanding of how dietary n-6 PUFA intake might affect neurological health, thereby providing epidemiological evidence for future clinical and public health interventions.

Keywords: dietary factors; n-6 polyunsaturated fatty acids; neurodegenerative disease; gray matter; white matter; genetic risk

1. Introduction

With the rapid global increase in aging populations, the burden of neurodegenerative diseases has become a major public health challenge, significantly affecting individual well-being and societal resources [1,2]. Conditions including dementia (DEM) and Parkinson's disease (PD) are escalating in prevalence among others [3], necessitating a greater focus on modifiable risk factors, particularly dietary components, which are increasingly recognized as critical determinants in the onset and progression of these neurodegenerative disorders [4,5]. The connection between diet and brain health has gained substantial interest in recent years, especially as research continues to reveal the significant impact of specific nutrients and dietary patterns on cognitive function among the elderly population [6]. Given the growing body of evidence linking dietary factors to brain health, including studies exploring their influence on brain structure, there is an urgent need for targeted nutritional interventions to mitigate the increasing global burden of neurodegenerative diseases.

Among dietary factors, polyunsaturated fatty acids (PUFAs) have been extensively recognized for their critical roles in maintaining brain health, with omega-6 (n-6) and omega-3

Nutrients 2024, 16, 4272. https://doi.org/10.3390/nu16244272 https://www.mdpi.com/journal/nutrients

Nutrients 2024, 16, 4272

Polyunsaturated fat intake and brain health

- UK Biobank
- 169,295 participants, 37-73 years
- Validated online dietary assessment
- Diet assessed up to 5 times
- 206 foods and 32 beverages

72

Low omega-6 fatty acid intake associated with:

- Increased risk of dementia
- Increased risk of Parkinson's disease
- Increased risk of multiple sclerosis
- Diminished volumes of various brain structures

73

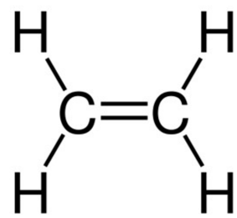
Why the need for high oleic soybean oil?

74

Factors affecting rancidity

- Light
- Temperature
- Air
- Time

Store oils in a dark dry location at room temperature. Keep lid tightly closed and buy amounts likely to be used within months

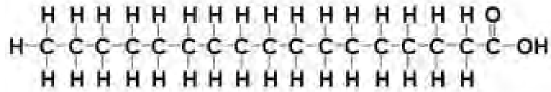


Susceptible to oxidation

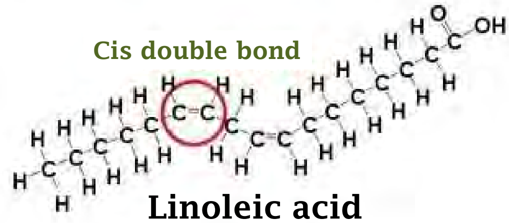
75

More resistant to oxidation than polyunsaturated fatty acids, but ...

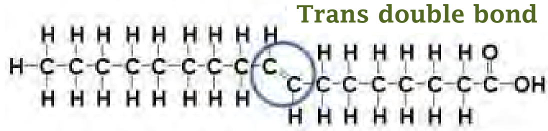
76



Stearic acid



Linoleic acid



Trans-linoleic acid

77

78

Fatty acid composition of high oleic soybean oil

79

Fatty Acid Content (percent) of High-Oleic and Commodity Soybean Oil

Fatty acid	High oleic	Commodity
Saturated	8.8	14.2
Palmitic	4.6	10.0
Stearic	3.1	3.4
Monounsaturated	70.9	22.0
Oleic	68.9	20.0
Polyunsaturated	14.8	58.2
Linoleic (n-6)*	11.9	51.2
Linolenic (n-3)*	2.3	7.0

Essential omega 6 and 3 fatty acids.Lipids 56: 313, 2021

80

Eur. J. Lipid Sci. Technol. 2013, *115*, 935–945 935

Research Article

Chemical and sensory assessment of deep-frying oil alternatives for the processing of French fries

Katharina Domitila Petersen[1], Gerhard Jahreis[2], Mechthild Busch-Stockfisch[1] and Jan Fritsche[1]

[1] Faculty of Life Sciences/Food Science, Hamburg University of Applied Sciences, Hamburg, Germany
[2] Faculty of Biology and Pharmacy, Department of Nutritional Physiology, Friedrich-Schiller-Universität Jena, Institute of Nutrition, Jena, Germany

The aim of the study was to evaluate volatile compounds as marker compounds for the edible oil deterioration during the production of deep-fried French fries. Additionally the sensory characteristics (taste and smell) were assessed and results were compared with the results of the volatile compound analysis. A 32-h deep-frying experiment was performed and different frying oils, namely sunflower oil (SF), high-oleic sunflower oil (HOSF), rapeseed oil (RO), high-oleic rapeseed oil (HORO), and palm olein, were subsequently analyzed for their oxidative properties by the determination of their total polar material (TPM), polymerized triglycerides (PTG), peroxide value, anisidine value, as well as the fatty acid composition. In addition, analysis of the volatile compounds derived from the thermal degradation of the frying oils was performed by means of headspace-GC/MS techniques (HS-SPME-GC/MS and DHS-GC/MS). Multivariate statistical methods (principal component analysis with VARIMAX rotation) were applied to identify sensitive volatile lipid degradation indicators, enabli[…] deep-frying. E,E-[…] various oxidative […] well-known lipid oxidation parameters, e.g., values for PTG or TPM. In addition to the chemical evaluation of the frying oils, the produced French fries were evaluated in terms of their taste and smell by an advanced scientific sensory method (balanced incomplete block design). French fries produced in conventional vegetable oils (SF and RO) were differentiated earlier from those prepared in fresh reference oil compared to HOSF and HORO. The perception of the French fries prepared in HOSF was comparable to those prepared in palm olein. Therefore, high-oleic vegetable oils, especially high-oleic SF, provide a frying oils alternative for the production of deep-fried French fries, delivering low proportions of trans and saturated fatty acids.

Practical applications: The combination of volatile compound analysis by headspace-GC/MS techniques with multivariate statistical methods is a sensitive tool to detect quality changes in deep-frying oils at an early stage of lipid deterioration. Evolved volatile marker compounds, e.g., E,E-2,4-heptadienal and heptanal correlated reasonably with quality parameters for the assessment of the thermal stability of frying oils, e.g., content of TPM polymerized triglycerides. Comprehensive scientific sensory evaluations of frying oils revealed high-oleic edible oils as promising frying oil alternatives for the processing of French fries providing low proportions of trans fatty acids and saturated fatty acids.

Keywords: Deep-fat frying / French fries / Frying oils / Sensory analysis / Volatile compounds

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Additional supporting information may be found in the online version of this article at the publisher's web-site.

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E-mail: jan.fritsche@haw-hamburg.de
Fax: (+49) 40 42875 6139

Abbreviations: AV, anisidine value; **BIB,** balanced incomplete block; **DHS,** dynamic headspace sampling; **FAME,** fatty acid methyl ester; **4-HNE,** 4-hydroxy-E-2-nonenal; **HORO,** high-oleic rapeseed oil; **HOSF,** high-oleic sunflower oil; **HS-SPME,** headspace solid-phase microextraction; **LOD,** limit of detection; **LOQ,** limit of quantification; **PCA,** principal component analysis; **PO,** palm olein; **PTG,** polymerized triglyceride; **PV,** peroxide value; ***r*,** coefficient of determination; **RO,** rapeseed oil; **SF,** sunflower oil; **TPM,** total polar material

 www.ejlst.com

Eur. J. Lipid Sci. Technol. 2013, 115, 935–945

" … high-oleic vegetable oils … provide a frying oils alternative for the production of deep-fried French fries, delivering low proportions of trans and saturated fatty acids."

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nutrients MDPI

Commentary

Potential Adverse Public Health Effects Afforded by the Ingestion of Dietary Lipid Oxidation Product Toxins: Significance of Fried Food Sources

Martin Grootveld *, Benita C. Percival, Justine Leenders and Philippe B. Wilson

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Abstract: Exposure of polyunsaturated fatty acid (PUFA)-rich culinary oils (COs) to high temperature frying practices generates high concentrations of cytotoxic and genotoxic lipid oxidation products (LOPs) via oxygen-fueled, recycling peroxidative bursts. These toxins, including aldehydes and epoxy-fatty acids, readily penetrate into fried foods and hence are available for human consumption; therefore, they may pose substantial health hazards. Although previous reports have claimed health benefits offered by the use of PUFA-laden COs for frying purposes, these may be erroneous in view of their […] LOPs t[…] such LOPs may significantly contribute to enhanced risks of chronic non-communicable diseases (NCDs), e.g., cancer, along with cardiovascular and neurological diseases. Herein, we provide a comprehensive rationale relating to the public health threats posed by the dietary ingestion of LOPs in fried foods. We begin with an introduction to sequential lipid peroxidation processes, describing the noxious effects of LOP toxins generated therefrom. We continue to discuss GI system interactions, the metabolism and biotransformation of primary lipid hydroperoxide LOPs and their secondary products, and the toxicological properties of these agents, prior to providing a narrative on chemically-reactive, secondary aldehydic LOPs available for human ingestion. In view of a range of previous studies focused on their deleterious health effects in animal and cellular model systems, some emphasis is placed on the physiological fate of the more prevalent and toxic α,β-unsaturated aldehydes. We conclude with a description of targeted nutritional and interventional strategies, whilst highlighting the urgent and unmet clinical need for nutritional and epidemiological trials probing relationships between the incidence of NCDs, and the frequency and estimated quantities of dietary LOP intake.

Keywords: lipid oxidation products; lipid hydroperoxides; aldehyde toxins; frying oils; fried foods; cytogenicity/gentoxicity/mutagenicity; cancer; atherosclerosis; acrolein; cooking oil fumes; maximum human dietary intake (MHDI)

1. Introduction

An increasingly large proportion of the human population consuming Western World diets frequently ingest oxidised/peroxidised lipids, and the possibility that regular ingestion of such agents may be deleterious to human health has recently attracted a large amount of high-impacting research interest and focus [1–5].

Such lipid oxidation products (LOPs), which include cytotoxic and genotoxic aldehydes, along with their lipid hydroperoxide precursors, epoxy-fatty acids, and many other secondary or even tertiary

Nutrients **2020**, *12*, 974; doi:10.3390/nu12040974 www.mdpi.com/journal/nutrients

Nutrients 2020, 12, 974; doi:10.3390/nu12040974

Oils high in polyunsaturated fatty acids (PUFAs), particularly those rich in *n*-3 and *n*-6 PUFAs, tend to produce higher levels of aldehydes compared to monounsaturated fatty acid (MUFAs)-rich oils.

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Eur. J. Lipid Sci. Technol. 2013, 115, 935–945

Research Article

Chemical and sensory assessment of deep-frying oil alternatives for the processing of French fries

Katharina Domitila Petersen[1], Gerhard Jahreis[2], Mechthild Busch-Stockfisch[1] and Jan Fritsche[1]

Eur. J. Lipid Sci. Technol. 2013, 115, 935-945

"Comprehensive scientific sensory evaluations of frying oils revealed high-oleic edible oils as promising frying oil alternatives for the processing of French fries …"

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J Am Oil Chem Soc (2021) 98: 129–137

REVIEW

Current Status of High Oleic Seed Oils in Food Processing

Andres Zambelli[1,2]

J Am Oil Chem Soc (2021) 98: 129-137

"There is a large amount of evidence on the beneficial effects of HO oil consumption on human health … as well as on the industrial advantages that its use provides in terms of oxidative stability …"

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Oxidative Stability

A measure of how well an oil or fat resists oxidation, or chemical breakdown, when exposed to oxygen

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Functional properties of high oleic soybean oil

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Benefits High Oleic Soybean Oil

- Grown and processed in the USA
- Superior high-heat stability
- 0 g *trans-* fat
- Neutral flavor profile
- High in monounsaturated fat (> 70%)
- Extended oxidative stability and shelf-life
- Low in saturated fat
- High oleic soybean oil shortenings can replace partially hydrogenated oils

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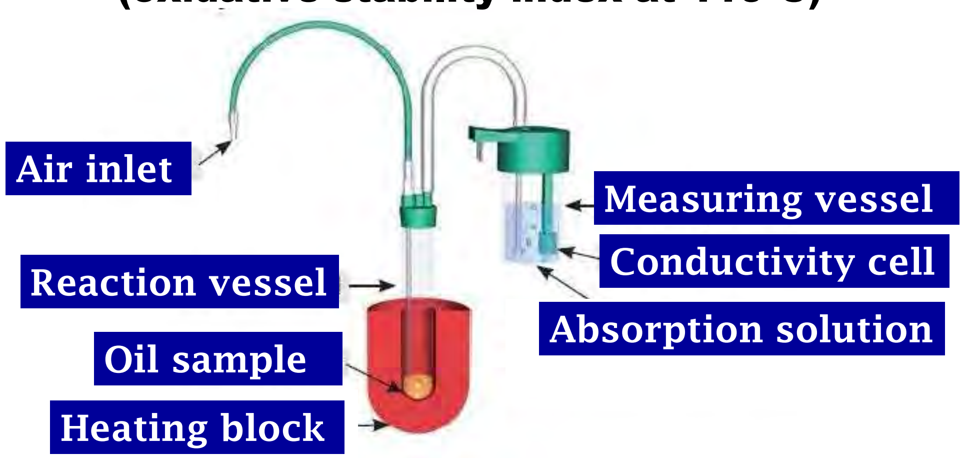
Resiliency to Oxidation

(oxidative stability index at 110°C)



OSI = The point of maximum change in the rate of oxidation

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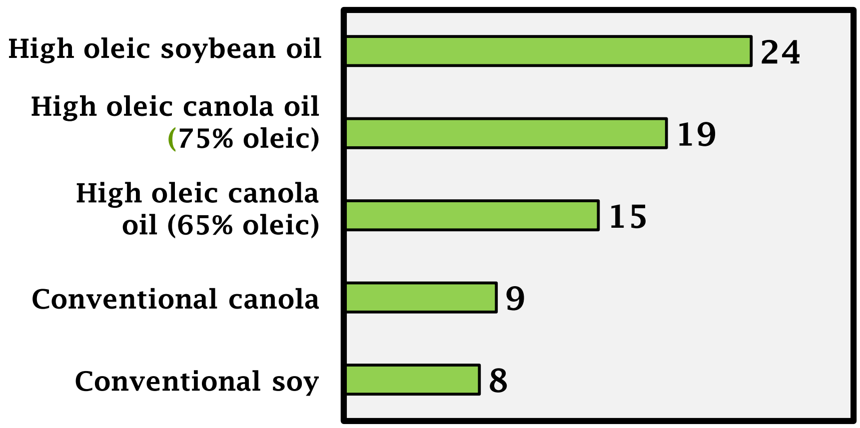
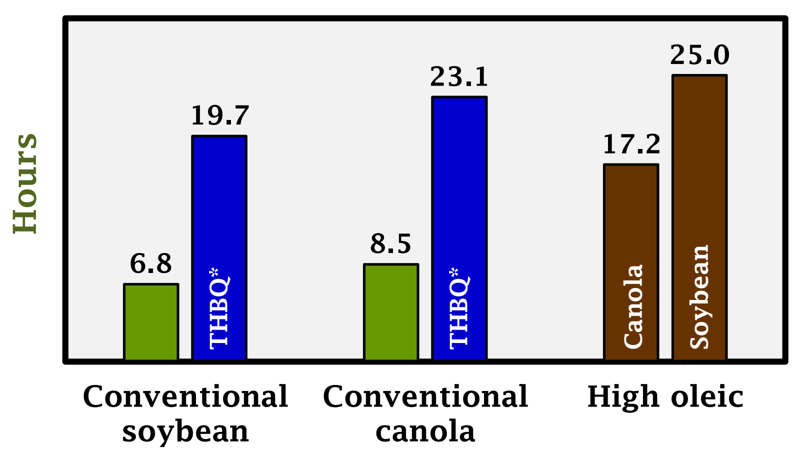
Oxidative Stability (hours) at 110° C



Resiliency to oxidation

89

Oxidative Stability Index (OSI) of Soybean Oil and Canola Oil with and without Added Antioxidants



High oleic soybean oil reduces the need for antioxidants

*180 ppm tertiary butylhydroquinone (antioxidant)

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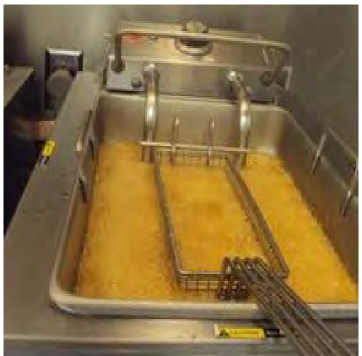
Foaming → Day 24



Conventional Soybean Oil

High Oleic Soybean Oil

Longer Fry Life = Cost Savings

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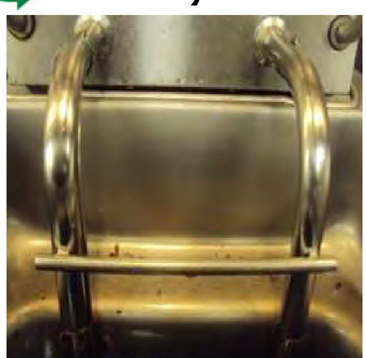
Polymerization → Day 24

Conventional Soybean Oil



High Oleic Soybean Oil

Improved Fryer Performance and Maintenance

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Annual Savings with High Oleic Soybean Oil

Fry cycle time	7 days	10 days	13 days
Oil changes (50 lbs/fryer)	52	37	28
Pounds of oil used	2607	1825	1404
Pounds saved/year	---	782	1203
Percent oil savings	---	30%	46%
Down time (~4 hours/change)	209	146	112
Shifts (8 hr.)	26	18	14
Percent labor savings	---	30%	46%

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CHAPTER 3

High-oleic soybean oil

Susan Knowlton
Corteva Agriscience, Wilmington, DE, United States

3.1 **Introduction**

High-oleic oils burst onto the market in anticipation of what was perceived to be a tremendous need for replacement of partially hydrogenated oils. Despite being early to the market in the beginning, and then late to the market on the second go-around, no oil has been more keenly awaited than high-oleic soybean oil. Almost 10 years after com- [illegible]

At its peak around 2004/2005, about one-half of all soybean oil, or around 8.5 billion lbs., was partially hydrogenated and used in foods ranging from solid baking shortenings to liquid fry oils and all forms in between (Wilson, 2012). The beauty of hydrogenation for the industry was the versatility of functionality the process could impart. In essence, both stability and the degree of solidity at room temperature could be dialed in, creating a wide range of fat products with tailored solid fat content profiles appropriate for the use. A review of the wide range of compositions and functionality exhibited by these products has been published (Stauffer, 1996).

Partially hydrogenated oils (PHOs) are resistant to oxidation because the process lowers the polyunsaturated fat content through saturation or partial saturation of the unsaturated bonds. Double bonds are the site of oxidation reactions and thus lowering their content increases stability. The likelihood of oil oxidation increases with an increasing number of double bonds. Oxidation is a highly complex series of chemical reactions that lower the quality of oil and has been the subject of many reviews (Decker, Elias, & McClements, 2010; Frankel, 2014; Logan, Nienaber, & Pan, 2013; Shahidi & Weenen, 2006).

Hydrogenation is a chemical process in which hydrogen is added to oil in the presence of a catalyst saturating the bonds, thereby increasing oxidative stability. Continued hydrogenation ultimately increases the melting point as the oil becomes more saturated. Thus, dual functions of increased solidity and stability are achieved through

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High Oleic Oils. Development, Properties, and Uses
https://doi.org/10.1016/B978-0-12-822912-5.00007-1

"Reports from end-users on oil quality and performance are almost unanimously positive."

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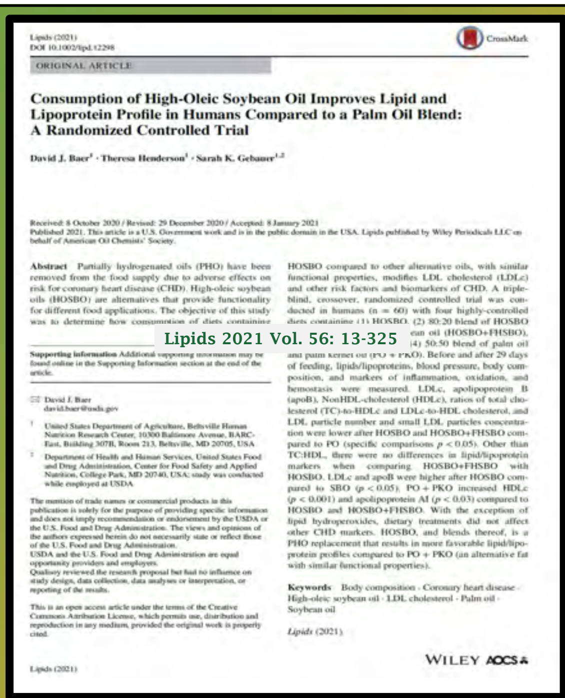

Lipids (2021)
DOI 10.1002/lipd.12298

ORIGINAL ARTICLE

Consumption of High-Oleic Soybean Oil Improves Lipid and Lipoprotein Profile in Humans Compared to a Palm Oil Blend: A Randomized Controlled Trial

David J. Baer[1] · Theresa Henderson[1] · Sarah K. Gebauer[1,2]

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Abstract Partially hydrogenated oils (PHO) have been removed from the food supply due to adverse effects on risk for coronary heart disease (CHD). High-oleic soybean oils (HOSBO) are alternatives that provide functionality for different food applications. The objective of this study was to determine how consumption of diets containing [illegible] HOSBO compared to other alternative oils, with similar functional properties, modifies LDL cholesterol (LDLc) and other risk factors and biomarkers of CHD. A triple-blind, crossover, randomized controlled trial was conducted in humans (n = 60) with four highly-controlled diets containing (1) HOSBO, (2) 80:20 blend of HOSBO [illegible]ean oil (HOSBO+FHSBO), [illegible] (4) 50:50 blend of palm oil and palm kernel oil (PO + PKO). Before and after 29 days of feeding, lipids/lipoproteins, blood pressure, body composition, and markers of inflammation, oxidation, and hemostasis were measured. LDLc, apolipoprotein B (apoB), NonHDL-cholesterol (HDLc), ratios of total cholesterol (TC)-to-HDLc and LDLc-to-HDL cholesterol, and LDL particle number and small LDL particles concentration were lower after HOSBO and HOSBO+FHSBO compared to PO (specific comparisons $p < 0.05$). Other than TC:HDL, there were no differences in lipid/lipoprotein markers when comparing HOSBO+FHSBO with HOSBO. LDLc and apoB were higher after HOSBO compared to SBO ($p < 0.05$). PO + PKO increased HDLc ($p < 0.001$) and apolipoprotein AI ($p < 0.03$) compared to HOSBO and HOSBO+FHSBO. With the exception of lipid hydroperoxides, dietary treatments did not affect other CHD markers. HOSBO, and blends thereof, is a PHO replacement that results in more favorable lipid/lipoprotein profiles compared to PO + PKO (an alternative fat with similar functional properties).

Keywords Body composition · Coronary heart disease · High-oleic soybean oil · LDL cholesterol · Palm oil · Soybean oil

Lipids (2021)

Supporting information Additional [illegible] found online in the Supporting Information section at the end of the article.

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USDA and the U.S. Food and Drug Administration are equal opportunity providers and employers.
Qualisoy reviewed the research proposal but had no influence on study design, data collection, data analyses or interpretation, or reporting of the results.

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Diets containing high-oleic soybean oil (HOSO) and a blend of HOSO and fully hydrogenated soybean oil beneficially affect cholesterol levels compared to a diet containing a palm oil + palm kernel oil blend.

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Thank you for your attention

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