

反式脂肪酸对心血管疾病的影响：好坏与丑

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反式脂肪酸对心血管疾病的影响：好、坏与丑 *Trans Fatty Acids and Cardiovascular Disease Risk: Good, Bad and Ugly*



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I. Classes of *Trans* Fatty Acids (反式脂肪酸的种类)

- Mono-*trans* fatty acids (单不饱和反式脂肪酸)
- Polyunsaturated *trans* fatty acids (多不饱和反式脂肪酸)
- Conjugated *trans* fatty acids (反式共轭脂肪酸)

CONTENT

- Types of *trans* fatty acids (反式脂肪酸的种类)
- Source of *trans* fatty acids (反式脂肪酸的来源)
- *Trans* fatty acids and heart disease risk (反式脂肪酸与心血管疾病)
 - * Mono-*trans* fatty acids (单不饱和反式脂肪酸)
Elaidic versus vaccenic acid (反式油酸与反式异油酸)
 - * Polyunsaturated *trans* fatty acids (多不饱和反式脂肪酸)
 - * Conjugated *trans* linoleic acids (反式共轭脂肪酸)
- *Trans* fat alternatives (反式脂肪酸的代用品与生产技术)

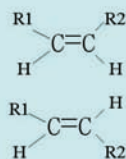
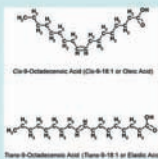
单不饱和反式脂肪酸

Common Mono *Trans* Fatty Acids

.....
18:1 t8
18:1 t9 (反式油酸, 氢化油)
18:1 t10
18:1 t11 (反式异油酸, 黄油)
18:1 t12
18:1 t13
18:1 t14
.....

反式脂肪酸的定义

What Are *Trans* Fatty Acids?



多不饱和反式脂肪酸

Common Polyunsaturated *Trans* Fatty Acids



.....
18:2 c9, t12
18:2 c9, c12
18:2 c9, c13
.....

反式共轭脂肪酸 Common Conjugated *Trans* Fatty Acids



18:2 c9,t11

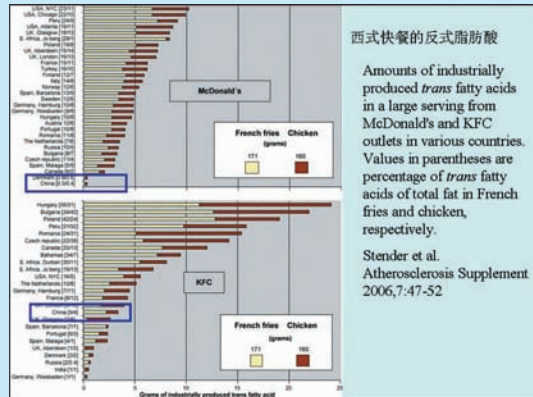
18:2 t9,c11

18:2 c8,t10

18:2 t8,c10

18:2 t10,c12

18:2 c10,t12



II. Source of *Trans* Fatty Acids (反式脂肪酸的来源)

- Chemical Hydrogenation (氢化油)
Partial hydrogenated vegetable oil
18:1 t9 (elaidic反式油酸)
- Bio-hydrogenation (ruminant fat 反刍动物脂肪)
18:1 t11 (vaccenic acid反式异油酸)
- Deodorization (油加工中的除臭)

反式脂肪酸的摄入量 *Trans* Fat Intake (g/day)

- China: 0.6 g
- EU-USA: 1.4-8.0 g
- Korea: 0.4 g
- Japan: 0.1-0.3 g

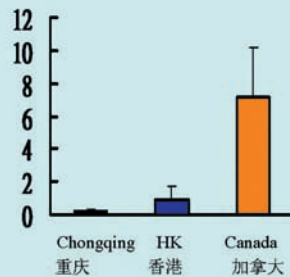
Xie MY, Nanchang University

为什么植物油要氢化? Partial Hydrogenation, Why?

- Increase the stability
 - Increase the melting point
 - Replace natural butter - margarine
 - Modify texture of oils
- Crispiness
Snap
Better mouth feel

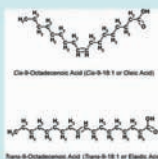


母乳中的反式脂肪酸 Breast Milk *Trans* Fatty Acids (% of total fat)



Chen et al. Lipids 1997;32:1061-1067

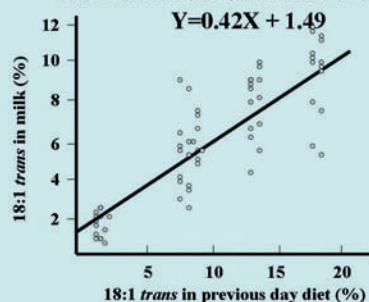
Trans-fatty acids have high melting points (MP)



Oleic acid MP 16C

Elaidic acid MP 52C

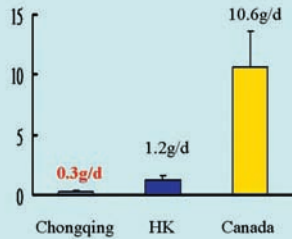
母乳中反式脂肪酸与哺乳妇女的反式脂肪酸摄入量成正比



Craig-Schmidt et al. Am. J. Clin. Nutr. 1984, 39:778

测定母乳中的反式脂肪酸可以算出哺乳妇女的反式脂肪酸摄入量

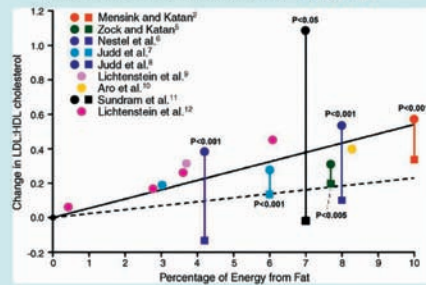
Estimation of *Trans* Fat Intake



Chen et al. *Lipids* 1997;32:1061-1067

氢化油中反式脂肪酸升高LDL/HDL比值

Trans intake increases the ratio of LDL:HDL



III. Total *Trans* and Mono-*Trans* Fatty Acids from Partially Hydrogenated Vegetable Oils and cardiovascular disease risk

氢化油中反式脂肪酸与心血管疾病

为什么氢化油中的反式脂肪酸能升高LDL/HDL比值？

Why do *trans* fatty acids increase the ratio of LDL to HDL?

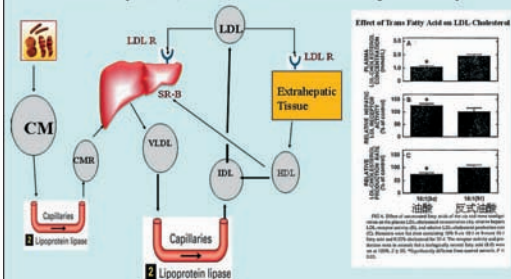
氢化油中反式脂肪酸升高LDL但降低HDL *Trans* Fatty Acids Increase LDL and Reduce HDL-Cholesterol

(Mensink, et al. *New Eng. J. Med.* 1990. 323:439)

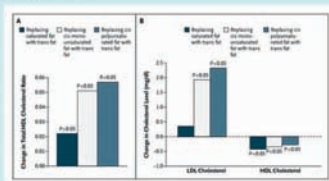
(mmol/L)	Cis	Trans	Saturated
Total Cholesterol	4.46	4.72 *	5.01 *
LDL-Cholesterol	2.67	3.04 *	3.14 *
HDL-Cholesterol	1.42	1.25 *	1.42
Triglyceride	0.81	0.94	0.94

Mechanism 1

反式脂肪酸降低LDL受体的活性
Trans fatty acid (18:1 Δ^9) decreases LDL receptor activity



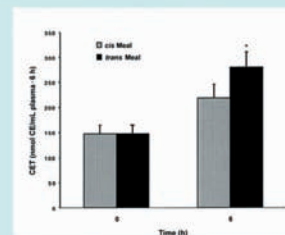
反式脂肪酸升高血清TC:HDL比值
Changes in Total:HDL Cholesterol (Panel A) and Levels of LDL and HDL Cholesterol (Panel B) Resulting from the Replacement of Saturated or Cis Unsaturated Fatty Acids with *Trans* Fatty Acids



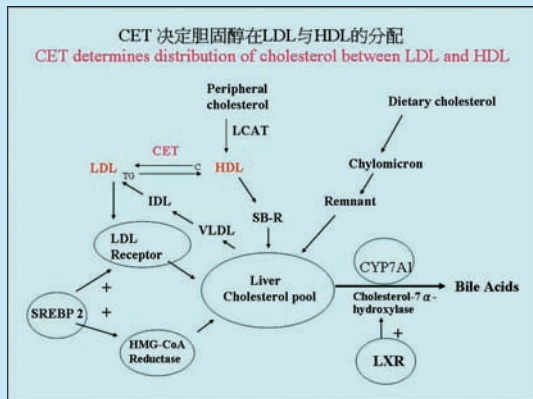
Mozaffarian et al. *NEJM* 2006;354:1601-13

Mechanism 2

反式脂肪酸升高CET的活性
Trans fatty acid (18:1 Δ^9) up-regulates cholesteryl ester transporting protein (CET or CETP) activity in humans

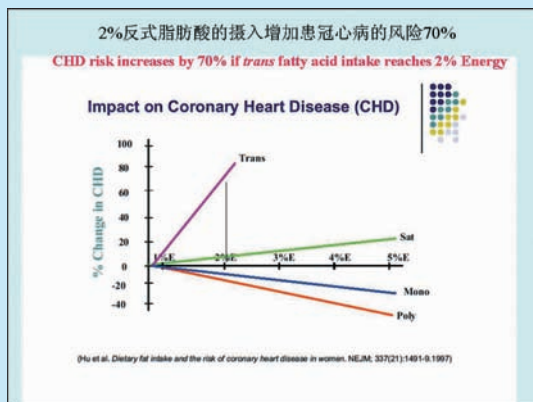
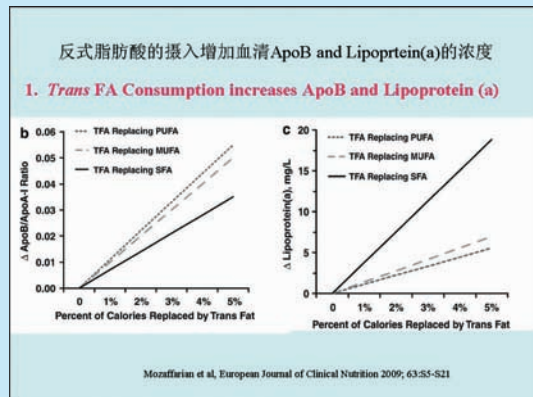
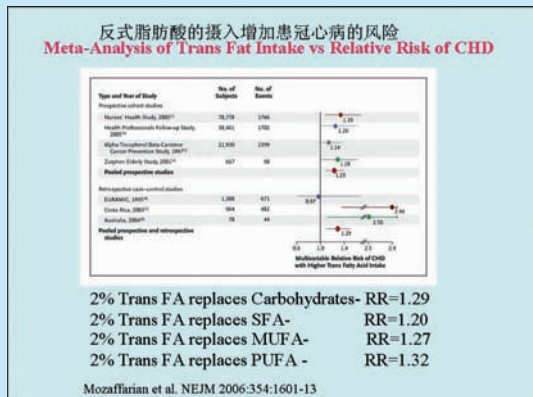


Gatto et al. *Am J Clin Nutr* 2003 May;77(5):1119-24



除了能升高血胆固醇，还有哪些因素使反式脂肪酸能增加患冠心病的风险？

Why does elaidic acid (18:1 ω 9) increase the risk of CHD beyond its cholesterol-raising property?



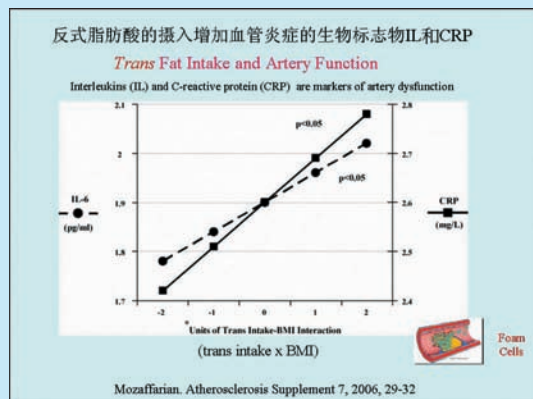
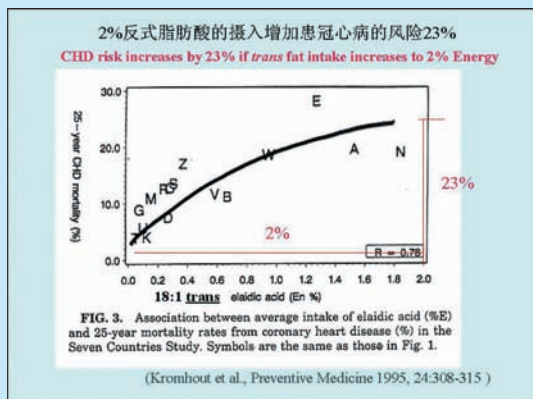
反式脂肪酸的摄入引起血管炎症

2. Trans mono fat Causes arterial inflammation

Atherosclerosis and Inflammation

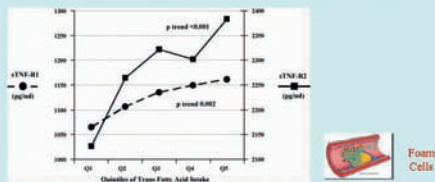
炎症与动脉粥样硬化

- * High sensitivity C-reactive protein (hsCRP) is a biomarker of inflammation in the body
- * Elevated hsCRP is a stronger predictor of heart disease than a high LDL (harmful) cholesterol



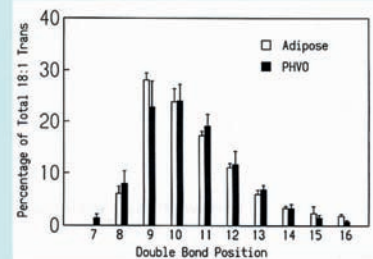
反式脂肪酸的摄入增加血管炎症的生物标志物STNF-R *Trans Fat Promotes Inflammation and Causes Artery Dysfunction*

Soluble tumor necrosis factor receptor (STNF-R) is a biomarker of artery dysfunction



Mozaffarian. *Atherosclerosis Supplement* 7, 2006, 29-32

人体脂肪组织中的单一不饱和反式脂肪酸异构体的分布 与氢化植物油单一不饱和反式脂肪酸异构体的分布相同 Distribution of 18:1 trans isomers in human adipose and partially hydrogenated canola/soybean oil (PHVO)

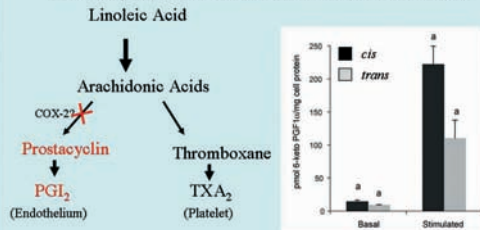


Chen et al. *Can J Physiol Pharmacol* 1995;73:718-723

反式脂肪酸的摄入降低前列环素 (PGI₂) 的合成

3. Mono-Trans Fatty Acids Prevents PGI₂ Release in Endothelial Cells

前列环素 (PGI₂) 是已知最强的血小板凝集抑制剂和血管扩张剂, 能抑制血栓的形成



Kummerow et al. *Prostaglandins & Other Lipid Mediators* 84(2007):134-153

每天摄入3.6克反式脂肪酸不升反降血清胆固醇

Effect of 3.6 g/d vaccenic acid on blood cholesterol in humans

TABLE 4
Effect of the 5-wk dietary intervention on fasting blood lipids,
lipoproteins, oxidative stress, and inflammatory and hemostatic markers¹

Marker	Vaccenic acid-rich diet (n = 22)	Control diet (n = 20)
HDL (mmol/L)	1.39 ± 0.03 ²	1.54 ± 0.03
LDL (mmol/L)	3.17 ± 0.10	3.44 ± 0.11
Total cholesterol (mmol/L)	4.57 ± 0.10 ²	4.87 ± 0.11
Triacylglycerols (mmol/L)	1.01 ± 0.07	0.89 ± 0.05
Urinary 8-iso-PGF _{2α} (ng/mL) ²	1.35 ± 0.18	1.37 ± 0.20
CRP (mg/L)	0.25 ± 0.09	0.31 ± 0.12
FVIIc (%)	95 ± 2	90 ± 2
PAI-1 (ng/mL)	7.79 ± 0.84	8.69 ± 0.87
Insulin (pmol/L)	25.55 ± 1.61	24.87 ± 1.68
Glucose (mmol/L)	4.56 ± 0.07	4.99 ± 0.08

¹ All values are $\bar{x} \pm \text{SE}$. 8-iso-PGF_{2α}, 8-iso-prostaglandin F_{2α}; CRP, C-reactive protein; FVIIc, factor VII coagulant activity; PAI-1, plasminogen activator inhibitor 1. Mixed model analysis of covariance; mean values are adjusted for baseline values, which were used as covariates.

^{2,3} Significantly different from the control diet: ²P < 0.01, ³P < 0.05.

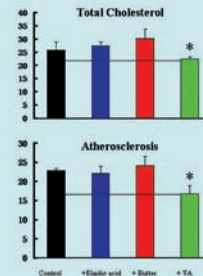
Thaler et al. *Am J Clin Nutr* 2006;83:227-43

反动物脂肪中的反式油酸与心血管疾病

IV. Mono-Trans Fatty Acids from ruminant fat and cardiovascular disease risk

- * Vaccenic acid (反式油酸 VA) in ruminant fat
- * VA has no effect on TC, LDL-C

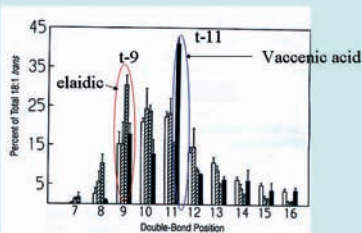
Vaccenic acid decreases TC and atherosclerosis in Mice



Bassett et al. *J Nutr* 2010; 140(1):18-24

氢化油富含反油酸 (elaidic), 反脂肪富含反油酸 (vaccenic)

Distribution of 18:1 Trans Isomers



- Human milk fat
- ▒ Partially hydrogenated soybean oil
- ▓ Partially hydrogenated canola oil
- Cow's milk fat

Review Paper

Human health benefits of vaccenic acid

Field et al. *Appl. Physiol. Nutr. Metab.* 2009; 34:979-991

Why ?

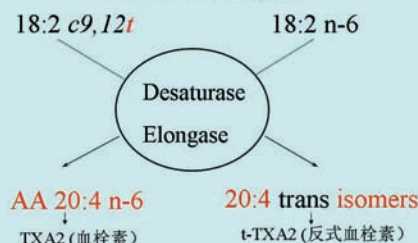
反式异油酸能被转化成共轭反式脂肪酸

Metabolism of Vaccenic Acid



多不饱和反式脂肪酸可能代谢成反式花生四烯酸并增加血小板的凝聚

Poly 18:2 *Trans* fatty acids may be converted to trans Arachidonic Acid (AA)



Kwan et al. Lipids 1998, 33:409-416.

氢化油中多不饱和反式脂肪酸与心血管疾病

V. Polyunsaturated *Trans* Fatty Acids from PHVO and cardiovascular disease risk

共轭反式脂肪酸与心血管疾病

VI. Conjugated *Trans* Fatty Acids and Cardiovascular Disease Risk

18:2 c9, t11 (CLA)

18:2 t10, c12 (CLA)

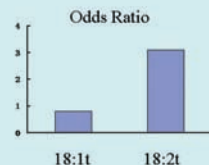


氢化油中多不饱和反式脂肪酸对心血管疾病的
影响是单一不饱和反式脂肪酸的三倍

Poly-trans increase the risk of primary cardiac arrest

Seattle study

- 179 patients and 286 controls
- Red blood cell membrane lipids
- Poly 18:2 *Trans* isomers – 3-folds

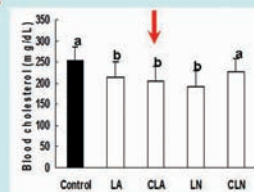


Lemaitre et al. Circulation 2002; 105:697-701

没有证据显示共轭脂肪酸增加心血管疾病的风险，
相反动物与细胞实验发现它们可能是有益的

Animals and cell culture studies

- * Anti-obesity
- * Antioxidants
- * Anti-mutagenesis
- * Anti-carcinogenesis
- * Cholesterol-lowering



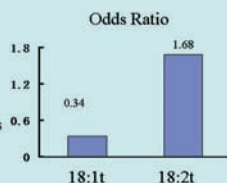
Human trials are lacking

Lam et al. Atherosclerosis 2008; 198:85-93

氢化油中多不饱和反式脂肪酸对心血管疾病的
影响是单一不饱和反式脂肪酸的五倍

**Plasma phospholipid 18:2 *trans* fatty acids increases fatal
ischemic heart disease (IHD)**

- 214 IHD and 214 controls
- Plasma phospholipids analysis
- Poly 18:2 *Trans* isomers – 5-folds



Lemaitre et al. Circulation 2006; 114:209-215

Good, Bad and Ugly
鏢客三部曲



国际食品法典委员会 对反式脂肪酸的定义

Codex Definition

- Trans fatty acids refer to all the geometrical isomers of **monounsaturated** and **polyunsaturated fatty acids** having non-conjugated, interrupted by at least one methylene group, carbon-carbon double bonds in the *trans* configuration

反式脂肪酸的代用品与生产技术

VI. Trans Fat Alternatives

- Modification of Partial Hydrogenation Process
- Plant breeding and genetic engineering
- Tropical oil substitute
Palm, Palm kernel oil, coconut oil
- Fractionation
- Inter-esterification

Regulatory Issues of *Trans* Fatty Acids

USA

FDA requires labeling of *trans* fatty acids in Nutrition Facts effective on Jan 1 2006.

Canada

Labeling of *trans* fatty acids was effective on July 1, 2003.

Denmark

No permit was given if food contained 2% *trans* derived from partial hydrogenation.

EU

EU requires labeling of any food contains partially hydrogenated vegetable oil

改良氢化油的生产技术

Modification of Partial Hydrogenation Process

- Low-trans products
- Choice of catalyst
- Pressure
- Temperature
- Choice of solvents

Label Format

Nutrition Facts	
Per 1 cup (204g)	
Amount	% Daily Value
Calories 280	
Fat 13g	20%
Saturated Fat 3g	
+ Trans Fat 2g	25%
Cholesterol 30mg	
Sodium 660mg	28%
Carbohydrate 31g	10%
Fibre 0g	0%
Sugars 5g	
Protein 5g	
Vitamin A 4% • Vitamin C 2%	
Calcium 15% • Iron 4%	

用生物科技改良植物油的品种

Plant breeding and genetic engineering-oilseeds

- High-oleic Oilseeds
Sunflower
Canola
Soybean
Corn

世界卫生组织推荐反式脂肪酸的摄入不应超过总能量的1%

WHO Recommendation

- *Trans* fat intake should not exceed **1 percent** of the total calorie, and saturated fat should not exceed 10 percent of total calories.

about 2.2 g /day

混用高溶点和低溶点的植物油

Blending Hard Fat and Liquid Fat

- Palm oil, Palm Kernel Oil, Coconut Oil (A)
- Liquid vegetable oils (B)
- Partially hydrogenated vegetable Oil (C)
- Blending
- Addition of antioxidants

混和棕榈 油和豆油

Blending

Palm Oil / Soybean Oil Blends

Analysis	Palm	90% Palm 10% SBO	80% Palm 20% SBO	70% Palm 30% SBO	60% Palm 40% SBO	50% Palm 50% SBO
SFI S0F	37.6	29.5	24.9	19.1	14.2	10.2
SFI 70F	17.2	12.4	10.6	7.8	6.1	5.1
SFI 80F	14.1	10.4	9.0	6.6	5.2	4.4
SFI 92F	8.4	6.3	6.9	5.0	3.6	3.3
SFI 104F	4.2	4.9	4.2	2.6	1.3	1.2
MDPF	105.3	102.0	99.1	98.9	96.8	93.7
%C16:0	44.0	40.6	37.3	33.8	30.4	27.2
%C18:0	4.3	4.3	4.3	4.3	4.3	4.3
%C18:1	40.0	31.2	35.9	34.5	32.9	31.3
%C18:2	9.1	13.5	13.5	22.1	26.4	30.5
%C18:3	0.3	1.0	1.8	2.6	3.3	4.0
% Total Sats	51.2	47.6	44.1	40.4	36.9	33.5
%Total trans	0.6	0.6	0.6	0.6	0.6	0.6

Kodali and List, 2005



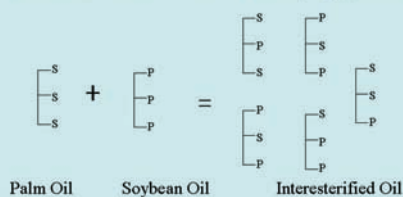
Composition of Spreads Studied

	Trans Fats (%)	Polysaturated Fats (%)	Saturated Fats (%)	Stearic Acid (%)
Typical Margarine	17	27	16	7
Non-Trans Margarine	0	49	21	13
Butter	3	5	53	15

Source: Joseph T. Judd, Agricultural Research Service

甘油三酯分子交换技术

Interesterification-Triacylglycerols



Summary

- * Chemistry of trans fatty acids is complex (反式脂肪酸的结构很复杂)
- * Varying effect on cardiovascular disease risk with three types of trans fatty acids (三种反式脂肪酸对心血管疾病的影晌有所不同)
- * Chinese have a very low intake of trans fat and the associated cardiovascular disease risk is minimal (目前中国居民反式脂肪酸摄入较低，对心血管疾病的影响可能不是很大)
- * Alternatives to trans fat are available and high intake of trans fat can be avoided (工业界已有氢化油的代用品与生产技术，反式脂肪酸的摄入是可以避免的)

植物油的分离与重组

Fractionation

- Palm Oil
Olein and Stearine
- Stearine-soybean inter-esterification-
Zero-trans margarine

早预防，早订目标，早做准备！

-谢谢-