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 would reduce the risk of MI. J. Nutr. 135: 2674–2679, 2005.

KEY WORDS: • *fatty acids* • *palm oil* • *soybean oil* • *myocardial infarction* • *cardiovascular disease*

Palm oil and soybean oil are the 2 most used cooking oils worldwide (1). Palm oil is less expensive than soybean oil and has more diverse uses in nonfood industries. The palm oil industry is a major source of income for many people in the rural areas of many developing countries (2). Most of the production (84%) occurs in South East Asia (1), and most of the palm oil (84–90%) is used in food preparation. Palm oil is consumed mainly in developing countries (1) that are undergoing an adverse nutritional transition and in which morbidity and mortality due to cardiovascular disease (CVD)[4] are increasing (3–5). Soybean oil, produced mainly in the United States, Brazil, and Argentina as a secondary product of the soybean protein meal industry, is rich in *cis*-PUFAs. Because soybean oil is usually partially hydrogenated, it has a high content of *trans*-PUFAs. The atherogenic potential of palm oil was proposed because it is low in polyunsaturated and high in saturated fat (36–50%), predominantly palmitic acid (6–8). High palm oil and coconut oil intakes were proposed as potential explanations for the high cardiovascular disease rates in Singapore compared with Hong Kong (5). Studies in humans and animals showed that palm oil per se compared with safflower oil or sunflower oil increased plasma total and LDL cholesterol (9–13), and compared with safflower oil, palm oil caused atherosclerosis in monkeys (14). Other studies showed no or the opposite effect (15). In contrast, soybean oil and other oils rich in PUFAs are considered beneficial for cardiovascular health (16,17). Nevertheless, a large proportion of soybean oil is partially hydrogenated, a procedure that generates *trans* fatty acids, which are associated with increased risk of coronary heart disease (18,19). Despite the worldwide economic and health importance of palm oil and soybean oil, there are no epidemiologic studies assessing the association between these oils and cardiovascular endpoints. We conducted a large population-based incident case-control study to determine whether the use of palm oil compared with other cooking oils was associated with the risk of nonfatal acute myocardial infarction (MI). Unlike soybean oil, which is mostly imported, palm oil is produced and used widely for cooking in Costa Rica (7,20).

SUBJECTS AND METHODS

Study population and design. All subjects were Hispanic Americans of Mestizo background who lived in the central valley of Costa Rica between 1995 and 2004. The details of the study design were

[1] Presented at the 42nd Annual Conference on Cardiovascular Disease Epidemiology and Prevention, April 2002, Honolulu, HI (Kabagambe EK, Baylin A, Ascherio A, Campos H. Palm oil and risk of myocardial infarction in Costa Rica. Proceedings of the 42nd Annual Conference on Cardiovascular Disease Epidemiology and Prevention, April 2002, Honolulu, HI. Abstract # 11).

[2] Supported by grants HL49086 and HL60692 from the National Institutes of Health.

[3] To whom correspondence should be addressed.
E-mail: hcampos@hsph.harvard.edu.

[4] Abbreviations used: CVD, cardiovascular disease; FA, fatty acid; MI, myocardial infarction; OR, odds ratio.

Manuscript received 2 June 2005. Initial review completed 28 June 2005. Revision accepted 2 August 2005.

published elsewhere (21–23). Briefly, eligible case subjects were men and women who were diagnosed as survivors of a first acute MI by 2 independent cardiologists at any of the 6 recruiting hospitals in the catchment area. To achieve 100% ascertainment, fieldworkers visited the 6 hospitals daily. All cases met the WHO criteria for MI, which require typical symptoms plus either elevations in cardiac enzyme levels or diagnostic changes in the electrocardiogram (24). Cases were ineligible if they *1*) died during hospitalization, *2*) were ≥75 y old on the day of their first MI, and *3*) were physically or mentally unable to answer the questionnaire. Enrollment took place while cases were in the hospital's step-down-unit. Cases were matched by age (±5 y), sex, and area of residence to population controls who were randomly identified with the aid of data from the National Census and Statistics Bureau of Costa Rica. Because of the comprehensive social services provided in Costa Rica, all persons living in the catchment area had access to medical care without regard to income. Therefore, control subjects came from the source population that gave rise to the cases and were not likely to have been having undiagnosed cardiovascular disease because of poor access to medical care. Control subjects were ineligible if they had ever had an MI or if they were physically or mentally unable to answer the questionnaires. Participation was 98% for cases and 88% for controls. All subjects gave informed consent on documents approved by the Human Subjects Committee of the Harvard School of Public Health and the University of Costa Rica.

Data collection. Trained personnel visited all cases and controls at their homes for the collection of dietary and health information, anthropometric measurements, and biological specimens. Sociodemographic characteristics, smoking, socioeconomic status, physical activity, and medical history data were collected during an interview using a questionnaire with close-ended questions. Self-reported diabetes and hypertension were validated using the recommended definitions by the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (25), and the Third Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (26). We computed sensitivities, specificities, and positive and negative predictive values from the questionnaire data and measurements of blood pressure and blood sugar. These variables showed that self-reported assessments of diabetes and hypertension were reliable in this population (21).

Dietary assessment. We collected dietary data using a FFQ that was developed and validated specifically to assess nutrient intake among the Costa Rican population (22,27). The FFQ asked subjects to specify the principal type of oil used for cooking and frying at home and the duration of use. The type of oil was confirmed by visual inspection of the oil containers at the time of the home visit. The cooking oils were coded and periodic assessments of the fatty acid compositions of samples from the market in Costa Rica were performed at Harvard School of Public Health using a GLC procedure described elsewhere (27).

The fatty acid composition of the most widely used oils and margarines in Costa Rica were incorporated into the food composition database. The proportions of saturated, monounsaturated, polyunsaturated, and *trans* fatty acids in palm oil (mostly consumed in solid form) were 49.7, 39.0, 9.6, and 1.7%, respectively. Partially hydrogenated soybean oil brands used in Costa Rica between 1994 and 1998 were high in *trans* fatty acids (22 ± 4%) and low in α-linolenic acid (1.8 ± 0.3%). After changes in the edible oil industry in Costa Rica, the *trans* fatty acid content of soybean oil was reduced to 5 ± 3%, and the α-linolenic acid content increased to 5.1 ± 0.7%. The *trans* fatty acid content of palm oil did not change over the years, and was 1.5 ± 0.3% in our recent analyses. The *trans* fatty acid contents of other cooking oils analyzed were relatively low; they were 0.17 ± 0.34% for sunflower oil, 0.11 ± 0.35% for corn oil, 0.06 ± 0.13% for canola oil, and 0.02 ± 0.04% for olive oil. The fatty acid compositions of the palm and soybean oils consumed by the Costa Rican population are comparable to those of the palm and soybean oils consumed by other populations (7,28).

Adipose tissue fatty acids. A subcutaneous adipose tissue biopsy was collected from the upper buttock, stored in a cooler with ice packs at 4°C, transported to the fieldwork station within 4 h, and stored at −80°C until analysis. Fatty acids from adipose tissue were quantified by GLC as described previously (27). Fatty acids in subcutaneous adipose tissue reflect long-term intake (29,30) and are preferred in case-control studies over other biomarkers of fatty acid intake (31). In the Costa Rican population, adipose tissue linoleic acid, α-linolenic acid, and *trans* fatty acids were found to be excellent biomarkers of intake (22,27). We used *cis-* and *trans*-PUFAs in adipose tissue to identify and confirm the presence of fatty acids that are likely to be responsible for the observed results.

To avoid the potential for recall bias among cases, data were collected as close to the diagnosis of MI as possible. For instance, data collection was completed within 2 wk of discharge from the hospital for 73% of the cases. A matched population control was recruited within 10 ± 11 d of the recruitment of a case. The mean (SD) interval between completion of data collection for a case and completion of data collection for a matched control was 12 (16) d.

Statistical analysis. SAS Software version 8.00 (SAS Institute) was used for all statistical analyses. Subjects who were missing values ($n = 326$) for major confounders were excluded, leaving 2111 cases and 2111 matched population controls for the final analysis. If a case or control was missing data on key variables, the whole pair was deleted. If among deleted controls there was one that had complete data and matched a deleted case by age, sex, and area of residence, the 2 were rematched and added to the data set to avoid power loss. Thus, 32 cases and 32 rematched controls with complete data were included in the final data set for a total of 2111 case-control pairs. Because individual nutrients were correlated with total energy intake, each was adjusted for energy intake using regression methods (22,32). We also estimated the amount of energy consumed as fat and expressed it as a percentage of daily total energy intake. Because of the matched design, the significance of differences in the distributions of categorical variables by case-control status was tested using McNemar's test; continuous variables were tested by the paired t test, if normally distributed, or by the Wilcoxon signed rank test, if not normally distributed. Differences were considered significant at $P \leq 0.05$.

Because the content of *trans* fatty acids in soybean oil brands used before 1998 was >16%, and <10% for those used after 1998, we grouped together all brands before 1998 (mean *trans* content 22%) and those after 1998 (mean *trans* content 5%). We then divided soybean oil users into 2 groups, namely, users of soybean oil with high *trans* content (22%) and users of soybean oil with less *trans* fat (5%). This is because our earlier analyses (18) showed that a high intake of *trans* fat, which in this population comes mainly from partial hydrogenation of soybean oil, is associated with increased risk of MI. If not adjusted for, high *trans* fat intake in the reference group could confound any association between palm oil and MI. There were fewer users of oils other than palm oil or soybean oil ($n = 977$); therefore, they were grouped together in a category called other oils, which included consumers of sunflower oil (53%), corn oil (27%), olive oil (10%), canola oil (3%), and a few less common oils (7%). We thus modeled a 4-level categorical variable (palm oil, soybean oil with 22% *trans* fat, soybean oil with 5% *trans* fat, and other oils) as the main predictor of MI. In the analyses, palm oil was compared with soybean oil with 22% *trans* fat, soybean oil with 5% *trans* fat, or other oils as reference categories.

We assessed variables for confounding first by determining their univariate associations with MI and the type of oil used for cooking; second, we investigated the change in odds ratios (OR) when a given variable was entered into the conditional logistic regression model. In these analyses, continuous variables were analyzed as quintiles of nondietary or energy-adjusted dietary variables. We assessed the possibility of an association between palm oil consumption and MI, first univariately, then with established CVD risk factors only, and finally with dietary confounders assessed with an FFQ. Multivariate OR and 95% CI were obtained for palm oil using 22% *trans*-soybean oil, 5% *trans*-soybean oil, or other oils as the referent group. All 3 analyses used a fixed sample size of 2111 case-control pairs and the same set of covariates.

To determine whether there was a dose-response relation between the use of palm oil and MI, we reanalyzed the data using the estimated daily amount of palm oil (expressed as a percentage of total energy intake) consumed at home. This analysis was made for 926 subjects who provided their food preparation recipes for use in estimating the

intake of palm oil. We used the median to divide palm oil users into 2 equal groups (low and high palm oil users) and then compared them to subjects who did not use palm oil (0% of energy from palm oil). Thus we had a 3-level categorical variable in which those below and above the median of palm oil intake were compared with non-palm oil users. Because mixing of cooking oils is not common in Costa Rica and the variable for intake of soybean oil was negatively correlated with that of palm oil, we only used the palm oil variable in the multivariate dose-response analyses. Multivariate unconditional OR and 95% CI were estimated for the low and high palm oil users relative to non-palm oil users. These unconditional logistic analyses controlled for age (quintiles), sex, area of residence, smoking (never, past, <20 cigarettes/d, and ≥20 cigarettes/d), history of diabetes, history of hypertension, abdominal obesity (quintiles), physical activity (quintiles), income (quintiles), intake of alcohol (never, past, and tertiles of current drinkers), total energy (quintiles), fiber (quintiles), dairy, and meat products (continuous), and *trans* fat in adipose tissue (quintiles).

We performed additional analyses to further explore the effects of potential confounders such as smoking, area of residence, α-linolenic acid in adipose tissue, intake of folate, alcohol, and vitamin B-6 by stratifying the analyses by these variables. In these analyses, we used unconditional logistic regression with matching variables in the model and the other variables modeled as continuous covariates. We computed the Hosmer-Lemeshow statistic to test for goodness of fit.

RESULTS

General characteristics. Characteristics of nonfatal MI cases and population-based matched controls in Costa Rica were compared (**Table 1**). The cases had a higher number ($P < 0.05$) of current smokers and individuals with a history of diabetes and hypertension. Compared with controls, cases also had higher ($P < 0.05$) abdominal obesity, less income, fewer current alcohol drinkers, and higher intakes of total energy and saturated fat but less polyunsaturated fat. Intakes of α-tocopherol, γ-tocopherol, and adipose tissue concentrations of most carotenoids were significantly lower in cases than in controls (data not shown). The distribution of potential confounders was examined by the type of oil used for cooking (**Table 2**). Use of palm oil was associated with the area of residence in both cases and controls. Most palm oil users were of low socioeconomic status as shown by their income and level of education, were physically more active, and were more likely to be current smokers than users of other cooking oils. Palm oil was used more frequently ($P < 0.01$) for cooking by cases (30%) than by controls (23%). Compared with soybean oil and other oil users, palm oil consumers had higher intakes of saturated fat and lower intakes of total polyunsaturated fat and α-linolenic acid. The difference in intake of saturated fat was due mainly to palmitic acid.

Type of cooking oil and MI. In the analysis adjusted for age, gender, and area of residence through matching (**Table 3**), consumption of palm oil compared with soybean oil (containing 22% *trans* fat) was associated with increased risk of MI (OR = 1.40; 95% CI: 1.07–1.82). Adjusting for smoking, alcohol intake, history of diabetes, history of hypertension, abdominal obesity, physical activity, and income attenuated the association (OR = 1.16; 95% CI: 0.86–1.56), mainly because of the high number of current smokers in the palm oil group and less abdominal obesity in the soybean oil group. Further adjustment for energy and fiber intake did not change the association appreciably (OR = 1.14; 95% CI: 0.84–1.56).

Compared with users of soybean oil with 5% *trans* fat, palm oil consumers were more likely to have an MI (OR = 1.39; 95% CI: 1.16–1.65). Adjustment for dietary and nondietary confounders as above did not change the association appreciably (OR = 1.33; 95% CI: 1.08–1.63).

TABLE 1

Characteristics of nonfatal MI cases and population-based matched controls in Costa Rica[1]

Variable	Controls (n = 2111)	Cases (n = 2111)
Age,[2] *y*	58.2 ± 11.3	58.5 ± 11.0
Women,[2] %	27	27
Living in rural areas,[2] %	26	26
Current smokers, %	21	39*
History of diabetes, %	14	25*
History of hypertension, %	30	38*
Abdominal obesity[3]	0.95 ± 0.08	0.97 ± 0.07*
Physical activity, *MET*[4]	1.55 ± 0.70	1.50 ± 0.69*
Formal education, *y*	7.6 ± 5.3	7.1 ± 5.4*
Household income, *US $*	571 ± 426	498 ± 392*
Daily intakes		
Total energy, *kJ*	10249 ± 3207	11299 ± 3913*
Saturated fat, % *energy*	11.7 ± 2.9	12.4 ± 3.1*
Monounsaturated fat, % *energy*	11.2 ± 4.0	11.2 ± 3.5
Polyunsaturated fat, % *energy*	7.1 ± 2.3	6.8 ± 2.3*
α-Linolenic acid, % *energy*	0.59 ± 0.22	0.57 ± 0.22*
Trans fat, % *energy*	1.31 ± 0.64	1.34 ± 0.64
Cholesterol, *mg/4.2 MJ*	118 ± 52	126 ± 59*
Dietary fiber,[5] *g*	25 ± 6	24 ± 6*
Folate,[5] *μg*	431 ± 113	422 ± 117*
Current drinkers, %	53	49*
Alcohol intake,[6] *g*	11.2 ± 18.0	14.8 ± 24.8*
Type of oil used for cooking, %		
Palm oil	23	30†
Soybean oil (22% *trans* fat)	11	10
Soybean oil (5% *trans* fat)	41	39
Other oils[7]	25	21

[1] Values are means ± SD or %. * Different from controls (McNemar's or paired *t* test or Wilcoxon signed rank test $P < 0.05$). † Global χ^2, $P < 0.0001$ for all oil-type categories.
[2] Matching variable.
[3] Based on waist-to-hip ratio.
[4] MET, metabolic equivalent of task.
[5] Adjusted for total energy intake using the residual method and does not include supplements.
[6] Mean calculated for current drinkers only.
[7] Other oils were sunflower oil, corn oil, olive oil, canola oil, and less common oils and fats.

Compared with other types of cooking oils that are very low in *trans* fatty acids, palm oil was significantly associated with increased risk for MI (OR = 1.53; 95% CI: 1.27–1.84). Adjustment for dietary and nondietary confounders as in the preceding models attenuated the association appreciably (OR = 1.23; 95% CI: 0.99–1.52), mainly because of the high proportion of smokers among palm oil users (29%) compared with users of other cooking oils (14%).

In a multivariate dose-response analysis, we found that relative to non-palm oil users (0% energy from palm oil), the risk of MI among low (median intake = 3.5% of energy) and high (median intake = 7.4% energy) palm oil users was 1.27 (95% CI: 0.84–1.94) and 1.48 (95% CI: 0.95–2.33), respectively (data not shown).

We also determined whether total fat or saturated fat intake was associated with the risk of MI. As in our previous study (23), the total amount of fat consumed was not associated with MI (OR for the 5th vs. 1st quintile = 1.02; 95% CI: 0.80–1.30) but saturated fat was significantly associated with the risk of MI (OR for the 5th vs. 1st quintile = 1.36; 95% CI: 1.05–1.75) (data not shown).

We determined the percentage of difference in PUFA in

TABLE 2

Characteristics of the Costa Rican adult subjects who served as population-based matched controls by type of oil used for cooking[1]

	Palm oil (1.5% *trans*)	Soybean oil (22% *trans*)	Soybean oil (5% *trans*)	Other oils[2] (0.12% *trans*)	*P*-value[3]
n	491	241	854	525	—
Age, *y*	58 ± 12	57 ± 11	58 ± 12	59 ± 11	0.10
Women, %	27	27	25	28	0.68
People living in rural areas, %	34	13	30	33	<0.0001
Current smokers, %	29	24	20	14	<0.0001
Current drinkers, %	46	56	52	58	0.001
History of diabetes, %	14	10	15	15	0.26
History of hypertension, %	25	25	29	36	0.001
BMI, kg/m^2	25.7 ± 4.3	25.8 ± 4.1	26.8 ± 4.2	27.0 ± 4.4	<0.0001
Abdominal obesity[4]	0.95 ± 0.07	0.93 ± 0.08	0.96 ± 0.07	0.95 ± 0.08	<0.0001
Physical activity, *MET*[5]	1.69 ± 0.86	1.37 ± 0.65	1.60 ± 0.70	1.45 ± 0.48	<0.0001
Formal education, *y*	5.4 ± 4.0	8.2 ± 5.1	7.6 ± 5.2	9.3 ± 6.1	<0.0001
Household income, *US$*	372 ± 290	605 ± 480	557 ± 388	754 ± 476	<0.0001
Daily intakes					
Total energy, *kJ*	10279 ± 3216	10120 ± 3006	10408 ± 3349	10014 ± 3035	0.15
Animal fat, % *energy*	12.5 ± 4.7	12.5 ± 4.5	13.1 ± 4.5	12.6 ± 4.9	0.06
Vegetable fat, % *energy*	18.3 ± 4.2	19.0 ± 5.1	18.7 ± 4.4	20.6 ± 6.4	<0.0001
Saturated fat, % *energy*	14.1 ± 2.5	10.7 ± 2.4	11.1 ± 2.5	10.8 ± 2.8	<0.0001
Monounsaturated fat, % *energy*	11.1 ± 2.8	11.1 ± 4.0	10.6 ± 3.2	12.5 ± 5.6	<0.0001
Polyunsaturated fat, % *energy*	4.3 ± 1.1	6.5 ± 1.3	8.0 ± 1.6	8.5 ± 2.2	<0.0001
α-Linolenic acid, % *energy*	0.39 ± 0.09	0.52 ± 0.11	0.77 ± 0.21	0.52 ± 0.14	<0.0001
Trans fat, % *energy*	0.89 ± 0.29	2.27 ± 0.44	1.53 ± 0.59	0.91 ± 0.30	<0.0001
Cholesterol, *mg/4.2 MJ*	121 ± 58	117 ± 50	119 ± 53	113 ± 46	0.05
Carbohydrate, % *energy*	56 ± 7	55 ± 8	56 ± 7	54 ± 8	<0.0001
Protein, % *energy*	12.8 ± 2.1	13.1 ± 2.2	13.0 ± 2.0	12.9 ± 2.2	0.22
Dietary fiber,[6] *g*	25 ± 6	24 ± 7	25 ± 6	25 ± 6	0.66
Folate,[6] μg	405 ± 110	347 ± 87	457 ± 108	451 ± 111	<0.0001
Alcohol,[7] *g*	11.4 ± 18.6	12.7 ± 19.5	11.3 ± 18.8	10.4 ± 15.5	0.65

[1] Values are means ± SD or %.
[2] Other oil users ($n = 525$) in the control group include consumers of sunflower oil (51.6%), corn oil (29.5%), olive oil (10.5%), canola oil (2.5%), and less common oils and fats (5.9%).
[3] *P* from the global ANOVA or χ^2 test.
[4] Based on waist-to-hip ratio.
[5] MET, metabolic equivalent of task.
[6] Nutrient does not include supplements and is adjusted for total energy intake using regression methods.
[7] Calculated for current drinkers only.

TABLE 3

Types of oil used for cooking and the risk of nonfatal acute MI in adult Costa Rican MI cases and controls[1]

	Type of oil used for cooking		
Model	Palm oil vs. soybean oil (22% *trans*)	Palm oil vs. soybean oil (5% *trans*)	Palm oil vs. other oils[2] (0.12% *trans*)
Basic model[3]	1.40 (1.07–1.82)	1.39 (1.16–1.65)	1.53 (1.27–1.84)
Multivariate 1[4]	1.16 (0.86–1.56)	1.33 (1.09–1.62)	1.26 (1.02–1.55)
Multivariate 2[5]	1.14 (0.84–1.56)	1.33 (1.08–1.63)	1.23 (0.99–1.52)

[1] Values are OR (95% CI) obtained from 3 analyses in which 22% *trans* soybean oil or 5% *trans* soybean oil or "other oils" was used as the referent oil. All 3 analyses used the same set of covariates and a fixed sample size of 2111 cases and 2111 matched controls.
[2] Other oil users ($n = 977$) include consumers of sunflower oil (53%), corn oil (27%), olive oil (10%), canola oil (3%), and less common oils and fats (7%).
[3] OR conditioned on matching variables (age, sex and area of residence).
[4] Adjusted for smoking, alcohol intake, history of diabetes, history of hypertension, abdominal obesity, physical activity, and income.
[5] Adjusted also for intake of total energy and fiber.

adipose tissue between palm oil consumers and users of other cooking oils (**Fig. 1**). Compared with palm oil users, linoleic acid, α-linolenic acid, and *trans* fat were higher among users of soybean oil and other oils. Adipose tissue linoleic acid and α-linolenic acid were highest in users of soybean oil containing 5% *trans* fatty acids. In contrast, *trans* fat was highest among users of soybean oil with 22% *trans* fat. Although linoleic acid in adipose tissue of consumers of other oils was comparable to that of users of soybean oil with 5% *trans* fat, users of other oils were lower in α-linolenic acid. These adipose tissue fatty acid profiles are consistent with the self-reported major oils used for cooking and indicate long-term intake. Most cooking oil users reported consuming oils for a relatively long period of time e.g., 17 ± 8 y for palm oil, 12 ± 8 y for soybean oil with high *trans* fat, 8 ± 8 y for soybean oil with less *trans* fat, and 5 ± 6 y for users of other oils.

Because smoking was a major confounder in conditional analyses, we reassessed the association between palm oil and MI among nonsmokers and current smokers, separately. The results from these analyses were similar to those in Table 3. Analyses stratified by residence also revealed that palm oil was positively associated with MI, irrespective of the area of residence. In all of the above analyses, adjustment for dietary

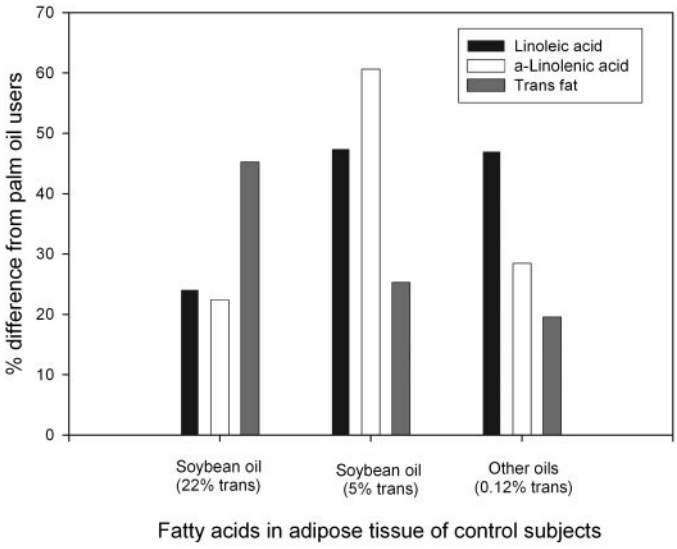

FIGURE 1 The percentage difference in mean adipose tissue linoleic, α-linolenic, and *trans* fatty acids between palm oil and the other oils used for cooking by adult control subjects in Costa Rica. Other oil users (n = 525) include consumers of sunflower oil (51.6%), corn oil (29.5%), olive oil (10.5%), canola oil (2.5%), and less common oils and fats (5.9%).

variables (e.g., intake of folate) did not change the results appreciably.

DISCUSSION

In this study we demonstrated that the use of palm oil compared with soybean oil and other cooking oils is independently associated with increased risk of MI. This association is not likely to have been confounded by age, gender, area of residence, income, lifestyle, or dietary intake because of the study's matched design, the restriction of recruitment to survivors of a first nonfatal acute MI, the use of randomly selected population controls, and the statistical adjustments for both lifestyle and dietary variables. Our validation of reported exposure (type of cooking oil) against adipose tissue fatty acid profiles suggests that reported cooking oil choices are accurate and are unlikely to be due to recall bias, and that oils may have been consumed over a long period of time e.g., 17 y for palm oil and 8–10 y for soybean oil. Existence of a positive relation in analyses stratified by smoking status or by area of residence further suggests that the association between palm oil and MI is not spurious.

Our data support concerns about the potential for atherogenesis with the use of palm oil. Although our population study did not address the mechanism by which palm oil may increase the risk of MI, we speculate that it does so in part by leading to an increased intake of saturated fat (~3% of energy/d), an established CVD risk factor (17,23). In our previous analyses, we showed that in Costa Rica, a high intake of saturated fat was associated with an increased risk of MI (23). We further showed that palmitic acid was less potent than other saturated fatty acids but because it was consumed in large quantities, it was likely to have a large population attributable risk (23). It is noteworthy that adjustments for other food sources of saturated fat had little effect on this association, whereas adjustment for total saturated fat intake attenuated the association between palm oil and soybean oil. In addition, consumption of dairy and meat products is relatively lower in Costa Rica than in Westernized countries; thus, the bulk of saturated fat would be from vegetable oils.

The low content of linoleic and α-linolenic acids in palm oil could have contributed to the observed positive association between palm oil and MI. Linoleic acid and α-linolenic acid, as well as other (n-3) and (n-6) fatty acids, protect against coronary heart disease (16,17,33). Linoleic acid lowers total and LDL cholesterol and may improve insulin sensitivity (17,33). α-Linolenic acid may protect against MI by inhibiting platelet aggregation and thrombosis, reducing blood pressure, and preventing cardiac arrhythmias. These effects can be achieved directly by α-linolenic acid or through its conversion to long-chain (n-3) fatty acids, including eicosapentaenoic acid and docosahexaenoic acid (16,17,33). If *trans* fatty acids were eliminated from soybean oil, as is the current trend in Costa Rica, the amount of available α-linolenic acid in soybean oil would be higher and the beneficial effects of this oil compared with palm oil might also be greater.

The other oils, mainly sunflower oil, also were protective compared with palm oil. Although the *trans* fatty acid content of adipose tissue of users of other oils was comparable to that of users of soybean oil with less *trans* fatty acids, their α-linolenic acid content was lower. It is possible that this lower α-linolenic acid accounts in part for the difference in OR when palm oil is compared with soybean oil (OR = 1.33; 95% CI: 1.08–1.63) or other oils (OR = 1.23; 95% CI: 0.99–1.52).

There were no significant differences (OR = 1.14; 95% CI: 0.84–1.56) between palm oil and soybean oil with high *trans* fatty acids content. This is likely to be due to the increase in risk of MI in the reference group that is attributable to the high *trans* fatty acids and low α-linolenic acid in the soybean oil. Partial hydrogenation of soybean oil destroys α-linolenic acid, increases the *trans* fatty acid content of soybean oil, and may therefore raise the risk of MI among consumers of partially hydrogenated soybean oil. Our previous studies showed that *trans* fatty acids increase risk (18), whereas (n-3) fatty acids such as α-linolenic acid (16) protect against the risk of MI in this population. These data also suggest that the potentially positive characteristics of palm oil such as its high oleic acid content (39%) are not sufficient to compensate for the deleterious effects of its attendant high saturated fat and low concentrations of linoleic acid and α-linolenic acid.

Because part of the reason for increased risk of MI among palm oil users may be attributed to low intake of polyunsaturated fat, and because palm oil is the cheapest oil available to most people in developing countries, replacing palm oil with unsaturated cooking oils may not be a practical solution in the short term. This is because the palm oil industry is a major source of employment and income for many people who might not be able to afford other oils. Despite these social concerns, which could be addressed in the long term by redirecting palm oil to other nonhuman food uses, it is important to attend to the health concerns of palm oil consumers. The increase in the risk of MI associated with palm oil use that was demonstrated in this study is important to public health. Production and consumption of palm oil are widespread and on the increase (1,34), especially in those developing countries in which diseases of affluence are also increasing (3,35–37). In Costa Rica, for instance, CVD is a leading cause of death, with ischemic heart disease accounting for 47.2% of CVD deaths (38).

In the dose-response analysis, we noted that the difference in risk of MI between low (3.5% energy) and high (7.4% energy) palm oil users was not substantial, suggesting that the type of oil used for cooking and frying is more important than the amount of oil used. It is therefore possible that recommending a decrease in intake of palm oil may not have a

significant effect on public health unless it is replaced with polyunsaturated oils. It would be valuable to establish per capita consumption levels in countries that produce or import large amounts of edible palm oil. It would also be of value to determine the levels of saturation and concentration of antioxidants in the most common brands of palm oil used for cooking in other developing countries. In our study, palm oil users had significantly lower amounts of antioxidants and α-linolenic acid compared with soybean oil users (39).

These data show that compared with soybean oil users, the risk of nonfatal acute MI in palm oil users is high (8–63%). Because palm oil is used widely, especially in developing countries in which the cardiovascular disease burden is on the increase, projected increases in palm oil consumption could greatly affect public health. Programs that lead to the reduction in consumption of palm oil and partially hydrogenated soybean oil or to the availability of inexpensive palm oil with improved fatty acid composition, or the substitution of palm oil with unsaturated cooking oils are warranted. One potential short-term intervention is to replace saturated fat with *cis*-polyunsaturated (n-3) and (n-6) fatty acids in palm oil by mixing it with other unsaturated oils.

ACKNOWLEDGMENT

We thank Ms. Xinia Siles of Proyecto Salud Coronaria, San José, Costa Rica for her help in data collection.

LITERATURE CITED

1. Landes R, Westcott P, Wainio J. International Agricultural Baseline Projections to 2005: Oilseeds and products. Agricultural Economic Report: USDA Economic Research Service; 1997 May, 1997; Report No. 750.

2. Palm oil, forests and sustainability. Discussion paper for the Round Table on Sustainable Oil Palm. [Cited 2004 November]. Available from: http://www.proforest.net/objects/Oil_Palm/Round%20Table%20Discussion%20Paper%202%20.pdf; 2003.

3. Reddy KS. Cardiovascular disease in non-Western countries. N Engl J Med. 2004;350:2438–40.

4. Popkin BM. The shift in stages of the nutrition transition in the developing world differs from past experiences! Public Health Nutr. 2002;5:205–14.

5. Zhang J, Kesteloot H. Differences in all-cause, cardiovascular and cancer mortality between Hong Kong and Singapore: role of nutrition. Eur J Epidemiol. 2001;17:469–77.

6. Kritchevsky D, Tepper SA, Czarnecki SK, Sundram K. Red palm oil in experimental atherosclerosis. Asia Pac J Clin Nutr. 2002;11 Suppl 7:S433–7.

7. Klurfeld DM. Tropical oil turmoil. J Am Coll Nutr. 1991;10:575–6.

8. Olson RE. Controversy about palm oil. Nutr Rev. 1988;46:174–6.

9. Mattson FH, Grundy SM. Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. J Lipid Res. 1985;26:194–202.

10. Rudel LL, Haines JL, Sawyer JK. Effects on plasma lipoproteins of monounsaturated, saturated, and polyunsaturated fatty acids in the diet of African green monkeys. J Lipid Res. 1990;31:1873–82.

11. Denke MA, Grundy SM. Comparison of effects of lauric acid and palmitic acid on plasma lipids and lipoproteins. Am J Clin Nutr. 1992;56:895–8.

12. Zock PL, de Vries JH, Katan MB. Impact of myristic acid versus palmitic acid on serum lipid and lipoprotein levels in healthy women and men. Arterioscler Thromb. 1994;14:567–75.

13. Cuesta C, Rodenas S, Merinero MC, Rodriguez-Gil S, Sanchez-Muniz FJ. Lipoprotein profiles and serum peroxide levels of aged women consuming palmolein or oleic acid-rich sunflower oil diets. Eur J Clin Nutr. 1998;52:675–83.

14. Rudel LL, Parks JS, Sawyer JK. Compared with dietary monounsaturated and saturated fat, polyunsaturated fat protects African green monkeys from coronary artery atherosclerosis. Arterioscler Thromb Vasc Biol. 1995;15:2101–10.

15. Ng TK, Hayes KC, DeWitt GF, Jegathesan M, Satgunasingam N, Ong AS, Tan D. Dietary palmitic and oleic acids exert similar effects on serum cholesterol and lipoprotein profiles in normocholesterolemic men and women. J Am Coll Nutr. 1992;11:383–90.

16. Baylin A, Kabagambe EK, Ascherio A, Spiegelman D, Campos H. Adipose tissue alpha-linolenic acid and nonfatal acute myocardial infarction in Costa Rica. Circulation. 2003;107:1586–91.

17. Hu FB, Manson JE, Willett WC. Types of dietary fat and risk of coronary heart disease: a critical review. J Am Coll Nutr. 2001;20:5–19.

18. Baylin A, Kabagambe EK, Ascherio A, Spiegelman D, Campos H. High 18:2 *trans*-fatty acids in adipose tissue are associated with increased risk of nonfatal acute myocardial infarction in Costa Rican adults. J Nutr. 2003;133:1186–91.

19. Ascherio A. Epidemiologic studies on dietary fats and coronary heart disease. Am J Med 2002;113 Suppl 9B:9S–12.

20. Monge-Rojas R. Dietary intake as a cardiovascular risk factor in Costa Rican adolescents. J Adolesc Health. 2001;28:328–37.

21. Campos H, Siles X. Siesta and the risk of coronary heart disease: results from a population-based, case-control study in Costa Rica. Int J Epidemiol. 2000;29:429–37.

22. Kabagambe EK, Baylin A, Allan DA, Siles X, Spiegelman D, Campos H. Application of the method of triads to evaluate the performance of food frequency questionnaires and biomarkers as indicators of long-term dietary intake. Am J Epidemiol. 2001;154:1126–35.

23. Kabagambe EK, Baylin A, Siles X, Campos H. Individual saturated fatty acids and nonfatal acute myocardial infarction in Costa Rica. Eur J Clin Nutr. 2003;57:1447–57.

24. Tunstall-Pedoe H, Kuulasmaa K, Amouyel P, Arveiler D, Rajakangas AM, Pajak A. Myocardial infarction and coronary deaths in the World Health Organization MONICA Project. Registration procedures, event rates, and case-fatality rates in 38 populations from 21 countries in four continents. Circulation. 1994;90:583–612.

25. Report of the expert committee on the diagnosis and classification of diabetes mellitus. Diabetes Care. 1998;21:S5–22.

26. Rose G, Blackburn H, Gillum RF, Prineas RJ. Cardiovascular research methods. 2nd ed; Geneva: World Health Organization; 1982.

27. Baylin A, Kabagambe EK, Siles X, Campos H. Adipose tissue biomarkers of fatty acid intake. Am J Clin Nutr. 2002;76:750–7.

28. Cottrell RC. Introduction: nutritional aspects of palm oil. Am J Clin Nutr. 1991;53:989S–1009.

29. Dayton S, Hashimoto S, Dixon W, Pearce ML. Composition of lipids in human serum and adipose tissue during prolonged feeding of a diet high in unsaturated fat. J Lipid Res. 1966;7:103–11.

30. Frayn KN. Regulation of fatty acid delivery in vivo. Adv Exp Med Biol. 1998;441:171–9.

31. Kark JD, Manor O, Goldman S, Berry EM. Stability of red blood cell membrane fatty acid composition after acute myocardial infarction. J Clin Epidemiol. 1995;48:889–95.

32. Willett WC. Nutritional Epidemiology. 2nd ed. New York: Oxford University Press; 1998.

33. Wijendran V, Hayes KC. Dietary n-6 and n-3 fatty acid balance and cardiovascular health. Annu Rev Nutr. 2004;24:597–615.

34. Weuxun F, Xiaoshu C. Food uses of palm oil in China. Food Nutr Bull. 1993/1994;15:4–7.

35. Ueshima H, Zhang XH, Choudhury SR. Epidemiology of hypertension in China and Japan. J Hum Hypertens. 2000;14:765–9.

36. Seedat YK. Hypertension in developing nations in sub-Saharan Africa. J Hum Hypertens. 2000;14:739–47.

37. Singh RB, Suh IL, Singh VP, Chaithiraphan S, Laothavorn P, Sy RG, Babilonia NA, Rahman AR, Sheikh S, et al. Hypertension and stroke in Asia: prevalence, control and strategies in developing countries for prevention. J Hum Hypertens. 2000;14:749–63.

38. Health in the Americas (Publication No. 569). Washington (DC): Pan American Health Organization; 1998.

39. Kabagambe EK, Baylin A, Siles X, Campos H. Comparison of dietary intakes of micro- and macronutrients in rural, suburban and urban populations in Costa Rica. Public Health Nutr. 2002;5:835–42.