Nutrition, Metabolism & Cardiovascular Diseases (2007) 17, 50–57

ELSEVIER

Nutrition, Metabolism & Cardiovascular Diseases

www.elsevier.com/locate/nmcd

Olive, soybean and palm oils intake have a similar acute detrimental effect over the endothelial function in healthy young subjects

Christian F. Rueda-Clausen [a], Federico A. Silva [a,b], Manuel A. Lindarte [a], Cristina Villa-Roel [a], Elieth Gomez [b], Roberto Gutierrez [c], Carlos Cure-Cure [d], Patricio López-Jaramillo [a,*]

[a] *Vilano Group and Research Institute, Cardiovascular Foundation of Colombia, Calle 155a #23-58, Third Floor, Floridablanca, Santander, Colombia*
[b] *Universidad Industrial de Santander, Santander, Colombia*
[c] *Compañía Grasas y Derivados, GRADESA S.A., Santa Marta, Colombia*
[d] *Universidad Metropolitana, Barranquilla, Colombia*

Received 22 February 2005; received in revised form 8 June 2005; accepted 16 August 2005

KEYWORDS
Vegetable oils;
Endothelial function;
Olive;
Palm;
Soybean;
Young volunteers

Abstract *Background and aim:* Currently, more than 30% of the caloric intake in the Colombian population comes from vegetable oil consumption mainly by the ingestion of deep-fried foods. Recently, it has been reported that unsaturated fatty acid rich oils have a beneficial effect on the endothelial function. Nevertheless, it is well know that the deep-frying process alters the chemical composition of vegetable oils and can produce adverse effects in the endothelial function.
Objective: To evaluate the acute effect of the ingestion of large amounts of olive, soybean and palm oils, fresh and at two different deep-fry levels, on the glucose and lipid profiles and the endothelial function.
Methods and results: Ten healthy young volunteers were included in the study. After performing a baseline evaluation of cardiovascular risk factors and drawing a fasting blood sample, subjects were exposed to a randomly assigned potato soup meal containing 60 mL of one of three different vegetable oils (olive, soybean and palm), either fresh or at one of two different deep-fry levels (10 and 20 fries, respectively). Flow-mediated vasodilation (FMD) was performed in fasting conditions and 3 h after the intake of the oil rich meal. Furthermore, blood samples were taken at these stages for the lipid profiles and plasma glucose determinations. All the meals resulted in a similar acute endothelial impairment (FMD decrease of 32.1%, confidence interval [CI] 95%, 28.0–36.2) and postprandial increase in triglycerides

* Corresponding author. Tel.: +57 7 639 9292; fax: +57 7 639 2744.
E-mail address: jplopezj@fcv.org (P. López-Jaramillo).

0939-4753/$ - see front matter
doi:10.1016/j.numecd.2005.08.008

(27.03%, CI 95%, 20.5—33.3), independently of the type of oil ingested ($p = 0.44$) and regardless of its deep-fry level ($p = 0.62$). No correlation was found between endothelial impairment and postprandial triglyceride increment ($r = -0.22$, $p = 0.09$).
Conclusions: No difference was found in the acute adverse effect of the ingestion of different vegetable oils on the endothelial function. All the vegetable oils, fresh and deep-fried, produced an increase in the triglyceride plasma levels in healthy subjects.

Introduction

Cardiovascular disease (CVD) constitutes an important health problem in Colombia today because of its high incidence rate. Currently, CVD is the principal cause of mortality among the adult population. Although the increased frequency of traditional cardiovascular risk factors (CRF) could explain the high rate of CVD in the population [1], the presence of inadequate sanitary conditions and inappropriate dietary habits may also act as triggers of this phenomenon [2,3]. Currently, the global availability of cheap vegetable oils is increasing the fat consumption in this population and this in turn exerts an influence on nutritional habits [4]. About 32.5% of the daily energy intake in Colombia comes from vegetable oil consumption, and over 94% of this oil is used for frying. These factors converge in fatty hypercaloric meals, which are poor in fiber and micronutrients [5].

High-fat meals, which are strongly associated with traditional CRF such as obesity and dyslipidemia [6], have also been linked to the induction of oxidative stress [7] through different processes such as the production of superoxide and the subsequent deactivation of nitric oxide (NO) [8], the production of peroxynitrite, and insulin release [9].

Although olive and soybean oils are highly recommended for human consumption due to their high content of monounsaturated (MUFAs) and polyunsaturated (PUFAs) fatty acids [10,11], it has been reported that exposing oil (especially PUFA rich oils) to deep frying temperatures (>200 °C) affects the chemical composition by saturating its fatty acids (FFA) [12] and generating other oxidation products, leading in turn to a deleterious effect in the endothelial function [13]. Moreover, the thermoxidation of vegetable oil can produce a class of unstable compounds called peroxides. These are known to generate free radicals that have a direct deleterious effect on the endothelial function [14] and can, in combination with free fatty acids, produce monomers and other products like penzopirene, which have a recognized toxic effect on endothelial cells [15].

Currently, Colombia is the main palm oil producer in South America; being this one of the reasons why the oil consumption constitutes the main source of fat intake in this population [5]. Palm oil is known to contain a lower level of PUFAs than olive or soybean oils and its consumption has been associated with a higher risk of CVD [6,16]. On the other hand, due to its composition and the presence of higher concentrations of antioxidants like tocotrienols, palm oil could be highly suitable for frying preparations [17].

The main aim of the present study was to evaluate and to compare the acute effects of three different kinds of vegetable oils (palm, soybean, and olive) in fresh state and after exposure to different deep frying levels on endothelial function in healthy young volunteers.

Methods

Study population

Ten healthy, normolipidemic, non-smoking, young men (between 18 and 23 years old), without CRF or family history of coronary heart disease (CHD), were recruited. None of the subjects was taking any supplemental vitamins or medication at that time. All subjects refrained from exercise during the study period and fasted for 12 h overnight before each visit. All subjects signed their written informed consent before participating in the study, which had previously been approved by the institutional review board.

Clinical parameters

On the first day of the study, after a baseline medical examination (cardiovascular risk determination, anthropometrical measurement and nutritional evaluation), fasting venous blood samples were taken to determine glucose, leukocyte count

and lipid profile (total cholesterol (TC), triglycerides (TG), HDL-cholesterol (HDL-C) and LDL-cholesterol (LDL-C)). Biochemical parameters were determined by a reference laboratory using a standard colorimetric technique for lipid profile and glucose determination.

Flow-mediated vasodilation (FMD) in the brachial artery was performed twice during each visit (weekly during 9 weeks), in fasting conditions and 3 h after each meal intake. At these times, new venous blood samples (for glucose and lipid profile determinations) were drawn.

FMD studies were performed following a previously published technique [18]. Subjects who had refrained from heavy exercise, caffeine-containing drinks and nitrite-nitrate rich meals for at least 24 h and who had fasted for at least 10 h, were admitted at 07:00 h to the Non-invasive Test Department of the Cardiovascular Foundation of Colombia. All measurements were performed in a temperature-controlled room (24 °C). The study was performed following 10 min of rest with the subject in a supine position. The left arm was comfortably immobilized in the extended position to allow consistent access to the brachial artery for imaging. Brachial artery diameter and blood flow velocity were imaged using a 7.5-MHz linear-array transducer ultrasound system (Aloka®, Vario View SDD2200, Tokyo, Japan), located between 4 and 10 cm above the antecubital fossa. Baseline measurements of brachial artery diameter and arterial flow velocity were both obtained by means of a pulsed Doppler signal at a 70° angle to the vessel. After baseline measurements, a small-width blood pressure cuff was inflated on the most proximal portion of the forearm to occlusive pressure (300 mmHg) for 5 min in order to induce hyperemia. The cuff was then deflated and pulsed Doppler signals were recorded for 15 s. Images of the brachial artery were obtained after 60 s of cuff deflation. Vessel diameter was measured with ultrasonic calipers from the leading edge of the anterior wall to the leading edge of the posterior wall of the brachial artery at end diastole, incident with the R wave on the simultaneously recorded electrocardiogram. Change in diameter was calculated as a percentage of change relative to the baseline diameter using the following equation: [(vessel diameter after cuff deflation − resting vessel diameter)/resting vessel diameter] × 100. The flow velocity was taken from the center of the vessel. Reactive hyperemia was calculated as follows: [(blood flow at 15 s after cuff deflation − resting blood flow)/resting blood flow] × 100. All images were recorded on Super VHS tape for later analysis. The studies were subsequently analyzed by two blinded observers; the mean values obtained from the two observers were used for the analysis. The mean within-subject variance for FMD obtained was 6.7%, and the interobserver linear correlation coefficient was 0.91. The anthropometrical parameters were measured using the Airle Consensus [19].

Diet preparation and oil administration

To administer the vegetable oils, a special meal consisting of 250 mL of salt-free light soup prepared with 60 g of potatoes, salt (approximately 25 mEq of Na) and water (total calories 55.2 kcal, carbohydrates 50.6 kcal and protein 4.5 kcal) was prepared under the supervision of a qualified nutritionist.

The vegetable oil intake consisted of 60 mL (541 kcal) of the different types of vegetable oils (soybean, olive and palm), either fresh or at one of the two different deep-fry levels (10 and 20 fries). One deep-fry level of the oil is defined as a continuous exposure of potatoes to 200 °C of temperature for 8 min. The deep frying was carried out by GRADESA S.A (Barranquilla, Colombia), a specialist oil processing institution.

Intervention

Meals were administered once a week, starting with the first meal in the morning. Every portion of vegetable oil was added directly to the potato soup a few minutes before ingestion. For 9 weeks, subjects were exposed once a week to a randomly assigned portion of different kinds of vegetable oil at different deep-fry levels. Meal assignments were done independently for each volunteer, before the inclusion of the subjects, using a random number table. A 24-h recall was performed weekly to evaluate changes in nutritional habits of the subjects during the study. Both the study coordinator and the subjects were blinded to the assigned meal.

Biochemical evaluation of the oil

Samples of each type of oil subjected to different deep-fry levels were packed and sent to the biochemical laboratory of GRADESA S.A. and to the Department of Nutrition of the Universidad Industrial de Santander for biochemical analyses. Fatty acid composition was determined by high resolution gas chromatography (Hewlett Packard® HP 5890A Series II, Palo Alto, CA) after the derivation of the fatty acid methyl esters according to the standard methods of the International

Union of Pure and Applied Chemistry (IUPAC) [20]. Polar compounds were quantified by absorption chromatography in a silica gel column. The iodine, peroxide and acidity levels were determined by standard titration methods [20].

Statistics

The study had an 80% power to detect a 3% reduction in FMD and a 90% power to detect a 3.8% reduction in FMD. Group descriptive values are expressed as mean ± standard deviation (SD). The acute effects of the meals with the different vegetables oils on metabolic and endothelial parameters under-went to analyses of variance (ANOVA) for repeated measurements. Spearman rank correlation analysis was used to test for a relationship between changes in biochemical parameters and FMD. Multiple comparisons of the changes in FMD induced by the nine meals (once a week) were compared using repeated-measures ANOVA. The software program STATA 8.0 was used for all the analyses. Values of $p < 0.05$ were considered significant.

Table 1 Anthropometric, biochemical, and nutritional characteristics of 10 healthy volunteers

Variable	Mean	SD
Age (years)	20.8	2.4
Weight (kg)	66.2	9.8
Body mass index (kg/m^2)	21.9	2.6
Waist circumference (cm)	77.1	7.8
Waist/hip ratio	0.88	0.07
Heart rate (bpm)	72	6
Mean blood pressure (mmHg)	81.2	3.4
Fasting glucose (mg/dL)	89.4	7.03
Total cholesterol (mg/dL)	118	22.7
LDL-cholesterol (mg/dL)	64.6	19.3
HDL-cholesterol (mg/dL)	35.7	5.9
Triglycerides (mg/dL)	82.6	25
Baseline FMD (%)	11.18	2.8
Nutritional intake (kcal)	1859	588
Carbohydrates intake (g)	322	122
Protein intake (g)	69.8	24.1
Fat intake (g)	32.8	2.3
SFA intake (g)	10.6	1.7
MUFA intake (g)	9.3	2
PUFA intake (g)	5.2	1.9
Cholesterol intake (mg)	296	183

Intake, mean total daily intake; SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

Results

The anthropometrical, biochemical and nutritional characteristics of the 10 subjects are presented in Table 1. The subjects were healthy, normotensive, non-obese, and their biochemical determinations were normal. The 24-h recall analysis shows that mean caloric intake of the subjects at the beginning of the study was 1859 ± 588 kcal, carbohydrates 322 ± 122 g., protein 70 ± 24 g, saturated fatty acids 10.6 ± 1.8 g., MUFAs 9.3 ± 2 g. PUFAs 5.2 ± 1.9 g, which is considered an adequate and balanced diet with an appropriate proportion of macronutrients [21]. The nutritional intake of the subjects did not change during the course of the study (ANOVA = 0.63). The biochemical characteristics of the different oils used in the study and the effect of deep-frying on them are presented in Table 2.

Changes in serum lipid profile and glucose levels observed 3 h after each meal administration are shown in Table 3. Mean serum TG values showed a significant ($p < 0.05$) and similar increase

Table 2 Biochemical characteristics of the oils

	Olive oil			Palm oil			Soybean oil		
	Fresh	10 DFL	20 DFL	Fresh	10 DFL	20 DFL	Fresh	10 DFL	20 DFL
SFAs (%)	14.28	14.81	15.18	43.6	43.97	44.2	16.24	17.48	17.4
MUFAs (%)	77.77	77.7	78.35	46.4	46.03	46.37	24.4	25.7	25.53
PUFAs (%)	6.55	6.37	5.32	9.97	9.46	9.39	52.78	50.84	51.11
Peroxide index (mEq O_2/kg)	16.28	31.97	23.42	0.65	23.56	24.87	1.25	30.12	48.12
Acidity (% as oleic acid)	0.5	0.47	1.04	0.1	0.14	0.18	0.1	0.2	0.21
Iodine index (g/100 g)	84.5	83.68	81.44	59.01	58.27	58.9	130.3	124.9	123.8
Polar compounds (%)	1.19	5.82	6.7	5.16	5.78	8.27	5.06	6.17	8.61

DFL, deep-fry level; SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids.

Table 3 Changes in glucose, lipoproteins and leucocytes before and after meal ingestion (once a week) in 10 healthy subjects

Variable	Olive oil			Palm oil			Soybean oil		
	Fresh	10 DFL	20 DFL	Fresh	10 DFL	20 DFL	Fresh	10 DFL	20 DFL
ΔGlucose (%)	−12 (11.6)	−13 (8.3)	−8 (15.2)	−5 (15.4)	5 (18.9)	3 (20.8)	−11 (11.3)	−8 (14.8)	5 (14.7)
ΔCholesterol (%)	19 (17.1)	17 (17.8)	19 (15.3)	10 (12.2)	17 (21.7)	19 (30)	5 (12.9)	24 (19.2)	24 (16.7)
ΔLDL-cholesterol (%)	18 (44.2)	26 (44.8)	33 (40.1)	13 (13)	24 (38.8)	14 (46.3)	19 (38.3)	55 (59.4)	33 (57.6)
ΔHDL-cholesterol (%)	8 (31.7)	6 (25.6)	9 (24.8)	4 (23.5)	8 (24.6)	11 (31.2)	4 (25)	7 (17.7)	15 (26.4)
ΔTriglycerides (%)	31 (53.6)*	16 (31.9)*	10 (36)*	13 (26.3)*	18 (56.8)*	44 (16.5)*	16 (18.4)*	12 (38.5)*	15 (28.1)*
ΔLeucocytes (%)	8 (28.2)	−10 (15.4)	6 (25.7)	5 (6.8)	0.7 (29.1)	4 (28.5)	7 (24)	6 (29)	−1 (24.6)

Values are mean (SD). Δ%, values expressed as mean perceptual change vs. fasting levels (CI 95%). DFL, deep-fry level. *$p < 0.05$ vs. fasting values.

(27 ± 30%) 3 h after each meal intake. No acute changes were observed in glucose, TC, LDL-C, HDL-C or leukocytes after the administration of the different oils independently of its type or deep-fry level.

Blood pressure, heart rate, fasting and postprandial baseline arterial diameter (BAD), peak hyperemic arterial diameter (PAD), peak hyperemic flow (PHF) and FMD results are presented in Table 4. It was found that the different meals caused no acute change in basal brachial artery diameter (3.1 ± 0.3 mm fasting vs. 3.1 ±0.03 mm postprandial; $p = 0.91$), Fig. 1. There was a significant and constant decrease in FMD 3 h after each meal intake (32.1 ± 21.6%) ($p < 0.00001$) independently of the type of oil used for the preparation of the meal (ANOVA = 0.44) or the deep-fry level (ANOVA = 0.62). There was no significant correlation between postprandial changes in serum triglycerides and changes of FMD ($r = -0.22$, $p = 0.09$).

Discussion

Although the three kinds of vegetable oils used in the meals have different compositions of fatty acids and saturation levels, the deep frying process (10 and 20 levels) seems to have similar deleterious effects on the biochemical characteristics of each oil. These effects were particularly evident in parameters like polar compounds, acidity and peroxide index, which are markers of oil thermoxidation. However, all the oils administered fulfilled the biochemical parameters accepted by the Food Safety and Inspection Service of the United States Department of Agriculture (USDA/FSIS) for human consumption [22].

Fasting FMD was similar to that previously described and validated for a healthy Colombian population [23]. The significant decrease in postprandial FMD agreed with previous studies that linked high-fat content meals with an acute impairment of the endothelial function [24].

It has, however, been suggested that the decrease in postprandial FMD after a high-fat meal is due to an increase in the basal artery diameter related with a postprandial peripheral vasodilation, resulting in a lower FMD response [25,26]. We have found no differences between the preprandial and the postprandial baseline brachial artery diameter among the different types of meals/oils used. Thus, it is unlikely that the postprandial decrease in FMD observed in our subjects is due to postprandial vasodilation. Moreover, our findings suggest a comparable deleterious effect of all the meals ingested on the endothelial

Table 4 Acute effect of the high-fat meal on heart rate, mean blood pressure, and flow-mediated vasodilation in 10 healthy subjects

	Olive oil			Palm oil			Soybean oil		
	Fresh	10 DLF	20 DLF	Fresh	10 DLF	20 DLF	Fresh	10 DLF	20 DLF
Heart rate (bpm)	72.2 (6.4)	72.6 (5.7)	72.8 (6.2)	72.2 (5.6)	71.7 (6.2)	71.2 (5.9)	71.7 (6.2)	72.2 (5.9)	71.7 (6.2)
MBP (mmHg)	79.3 (3.6)	83.7 (2.9)	85.0 (3.6)	81.1 (3.2)	80.2 (3.6)	78.4 (3.4)	81.6 (3.6)	88.2 (3.4)	81.2 (3.6)
BAD pre (mm)	3.18 (0.35)	3.10 (0.37)	3.12 (0.36)	3.09 (0.37)	3.14 (0.39)	3.07 (0.46)	3.04 (0.47)	3.13 (0.36)	3.03 (0.47)
BAD post (mm)	3.18 (0.36)	3.13 (0.38)	3.1 (0.38)	3.09 (0.37)	3.13 (0.39)	3.07 (0.46)	3.04 (0.47)	3.13 (0.36)	3.04 (0.4)
PAD pre (mm)	3.5 (0.33)	3.4 (0.35)	3.4 (0.37)	3.4 (0.36)	3.4 (0.38)	3.5 (0.46)	3.3 (0.47)	3.4 (0.36)	3.3 (0.47)
PAD post (mm)	3.4 (0.32)	3.4 (0.36)	3.3 (0.32)	3.3 (0.39)	3.3 (0.38)	3.2 (0.41)	3.2 (0.46)	3.3 (0.33)	3.2 (0.52)
PHF pre (cm/s)	115.3 (25.3)	117.1 (29.5)	121.0 (16.9)	117.4 (27.7)	117.8 (28.8)	128.0 (23)	115.8 (20.9)	105.3 (18.5)	126.2 (19.4)
PHF post (cm/s)	108.1 (20.9)	111.8 (25.4)	121.0 (15.12)	104.0 (20.4)	123.11 (26.4)	106.2 (30.6)	118.5 (20.8)	121.3 (33.6)	116.8 (15.9)
FMD pre (%)	11.4 (3.2)	11.6 (3.9)	11.4 (2.9)	11.2 (2.7)	10.5 (3.0)	10.7 (3.0)	10.9 (3.1)	11.3 (3.1)	11.4 (3.3)
FMD post (%)	7.4 (2.7)	7.7 (2.6)	7.9 (2.2)	7.3 (2.9)	7.0 (2.9)	6.2 (3.2)	8.1 (3.4)	8.4 (4.3)	8.04 (2.7)
FMD Δ (%)	−34.6 (17.7)	−31.1 (17.3)	−27.9 (20.4)	−34.8 (20.2)	−32.7 (17.8)	−43.3 (19.1)	−27.5 (16.8)	−28.5 (3.8)	−27.3 (22.0)

Values are mean (SD). MBP, mean blood pressure; BAD, baseline arterial diameter; PAD, peak hyperemic arterial diameter; PHF, peak hyperemic flow; pre, preprandial; post, 3 h postprandial; FMD, flow-mediated vasodilation; FMD Δ, postprandial change or FMD.

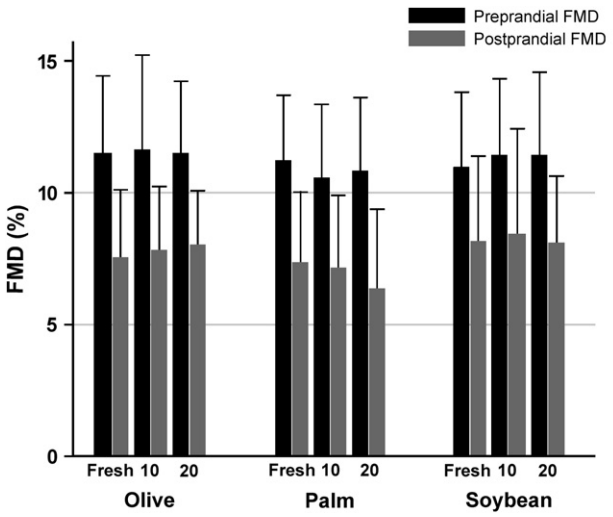

Figure 1 Postprandial change in FMD after high-fat meals prepared with different kinds of oils and deep-fry levels (mean ± SD).

vasodilating function. An acute decrease in FMD after the ingestion of a meal prepared with fat rich in oxidized fatty acids, but not after a meal containing the corresponding unused fat, has previously been reported [13]. Vogel et al. [27] showed that the ingestion of fresh olive oil (but not canola oil or salmon fat) acutely impairs endothelial function. Nevertheless, other studies conducted in healthy subjects reported that the ingestion of thermally oxidized safflower and olive oils do not acutely affect FMD [28]. More recently, West et al. [29] reported that a meal containing 50 g of either plant or marine derived fatty acids improves endothelial function. These contradictory results could be due to differences in the methodological design of the studies, the age, gender, ethnic background and metabolic status of the subjects, or to differences in the biochemical composition of the oils used in the high-fat meal.

The subjects in our study were relatively young (around 20 years old), healthy, Hispanic, normotensive; with normal weight and an equilibrated diet; their glycemia and plasma lipid profiles were also normal. In these subjects, all the three different oils used (palm, olive and soybean), with various degrees of deep-fry cooking levels, produced an acute detrimental effect on the endothelial function. As discussed above, regardless of the different fatty acid composition or saturation level, the deep-frying process produced a similar thermoxidation that explains the detrimental effect on FMD.

It has been proposed that the acute effect of fatty meals on endothelial function is due to an increased oxidative stress and its effect on NO

availability rather than a specific effect of postprandial hyperlipoproteinemia on the endothelial function [30,31]. This proposal is supported by several studies demonstrating that concomitant administration of fatty meals and antioxidants such as vitamins C or E [32], red wine [33] and black grape [34] can reduce the impairment in endothelial function following a high-fat meal by increasing NO availability.

While saturated fat-rich meals have a recognized pro-atherogenic activity [35], Mediterranean diets, which are rich in mono- and polyunsaturated fatty acids, have been associated with lower cardiovascular risks [36]. The repeated deep frying process has a proven deleterious effect on the stability of PUFAs and other biochemical parameters of vegetable oils (such as acidity, presence of polar compounds and peroxide index), and has been linked to an increase in the presence of free radicals [37].

Our results showed that 10 and 20 deep-fry levels (80 and 160 min of deep frying, respectively), caused a change in the biochemical parameters of the oils. Even though olive and soybean oils have a higher ratio of unsaturated fatty acids than palm oil, and unsaturated fatty acids are more susceptible to thermoxidation, all the three different vegetable oils had a similar response to repeated deep frying and caused the same acute effect on endothelial function, showing that there are no differences between the three kinds of vegetable oils at the frying levels tested. However, the harmful acute effects of oil intake on the endothelial function were also detected with the administration of fresh oil. Thus, these results suggest a direct acute effect of the fatty meals on the endothelial function.

Our results showed that the only biochemical parameter that had a significant acute change after each high-fat meal was TG. Postprandial hypertriglyceridemia and elevated levels of fatty acids [38] have been linked with endothelial dysfunction. Vogel and coworkers reported an inverse relationship between the 2-h increase in triglycerides and postprandial FMD after a high-fat meal [24]. However, we found no correlation between increases in triglycerides and postprandial endothelial impairment. A previous study demonstrated that endothelial function remains unchanged with an acute increase in plasma triglycerides after infusion of a lipid emulsion [39].

These contradictory results suggest that different mechanisms could be linked to the acute effects of a fatty meal over FMD. The influence of factors such as the oil preparation process, the subject's metabolic conditions, or even the ethnic or regional differences, in the acute endothelial response to fatty meal remains to be determined.

In conclusion, our results have demonstrated that the deep-frying process causes a comparable change in the biochemical characteristics of palm, olive or soybean oils. Moreover, all the high-fat meals prepared with fresh or cooked oils produced a similar detrimental acute effect in the endothelial function independently of the type of oil used or its deep-fry level. These results suggest that it is necessary to reevaluate the cost-effectiveness relationship of different disposable vegetable oils, considering that their preparation in South America and Asia [40] is different from their traditional fresh use in Europe. Finally, nutritional efforts should always be focused on the modification of dietary habits through the promotion of antioxidant rich product consumption instead of the commercially influenced selection of vegetable oils [17].

Acknowledgments

The authors would like to thank Dr. Marcos López for style correction. This study was partially supported by grants from COLCIENCIAS (Project Code 6566-04-11797).

References

[1] Ministerio de Salud de Colombia. II Estudio Nacional de Factores de Riesgo de Enfermedades Crónicas (ENFREC II). 2002.
[2] López-Jaramillo P, Casas JP, Morillo C. C-Reactive protein and cardiovascular diseases in andean population. Circulation 2002;105:6.
[3] López-Jaramillo P, Casas JP, Bautista L, Serrano NC, Morillo CA. An integrated proposal to explain the epidemic of cardiovascular disease in a developing country: from socioeconomic factors to free radicals. Cardiology 2001;96:1—6.
[4] Drewnowski A, Popkin BM. The nutrition transition: new trends in the global diet. Nutr Rev 1997;55:31—43.
[5] Bautista L, Herrán OF, Serrano C. Effects of palm oil and dietary cholesterol on plasma lipoproteins: results from a dietary crossover trial in free-living subjects. Eur J Clin Nutr 2001;55:748—54.
[6] Hu FB, Stampfer MJ, Manson JE, Rimm E, Colditz GA, Rosner BA, et al. Dietary fat intake and the risk of coronary heart disease in women. N Engl J Med 1997;337:1491—9.
[7] Slim RM, Toborek M, Watkins BA, Boissonneault GA, Henning B. Susceptibility to hepatic oxidative stress in rabbits fed different animal and plant fats. J Am Coll Nutr 1996;15:289—94.
[8] Ohara Y, Peterson TE, Harrison DG. Hypercholesterolemia increases endothelial superoxide production. J Clin Invest 1993;91:2546—51.
[9] Campia U, Sullivan G, Bryant MB, Waclawiw MA, Quon MJ, Panza JA. Insulin impairs endothelium-dependent

vasodilation independent of insulin sensitivity or lipid profile. Am J Physiol Heart Circ Physiol 2004;286:H76—82.
[10] Chahoud G, Aude YW, Mehta JL. Dietary recommendations in the prevention and treatment of coronary heart disease: do we have the ideal diet yet? Am J Cardiol 2004;94: 1260—7.
[11] Kok FJ, Kromhout D. Atherosclerosis—epidemiological studies on the health effects of a Mediterranean diet. Eur J Nutr 2004;(Suppl. 1):43. I/2—5.
[12] Dobarganes MC, Marquez-Ruiz G, Velazco J. Interactions between fat and food during deep frying. Eur J Lipid Sci Technol 2000;102:521—8.
[13] Williams MJ, Sutherland WH, McCormick MP, deLong SA, Walker RJ, Wilkins GT. Impaired endothelial function following a meal rich in used cooking fat. J Am Coll Cardiol 1999;33:1050—5.
[14] Clark WL, Serbia GW. Safety aspects of frying fats and oils. Food Technol 1991;45:75—81.
[15] Zhang WB, Addis PB. Prediction of level of cholesterol oxides in heated tallow by dielectric measurement. J Food Sci 1990;55:1380—5.
[16] Stone NJ. The optimal dietary strategy to manage risk associated with various dyslipidemias. Curr Cardiol Rep 2001; 3:391—400.
[17] Ong AS, Goh SH. Palm oil: a healthful and cost-effective dietary component. Food Nutr Bull 2002;23:11—22.
[18] Corretti M, Anderson T, Benjamin E, Celermajer D, Charbonneau F, Greager A, et al. Guidelines of the ultrasound assessment of endothelial-dependent flow-mediated vasodilation of the brachial artery. A report of the international brachial artery reactivity task force. J Am Coll Cardiol 2002;39:257—65.
[19] Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics; 1988.
[20] International union of pure and applied chemistry. Standard methods for the analysis of oils, fats and derivates. First supplement to the 7th edition. Oxford: Blackwell; 1992.
[21] Couzin J. Nutrition research. IOM panel weighs in on diet and health. Science 2002;297:1788—9.
[22] Norcross MA, Post AR. New food safety initiatives in the Food Safety and Inspection Service, U.S. Department of Agriculture. J Anim Sci 1990;68:863—9.
[23] Accini JL, Sotomayor A, Trujillo F, Barrera JG, Bautista L, López-Jaramillo P. Colombian study to assess the use of noninvasive determination of endothelium - mediated vasodilation (CANDEV). Set of normal values. Endothelium 2001;8:332—41.
[24] Vogel R, Corretti M, Plotnick G. Effects of single high-fat meal on endothelial function in healthy subjects. Am J Cardiol 1997;79:345—50.
[25] Gokce N, Duffy SJ, Hunter LM, Keaney JF, Vita JA. Acute hypertriglyceridemia is associated with peripheral vasodilation and increased basal flow in healthy young adults. Am J Cardiol 2001;88:153—9.
[26] Raitakari OT, Lai N, Griffiths K, McCredie R, Sullivan D, Celermajer DS. Enhanced peripheral vasodilation in humans after a fatty meal. J Am Coll Cardiol 2000;36:417—22.
[27] Vogel R, Corretti MC, Plotnick GD. The postprandial effects of components of the Mediterranean diet on endothelial function. J Am Coll Cardiol 2000;36:1455—60.
[28] Williams MJ, Sutherland WH, McCormick MP, Yeoman D, de Jong SA, Walker RJ. Normal endothelial function after meals rich in olive or safflower oil previously used for deep frying. Nutr Metab Cardiovasc Dis 2001;11:147—52.
[29] West SG, Hecker KD, Mustad VA, Nicholson S, Schoemer SL, Wagner P, et al. Acute effects of monounsaturated fatty acids with and without omega-3 fatty acids on vascular reactivity in individuals with type 2 diabetes. Diabetologia 2005;48:113—22.
[30] Title LM, Cummings PM, Giddens K, Nassar BA. Oral glucose loading acutely attenuates endothelium-dependent vasodilation in healthy adults without diabetes: an effect prevented by vitamins C and E. J Am Coll Cardiol 2000; 36:2185—91.
[31] Ceriello A, Taboga C, Tonutti L, Quagliaro L, Piconi L, Bais B, et al. Evidence for an independent and Cumulative effect of postprandial Hypertriglyceridemia and hyperglycemia on endothelial dysfunction and oxidative stress generation. Circulation 2002;106:1211—8.
[32] Plotnick G, Corretti M, Vogel R. Effect of antioxidant vitamins on the transient impairment of endothelium-dependent brachial artery vasoactivity following a single high-fat meal. JAMA 1997;278:1682—6.
[33] Djoussé L, Ellison C, McLennan C, Cupples L, Lipinska I, Tofler G, et al. Acute effects of a high-fat meal with and without red wine on endothelial function in healthy subjects. Am J Cardiol 1999;84:660—4.
[34] Stein JH, Keevil JG, Wiebe DA, Aeschlimann S, Folts JD. Purple grape juice improves endothelial function and reduces the susceptibility of LDL cholesterol to oxidation in patients with coronary artery disease. Circulation 1999; 100:1050—5.
[35] Gylling H, Miettinen TA. A review of clinical trials in dietary interventions to decrease the incidence of coronary artery disease. Curr Control Trials Cardiovasc Med 2001;2:123—8.
[36] Carluccio MA, Siculella L, Ancora MA, Massaro M, Scoditti E, Storelli C, et al. Olive oil and red wine antioxidant polyphenols inhibit endothelial activation: antiatherogenic properties of Mediterranean diet phytochemicals. Arterioscler Thromb Vasc Biol 2003;23:622—9.
[37] Marquez-Ruez G, Pere-Camino MD, Dobarganes MC. Evaluación nutricional de grasas termooxidadas y de fritura (Nutritional evaluation of frying and thermo-oxidated fats). Grasa y Aceite 1990;6:432—9.
[38] Steinberg HO, Tarshoby M, Monestel R, Hook G, Cronin J, Johnson A, et al. Elevated circulating free fatty acid levels impair endothelium-dependent vasodilation. J Clin Invest 1997;100:1230—9.
[39] de Man FH, Weverling-Rijnsburger AW, van der Laarse A, Smelt AH, Jukema JW, Blauw GJ. Not acute but chronic hypertriglyceridemia is associated with impaired endothelium-dependent vasodilation: reversal after lipid-lowering therapy by atorvastatin. Arterioscler Thromb Vasc Biol 2000;20:744—50.
[40] Leung KS, Lin A, Tsang CK, Yeung ST. Acrylamide in Asian foods in Hong Kong. Food Addit Contam 2003;20:1105—13.