Comparative cardiometabolic effects of diets with red palm olein, extra virgin coconut oil, and extra virgin olive oil in individuals with central obesity: a randomised trial

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MPOB

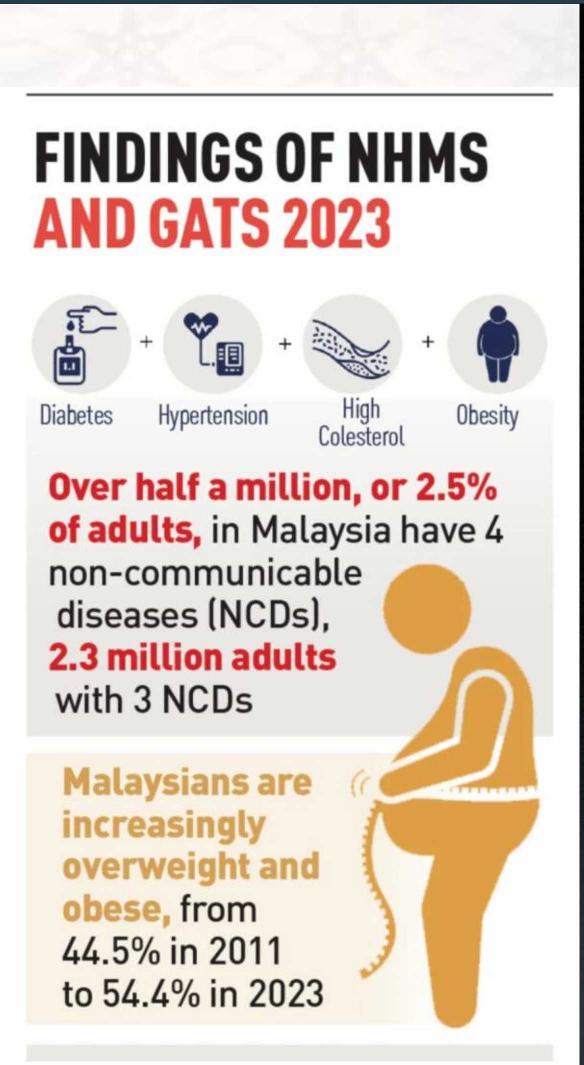
UPM UNIVERSITI PUTRA MALAYSIA BERILMU BERBAKTI

Presentation outline

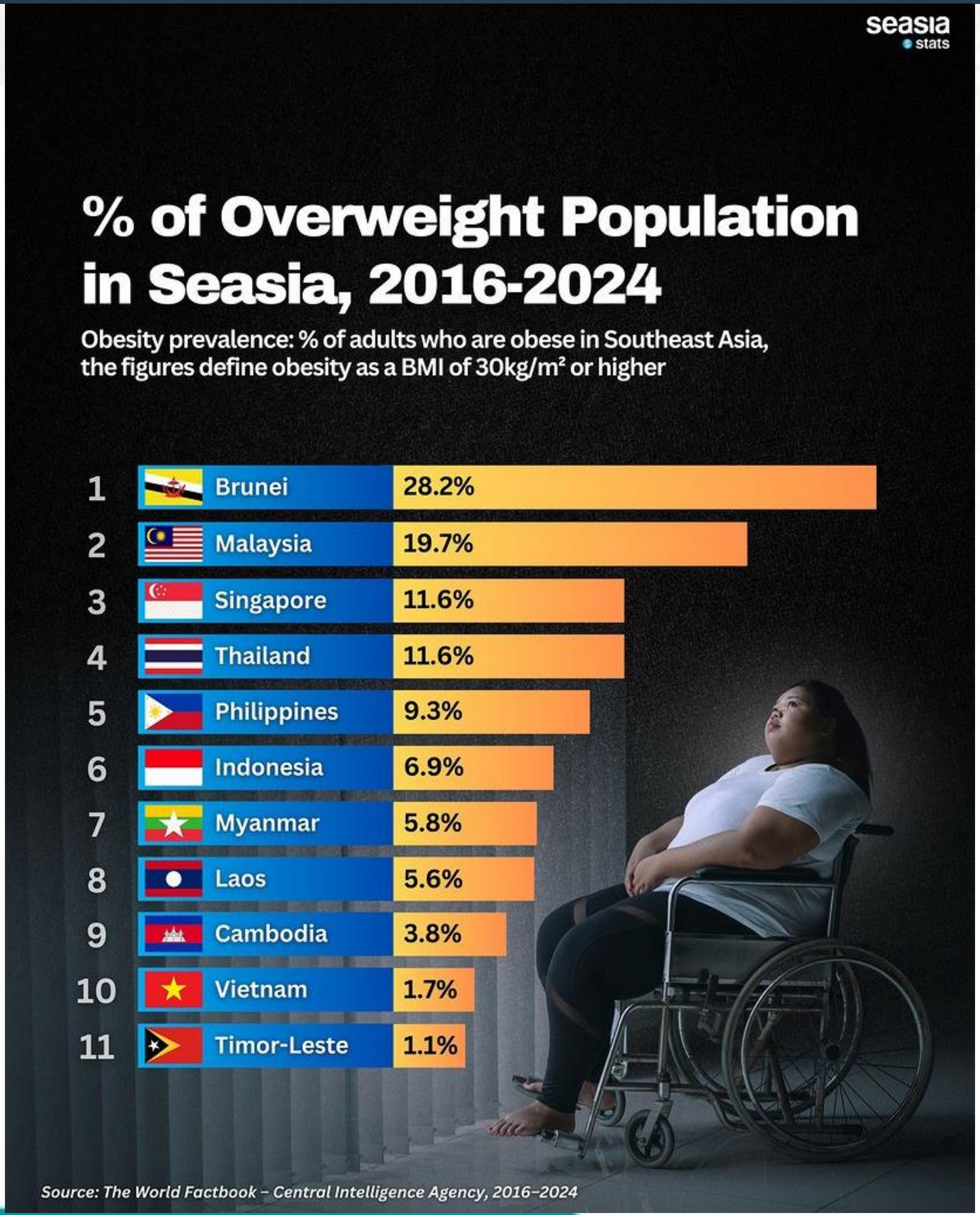
1. Introduction
2. Study Objective
3. Research Methodology
4. Results and Discussion
5. Conclusion

Presentation outline

Obesity related diseases



Picture: NST, 17 May 2024



SEDENTARY LIFESTYLE


Modern Technology

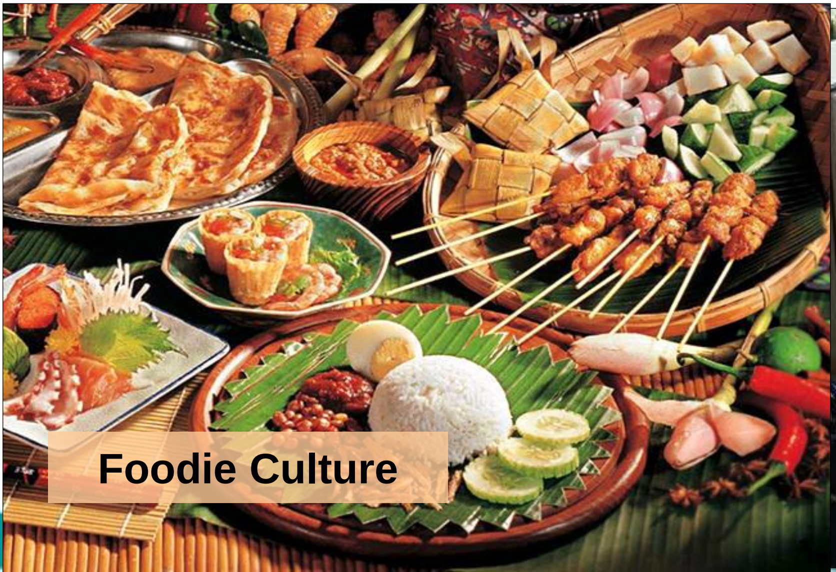

Alcohol/Smoke


Fast food


Lack of Exercise


Polution


Busy/Traffic/City Life

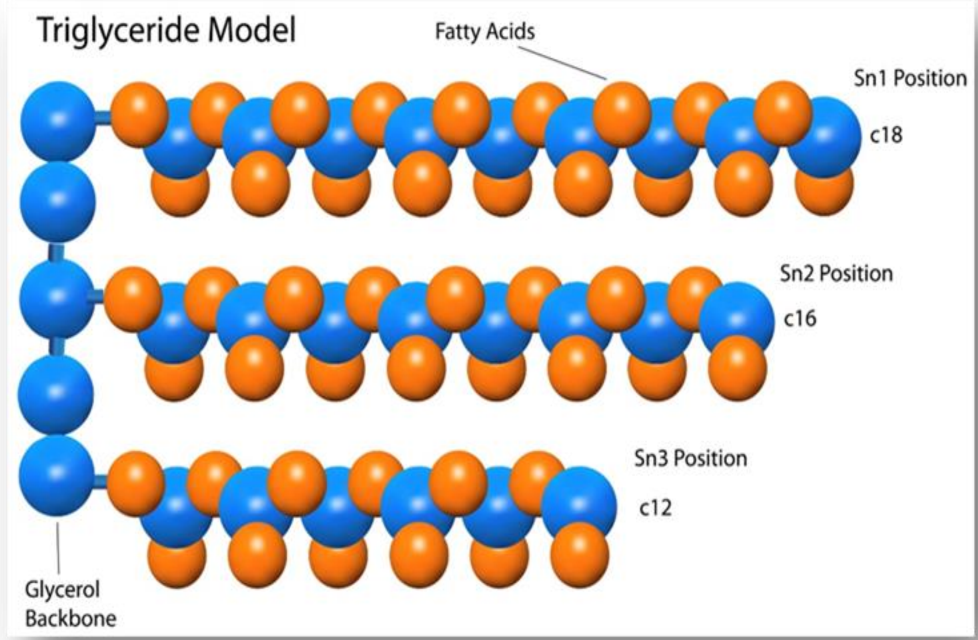

Foodie Culture


Couch Potato/Lazy/Entertainment

Stress

Does Fat make you FAT?

Fats and Oils



Types of Dietary Fats

Good Fat

Unsaturated

fatty acids

Polyunsaturated

Monounsaturated

Controversial Fat

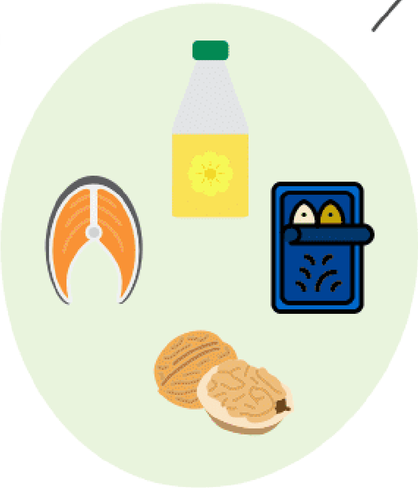
Saturated

fatty acids

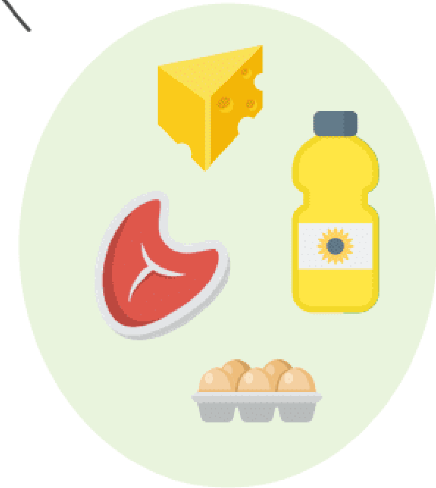
Bat Fat

Industrial « trans »

fatty acids

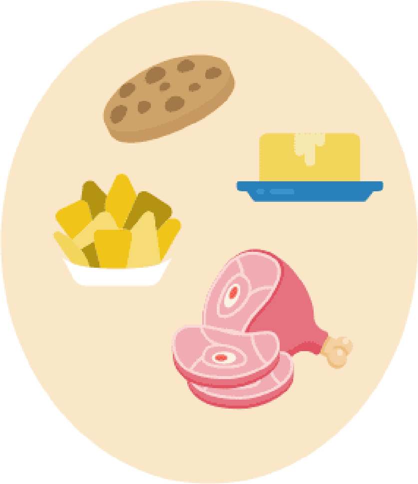


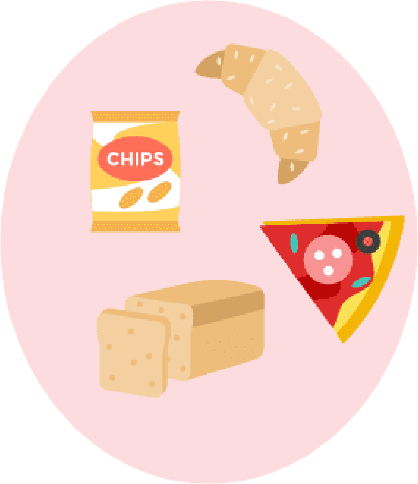
Omega-3



Omega-6

Omega-9

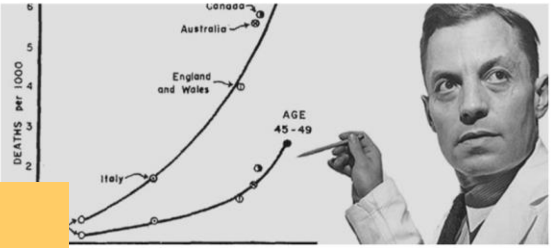




Saturated Fat Controversy

The entire lipid hypothesis was based on bad science - the flawed and fraudulent research of Ancel Keys

- **numerous methodological shortcomings were rebutted** (Teicholz, 2014; Heileson, 2020),
- **many critics were reported on the findings at that of time** (Ahrens, 1979; Council, 1980; Reiser. 1973: Shervin. 1978; Mann, 1978b)



...ently point out alleged flaws in the seminal study in order to contest its primary dietary ... saturated fat was correlated with heart disease, and call into question subsequent ...earch. This paper was commissioned by the True Health Initiative to explore the historical record and address the popular contentions with primary source material and related work, and in consultation with investigators directly involved. Popular criticisms directed at the study, and the lead investigator, Ancel Keys, turn out to be untrue when the primary source material is examined.

it came to big surprise when the long known "diet-heart theory" was recently proven manipulated by Ancel Keys (Ramsden et al., 2016).

- Ancel Keys cherry picked the data
- In his landmark Seven Countries Study which examined the association between dietary saturated fat and cardiovascular disease, Keys omitted data from countries like France, Germany, Switzerland and Sweden where fat intake is high yet they have less incidence of cardiovascular disease.
- This was done to help prove his hypothesis about fat causing heart disease.

RESEARCH

OPEN ACCESS

Re-evaluation of the traditional diet-heart hypothesis: analysis of recovered data from Minnesota Coronary Experiment (1968-73)

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ABSTRACT

OBJECTIVE
To examine the traditional diet-heart hypothesis through recovery and analysis of previously unpublished data from the Minnesota Coronary Experiment (MCE) and to put findings in the context of existing diet-heart randomized controlled trials through a systematic review and meta-analysis.

DESIGN
The MCE (1968-73) is a double blind randomized controlled trial designed to test whether replacement of saturated fat with vegetable oil rich in linoleic acid reduces coronary heart disease and death by lowering

oil polyunsaturated margarine). Control diet was high in saturated fat from animal fats, common margarines, and shortenings.

MAIN OUTCOME MEASURES
Death from all causes; association between changes in serum cholesterol and death; and coronary atherosclerosis and myocardial infarcts detected at autopsy.

RESULTS
The intervention group had significant reduction in serum cholesterol compared with controls (mean change from baseline −13.8% v −1.0%; P<0.001). Kaplan Meier graphs showed no mortality benefit for

Evolving View on Saturated Fats

Saturated fat intake shows no association with cardiovascular disease, myocardial infarction, or cardiovascular disease mortality and stroke

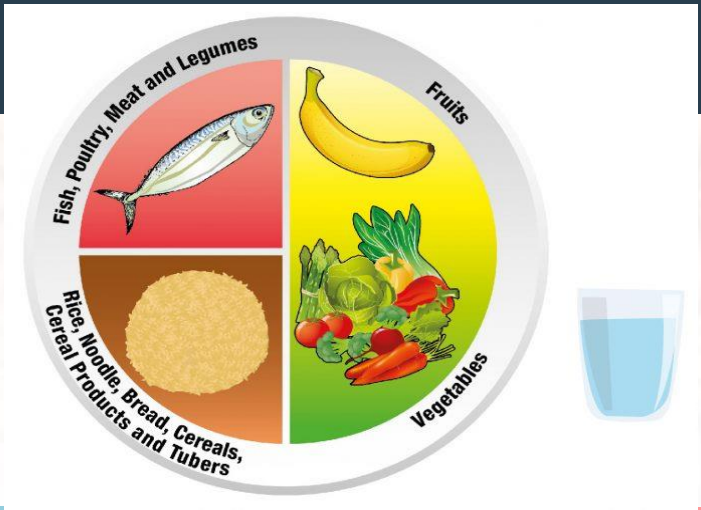
There are numerous :

- **reviews** (Heileson, 2020; Astrup et al., 2020; Astrup et al., 2019; Astrup et al., 2021; Mozaffarian, 2011; Gershuni, 2018),
- **systematic reviews** (Hooper et al., 2020; Astrup et al., 2011; Chowdhury et al., 2014; De Souza et al., 2015; Harcombe et al., 2015; Kang et al., 2020),
- **reviews on epidemiological studies** (Kannel and Gordon, 1968; Mann, 1978a; DuBroff and de Lorgeril, 2021), meta-analysis (Siri-Tarino et al., 2010; Heileson, 2020; Jakobsen et al., 2009; Farvid et al., 2014; Skeaff and Miller, 2009),
- **multicentre studies** (Laguzzi et al., 2021; Dehghan et al., 2017)

Balanced Diet is Important

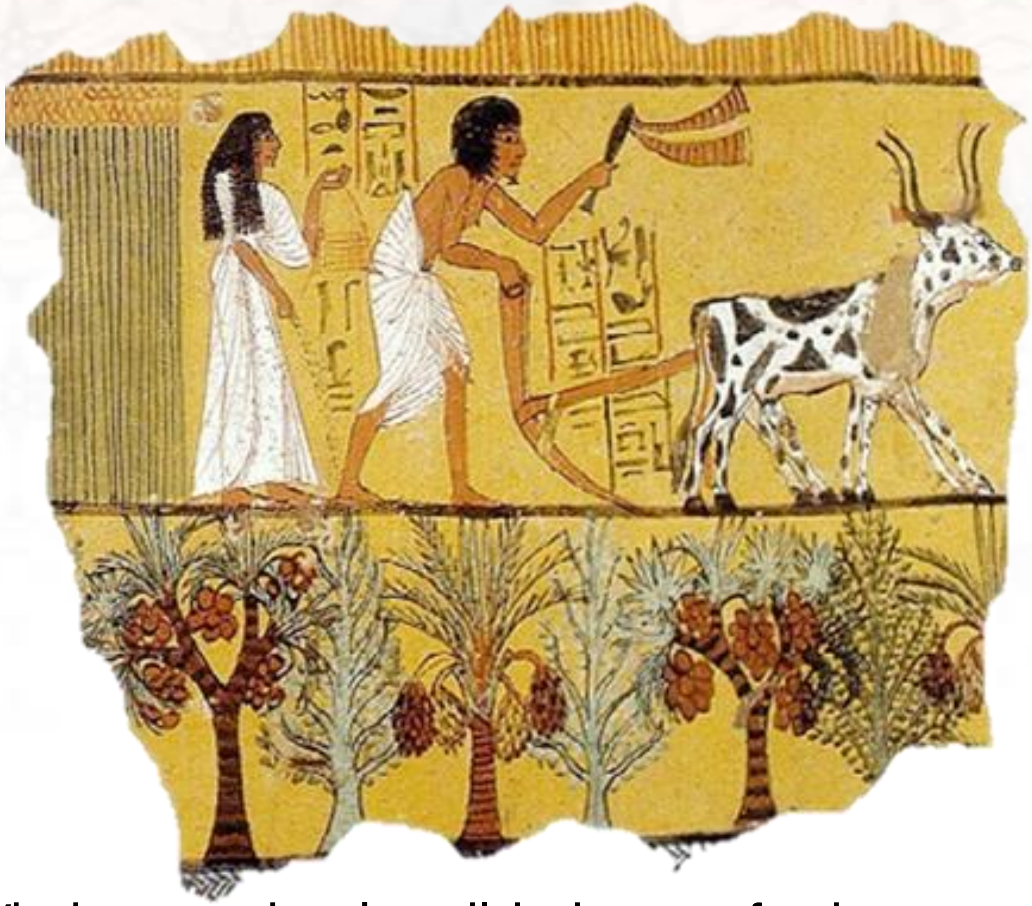
It's not FAT/SFA that makes one fat,

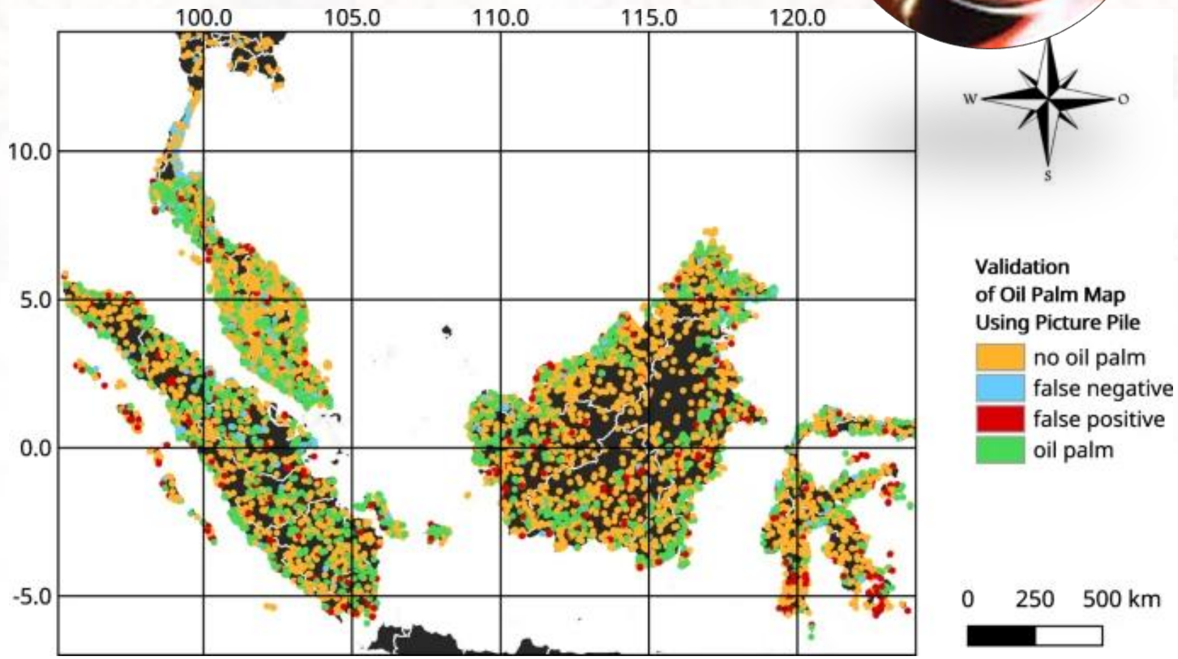
- *it's the amount of fat (too much-fried food!!!)*
- *large amounts of fat and carbohydrates i.e. Western diets*
- *Sugar*
- *Unbalanced fat intake: omega-6↑ relative to omega-3↓ intake*



Good Fat			Controversial Fat	Bat Fat
Unsaturated fatty acids			Saturated fatty acids	Industrial « trans » fatty acids
Polyunsaturated		Monounsaturated		
Omega-3	Omega-6	Omega-9		
encourage intake	limit intake	encourage intake	limit intake	avoid intake

Red Palm Oil: A Malaysian Treasure





(Danylo *et al.*, Scientific Data 2021)

Virgin or red palm oil is known for its versatility as both a food and health remedy for centuries. The oil was so highly valued that it was entombed with the pharaohs so that they would have access to it in the afterlife

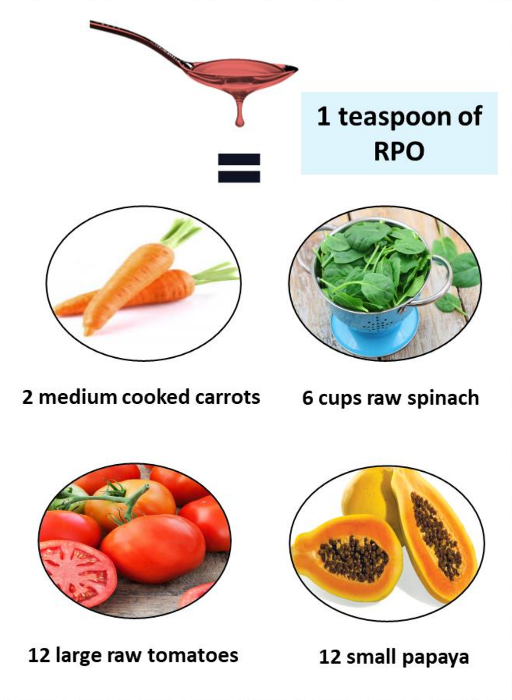
Red palm oil has not gained widespread usage despite the extensive production and utilization of RBD palm oil in countries like Malaysia and Indonesia

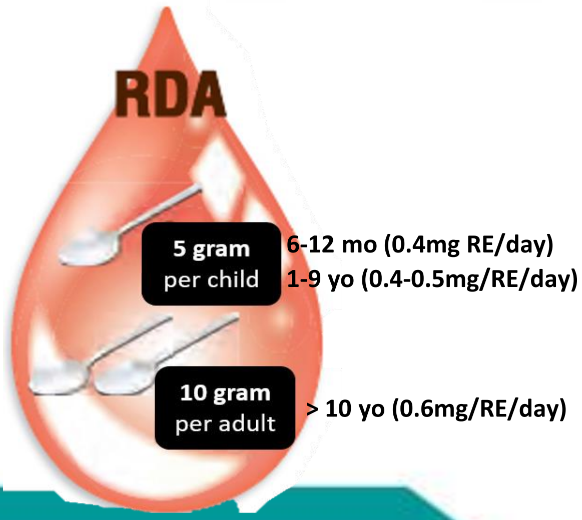
What's the difference?

Palm Oil		Red Palm Oil
Refined, bleached and deodorised (RBD)	Process	Molecular distillation method at low temperature
Carotenes are decomposed meanwhile other phytonutrients are retained	Yield	80% carotenes and vitamins present in crude palm oil could be retained

Red Palm Oil

- Richest plant sources of carotenoids (600-750 ppm)
- Natural
- Optimum absorption of carotenoids
- Beneficial for all age group
- Small quantity to fulfil RDA for vitamin A
- Rich in health-promoting phytonutrients

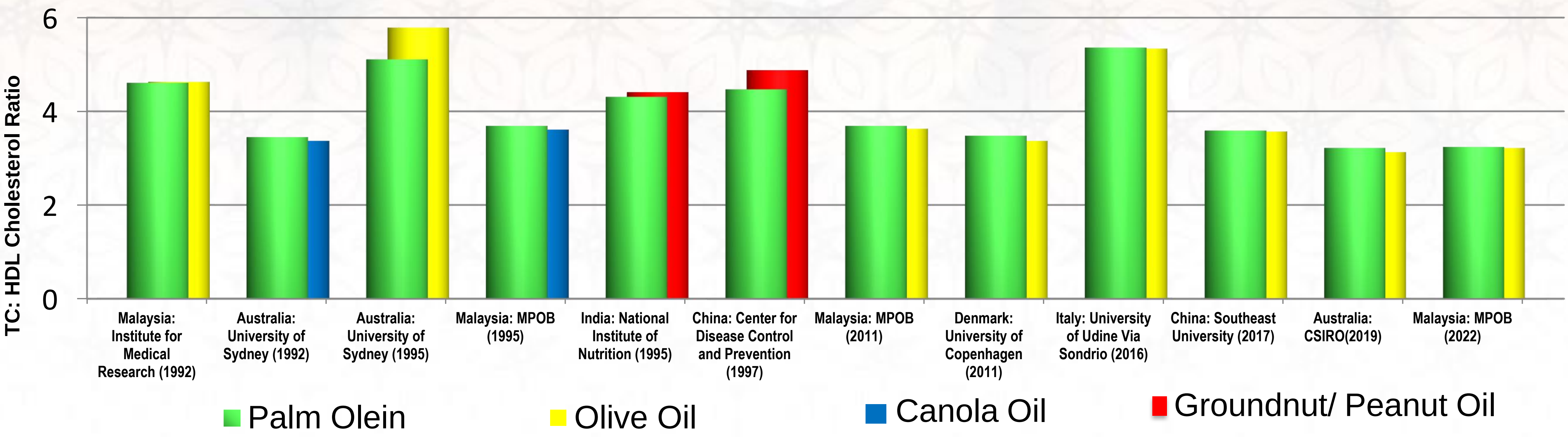




PHYTONUTRIENT (AMOUNT)	HEALTH BENEFITS
VITAMIN E (717–863 PPM)	*Composition : α-tocopherol (19%), α-tocotrienol (29%), γ-tocotrienol (41%), δ–tocotrienol (10%) Health benefits: anti-cancer, anti-angiogenic, anti-oxidant, anti-atherosclerotic, cardioprotective, and neuroprotective properties, inhibits cholesterol synthesis, aids in diabetes management
CAROTENOIDS (600–750 PPM)	*Composition: phytoene (0.2%), phytofluene (0.6%), β-carotene (41.0%), α-carotene (41.3%), cis-α-carotene (10.2%), ζ-carotene (0.6%), γ-carotene (0.8%), δ-carotene (0.8%), neurosporene (0.2%), β-zeacarotene (1.3%), α-zeacarotene (0.5%), lycopene (1.0%) Health benefits: provitamin A activity, cardioprotective and anti-cancer properties, prevents night blindness
PHYTOSTEROLS (325–365 PPM)	*Composition: cholesterol (6.6–11.5 ppm), campesterol (76–83 ppm), stigmasterol (59–64 ppm), β-sitosterol (187–218 ppm), unknown (<6 ppm) Health benefits: cholesterol-lowering properties, anti-cancer activity, enhances immune function
SQUALENE (14–15 PPM)	Health benefits: cardioprotective, radioprotective, and anti-cancer activity, inhibits cholesterol synthesis
CO-ENZYME Q10 (18–25 PPM)	Health benefits: enhances production of cellular energy, antioxidative defense mechanism, cardioprotective and anti-cancer activity

(Loganathan R., *et al*, Nutrition Reviews, 2017)

Chronic Human Studies: Palm Olein Vs Unsaturated Oils



Palm olein behaves more like a monounsaturated oil in its effects on blood cholesterol levels, although it contains saturated fatty acids

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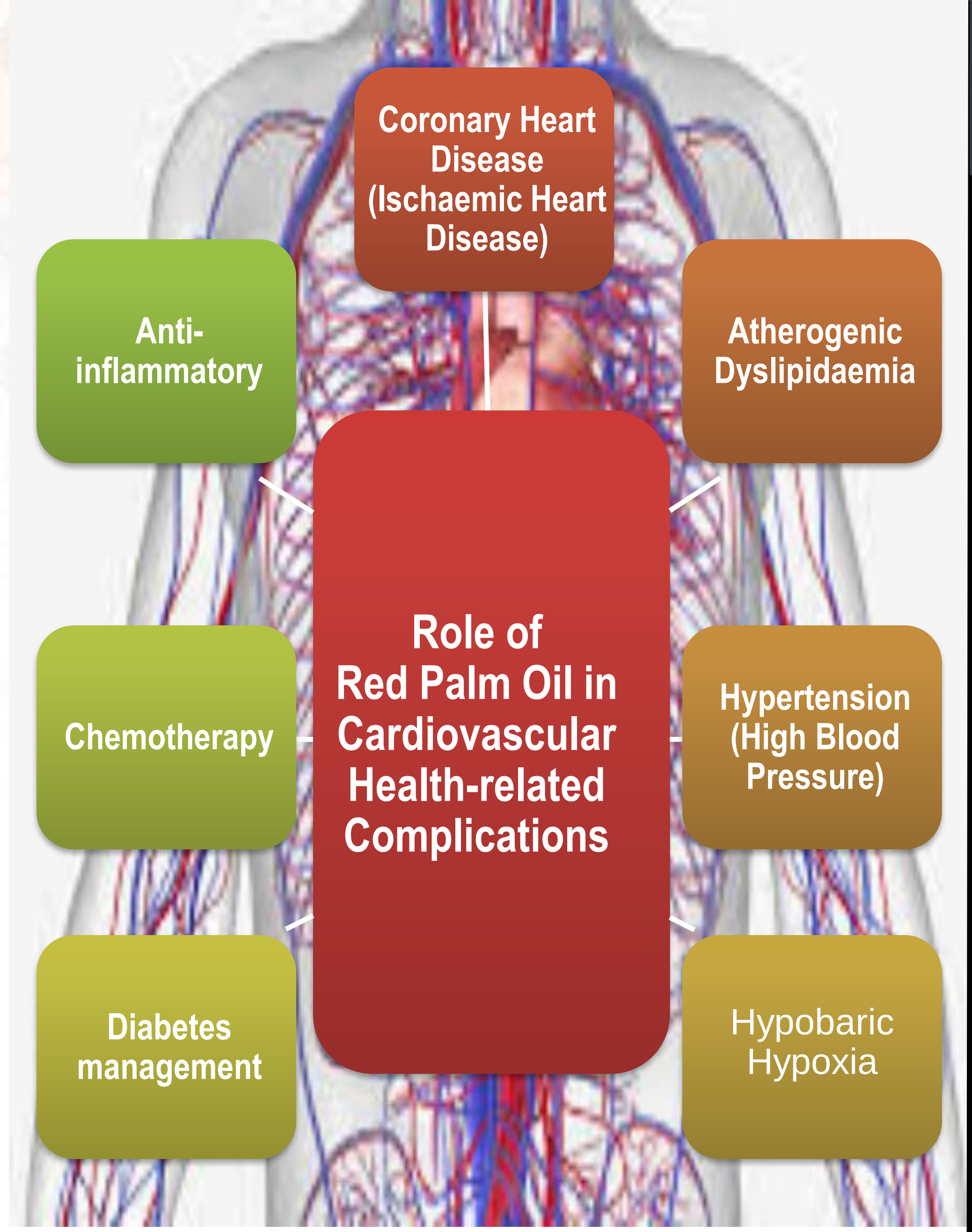

Loganathan et al, 2017

Chronic Human Studies: Red Palm Olein Vs Unsaturated Oils

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https://doi.org/10.1038/s41430-018-0236-5

ARTICLE

Lipids and cardiovascular/metabolic health

Red palm olein supplementation on cytokines, endothelial function and lipid profile in centrally overweight individuals: a randomised controlled trial

Radhika Loganathan[1,2] · Shireene Ratna Vethakkan[2] · Ammu K. Radhakrishnan[3] · Ghazali Abd Razak[1] · Teng Kim-Tiu[1]

Loganathan *et al* 2018	
Study Design	RCT(6-week crossover)
Subjects	n=53 free-living high-risk abdominally overweight subjects (32.83 ± 9.18 years old)
Dietary Intervention	Control arm: Palm Olein Experimental arm: Red Palm Olein
Outcomes	1) Inflammatory markers (IL-6, IL-1b, TNF-a, hsCRP): no difference 5) Retinol and RBP: no difference 6) Antioxidants (a-tocopherol, a-carotene, b-carotene): RPOo ↑
Remarks	RPO increases circulating antioxidants, reduce pro-atherogenic marker (oxidized LDL) and does not raise cholesterol levels.

Scholtz et al., 2004

Baked products containing:
Control arm:
- Sunflower Oil
- Palm Olein

Experimental arm:
- Red Palm Olein

Zhang et al., 2003

Control arm:
- Soybean Oil

Experimental arm:
- Red Palm Olein

Oimedilla et al., 1992

Control arm:
- Corn Oil

Experimental arm:
- Red Palm Olein
- Lutein
- Lycopene

Similarly, red palm olein behaves more like unsaturated oils in its effects on blood cholesterol levels

1. *Loganathan et al. 2018 Eur. J. Clin. Nutr.*
2. *Scholtz et al 2004, Thromb. Res.*
3. *Zhang et al 2003, Biomed. Environ. Sci.*
4. *Olmedilla et al 1992,*

Objective

EXTRA VIRGIN OLIVE OIL

Gold standard among all edible oils. Mediterranean diet and consumption of olive oil are associated with a low incidence of CVD.

Major Phytonutrients:

- **Vitamin E (150 to 200 mg/kg):** a-tocopherol (90%)
- **Total sterols (1000mg/kg):** b-sitosterol + d-5-avenasterol + d-5-23-stigmastadienol + clerosterol + sitostanol + d-5-24-stigmastadienol (>93%)
- **Total phenolic compound (40–530 mg GAE/kg)**

(Codex Alimentarius , 2003)

RED PALM OLEIN

Major Phytonutrients:

- **Vitamin E (717–863 mg/kg):** a-tocopherol (19%), a-tocotrienol (29%), g-tocotrienol (41%), d-tocotrienol (10%)
- **Carotenoids (600-750mg/kg):** b-carotene (41.0%), a-carotene (41.3%), cis-a-carotene (10.2%),
- **Phytosterols (325-365mg/kg):** campesterol (76–83 mg/kg), stigmasterol (59–64 mg/kg), b-sitosterol (187–218 mg/kg)
- **Squalene (14–15 mg/kg)**
- **Co-enzyme Q10 (18-25mg/kg)**

EXTRA VIRGIN COCONUT OIL

Coconut oil – super health food, claimed to be anti-inflammatory and weight loss promoting

Major Phytonutrients:

- **Total sterols (400-1200mg/kg):** Campesterol (6-11.2%), Stigmasterol (11.4-15.6%), b-sitosterol (32.6-50.7%), d-5-avenasterol (20-40.7%)
- **Vitamin E (0-50mg/kg)**

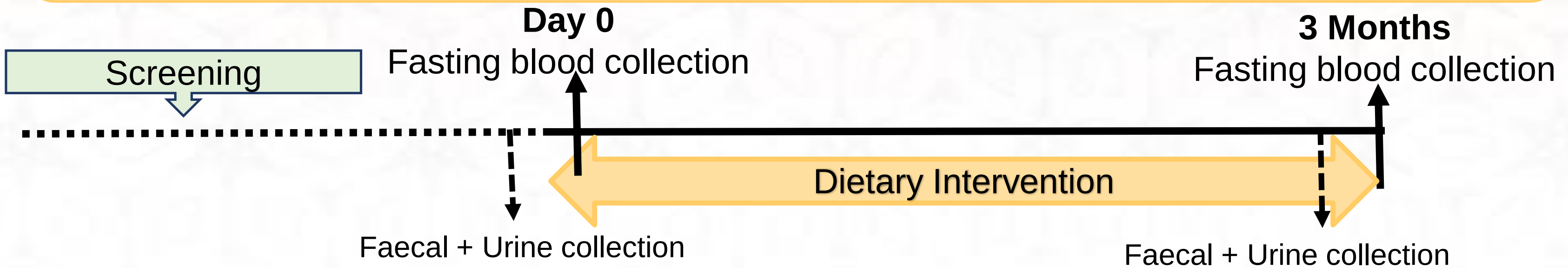
(Codex Alimentarius , 2003)

Red Palm Oil as Premium Oil

1. Introduction
2. Study Objective
3. **Research Methodology**
4. Results and Discussion
5. Conclusion

Study Design

Study Design: Randomised, single-blind, parallel study with 156 centrally overweight subjects.
Study Groups:
1. Red palm olein
2. Extra virgin coconut oil
3. Extra virgin olive oil



Outcome Measurement:

I. Lipid profile: Total cholesterol, LDL-choleterol, HDL-cholesterol, triacylglycerol, apolipoprotein A-1, apolipoprotein B-100, lipid subfractions
II. Plasma Inflammatory Response: IL-1Beta, TNF-Alpha, IL-6
III. Plasma Fatty Acid Composition
IV. Plasma Endothelial Function and Oxidative Stress: sICAM-1, sVCAM-1, fibrinogen
V. Plasma antioxidants: carotenes, retinol, RBP-4, α-tocopherol, total phenolic content
VI. Gut microbiome
VII. Subset: Dual-energy X-ray Absorptiometry (DEXA) Scan

Ethical Approval: JKEUPM (Ethic Committee For Research Involving Human Subject);
National Medical Research Register ID (NMRR-18-1628-42457);
Guidelines: Declaration of Helsinki; The trial was registered at ClinicalTrial.gov (NCT05791370).

Figure 1: Study Design

1) The dining hall of Nutrition Unit, MPOB

2) Chancellery Putra building, UPM

3) Corridor of the Department of Human Anatomy, UPM

Figure 2: Study Sites

Participation

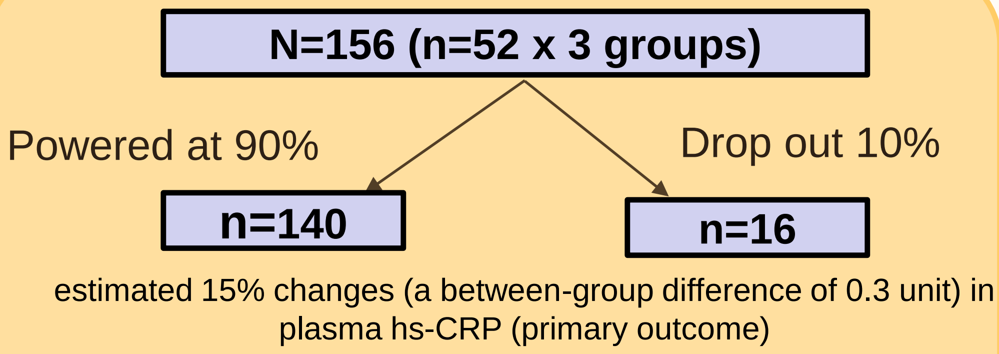


Figure 3: Sample Size Calculation

Inclusion criteria

- waist circumference of > 90cm for men and > 80 cm for women
- Age; 25-45years old
- BMI; ≥18.5kgm2

Exclusion criteria

- Medical history of myocardial infarction, angina, thrombosis, stroke, cancer or diabetes
- Blood glucose; >7.0 mmol/L
- Serum triglyceride; >4.5 mmol/L
- Serum total cholesterol; >6.5 mmol/L
- Body mass index <18.5 kg/m2
- Current use of antihypertensive or lipid-lowering medication
- Alcohol intake exceeding a moderate intake (>28 units per week)
- Breastfeeding or pregnant
- Consume supplements such as herbs and hormone pills
- Smoking

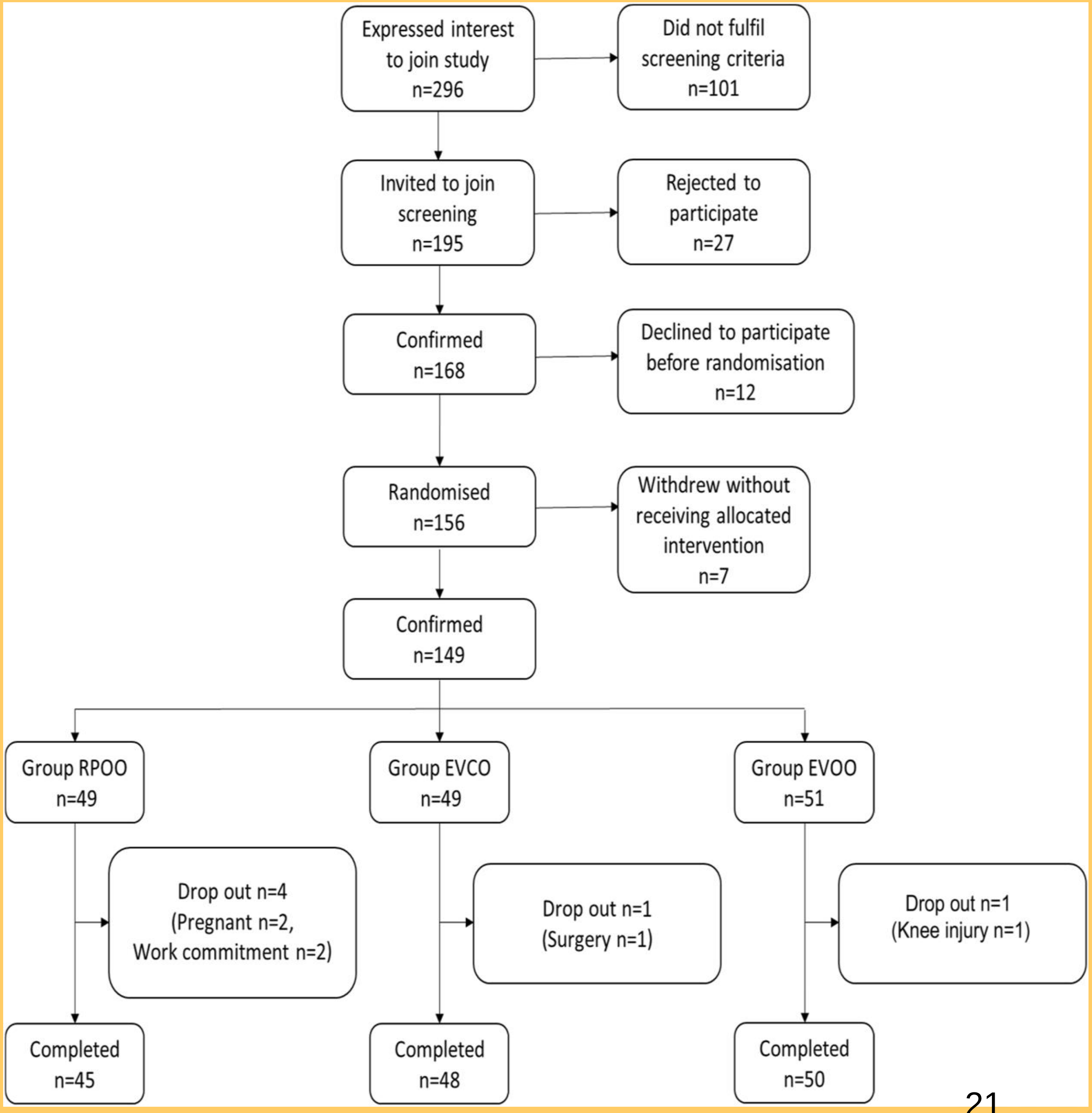


Figure 4. The flow of participants through the study

Experimental Oils

Table 1: Composition of experimental oils

Variables	RPOO	EVCO	EVOO
Fatty acid composition [3]			
SAFAs (%)	**42.2±0.02**	**84±0.03**	**12.7±0.01**
– **Lauric acid (C12:0)**	n.d.	45.29±0.03	n.d.
– **Myristic acid (C14:0)**	1.12±0.01	16.28±0.01	n.d.
– **Palmitic acid (C16:0)**	37.28±0.02	7.48±0.01	9.26±0.01
MUFAs (%)	**44.18±0.03**	**4.61±0.03**	**75.53±0.02**
– **Oleic acid (C18:1 n9c)**	43.96±0.05	4.61±0.03	74.86±0.02
PUFAs (%)	**13.62±0.05**	**11.37±0.02**	**11.15±0.06**
– **Linoleic acid (C18:2n6c)**	12.91±0.02	11.37±0.02	10±0
Phytonutrients			
Total carotenoids (μg/kg) [4]	**393.0±0.78**	85.3±0.25	87.4±0.33
Vitamin E (μg/kg) [5]	**808.61±1.38**	38.62±0.07	225.76±0.26
Total tocopherols	196.42±0.80	4.45±0.05	213.88±0.32
– **α-tocopherol**	128.55±2.03	4.45±0.05	196.85±0.71
– **β-tocopherol**	2.35±0.38	n.d.	2.74±0.09
– **γ-tocopherol**	47.85±0.90	n.d.	14.19±0.10
– **δ-tocopherol**	17.67±0.30	n.d.	0.11±0.03
Total tocotrienols	612.19±1.81	34.17±0.10	11.88±0.26
– **α-tocotrienol**	227.08±3.65	21.77±0.24	3.62±0.04
– **β-tocotrienol**	15.65±0.62	1.36±0.06	1.08±0.13
– **γ-tocotrienol**	282.21±3.77	8.81±0.07	5.50±0.60
– **δ-tocotrienol**	87.25±0.52	2.23±0.02	1.67±0.08
Total phenolic content (mg GAE/g sample) [6]	31.13±1.95	15.13± 3.75	**192.87±1.64**

[1] Abbreviation: RPOO, red palm olein; EVCO, extra virgin olive oil; EVOO, extra virgin olive oil; n.d. not detectable; SAFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; GAE, gallic acid equivalent; [2] All readings are duplicates of analysis, mean value±SD; [3] Analysed using gas chromatography; [4] Analysed using UV spectrophotometer; [5] Analysed using HPLC; [6] Analysed by Folin–Ciocalteu method; PUFA was standardized using safflower oil (10%) for EVCO.

Experimental Diets

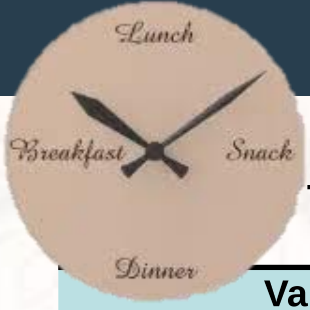


Table 2: Composition of experimental diets

Variables	Target	RPOO diet	EVCO diet	EVOO diet
Total calorie (kcal/day)	**2000**	**2399±327**	**2399±327**	**2399±327**
Protein (%E)	**15**	**17±3**	**17±3**	**17±3**
Carbohydrates (%E)	**55**	**52±7**	**52±7**	**52±7**
Fat (%E)	**30**	**27.6±7.3**	**27.6±7.3**	**27.6±7.3**
SAFAs (%)		**10.34±0.0**	**19.96±0.00**	**3.11±0.02**
– **Lauric acid (C12:0)**		n.d.	12.76±0.00	n.d.
– **Myristic acid (C14:0)**		0.27±0.00	4.58±0.00	n.d.
– **Palmitic acid (C16:0)**		9.14±0.00	1.91±0.00	2.27±0.01
MUFAs (%)		**11.41±0.53**	**1.56±0.53**	**19.15±0.57**
– **Oleic acid (C18:1 n9c)**		11.35±0.53	1.56±0.53	18.92±0.55
PUFAs (%)		3.80±0.55	3.62±0.66	3.19±0.64
– **Linoleic acid (C18:2n6c)**		3.56±0.47	3.56±0.54	2.84±0.47
Dietary fibre (g)		18.3±8.1	18.3±8.1	18.3±8.1

[1] Abbreviations: RPOO, red palm olein; EVCO, extra virgin olive oil; EVOO, extra virgin olive oil; n.d. not detectable; kcal, kilocalorie; % E, percentage energy; SAFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids
[2] All readings are duplicates of analysis, mean value±SD
[3] Calculated using NutritionistPro Software (AXXYA System, LLC, TX, USA)

Baseline Characteristics

Table 3: Baseline characteristics of participants with central obesity who had completed a 12-week

Variables	RPOO (n=45)	EVCO (n=48)	EVOO (n=50)
Age (year)	34.98 ± 0.98	34.71 ± 1.04	34.56 ± 0.89
Ethnicity (n)			
Malay	42	48	49
Chinese	1	0	1
Indian	1	0	0
Physical characteristics			
Gender (n)			
Female	38	39	41
Male	6	9	9
Weight (kg)	77.82 ± 2.28	74.79 ± 2.22	73.69 ± 2.33
Height (cm)	159.98 ± 1.07	159.67 ± 0.99	159.94 ± 1.20
BMI (kg/m²)	30.25 ± 0.74	29.28 ± 0.78	28.66 ± 0.75
Waist circumference (cm)	95.60 ± 1.62	94.35 ± 1.71	93.53 ± 1.55
Body fat percent (%)	39.87 ± 1.12	37.99 ± 1.13	37.12 ± 1.11

Abbreviation: RPOO, red palm olein; EVCO, extra virgin olive oil; EVOO, extra virgin olive oil.
Summary statistics presented in mean±SEM. P value adjustment was done using the Benjamini-Hochberg method. All three diet groups did not have statistically significant differences in mean for all the variables ($P > 0.05$).

Compliance and Monitoring Measures

Table 4: Measures and monitoring of compliance for meal, snack and weekend oil consumption of participants with central obesity who had completed a 12-week dietary intervention

Variables	RPOO (n=49)	EVCO (n=49)	EVOO (n=51)
Attendance (%)	90.83 ± 1.06	92.63 ± 0.96	92.76 ± 0.73
Total nett oil usage for weekends (kg)	1.59 ± 0.13	1.49 ± 0.15	1.66 ± 0.12
Snack summary (%)	64.3 ± 4.96	65.64 ± 4.72	69.91 ± 4.22
VAS acceptability (%)	6.93 ± 0.24	6.85 ± 0.24	6.76 ± 0.22
VAS palatability (%)	6.90 ± 0.23	6.76 ± 0.23	6.71 ± 0.23

Abbreviation: RPOO, red palm olein; EVCO, extra virgin olive oil; EVOO, extra virgin olive oil; VAS, visual analogue scale
Summary statistics presented in mean±SEM. P value adjustment was done using the Benjamini-Hochberg method. All three diet groups did not have statistically significant differences in mean for all the variables ($P > 0.05$).

Plasma Inflammatory Markers : no differences between groups

Table 5: Cardiometabolic risk markers in participants with central obesity who had completed a 12-week dietary intervention

Variables	RPOO diet (n=44)	EVCO diet (n=48)	EVOO diet (n=50)	ANCOVA p-value (Interaction effects)	ANCOVA p-value (Main effects)
Plasma inflammatory markers					
hs-CRP (mg/L) -(Primary outcome)	5.48 (3.28,7.68)	4.45 (2.81,6.09)	4.63 (2.64,6.63)	<0.01*	-
IL-6 (pg/mL)	5.15 (3.6, 6.7)	8.66 (5.71,11.61)	7.3 (5.47,9.14)	0.58	0.91
IL-1β (pg/mL)	1.67 (1.15, 2.19)	1.85 (1.39,2.31)	2.41 (1.85,2.97)	0.09	0.49
TNF-α (pg/mL)	3.15 (2.42, 3.89)	3.29 (2.55,4.03)	4.79 (3.73,5.84)	0.49	0.22
sICAM-1 (ng/mL)	335.3 (312.66,357.96)	320.18 (303.75, 336.61)	355.43 (317.75,393.12)	<0.01*	-
sVCAM-1 (ng/mL)	697.63 (652.74,742.53)	668.88 (636.02, 701.75)	750.07 (703.88,796.25)	0.64	0.21

Abbreviation: EVOO, extra virgin olive oil; EVCO, extra virgin olive oil; hs-CRP, high sensitivity C-reactive protein; IL-6, interleukin-6; IL-1b, interleukin 1b; RPOO, red palm olein; sICAMs, soluble intercellular adhesion molecules; sVCAMs, soluble intravascular adhesion molecules; TNF-a, tumour necrosis factor-a.

Summary statistics are presented in mean, with corresponding 95% CI. For each of these markers, an initial ANCOVA model with main and interaction effects was fitted; the smallest P value for the ANCOVA regression coefficients of interaction effects is given. If statistical significance (*P* < 0.05) is absent, then an ANCOVA model with only main effects was fitted; the smallest *P* value of the ANCOVA regression coefficients of main effects is given. Variables with statistically significant results are flagged by an asterisk. For these variables, pairwise group comparisons of the residuals of regressing the variable at the endpoint against baseline were done using the two-sample t-test.

Antioxidants Markers : ↑ α- and β-carotenes with RPOO diet

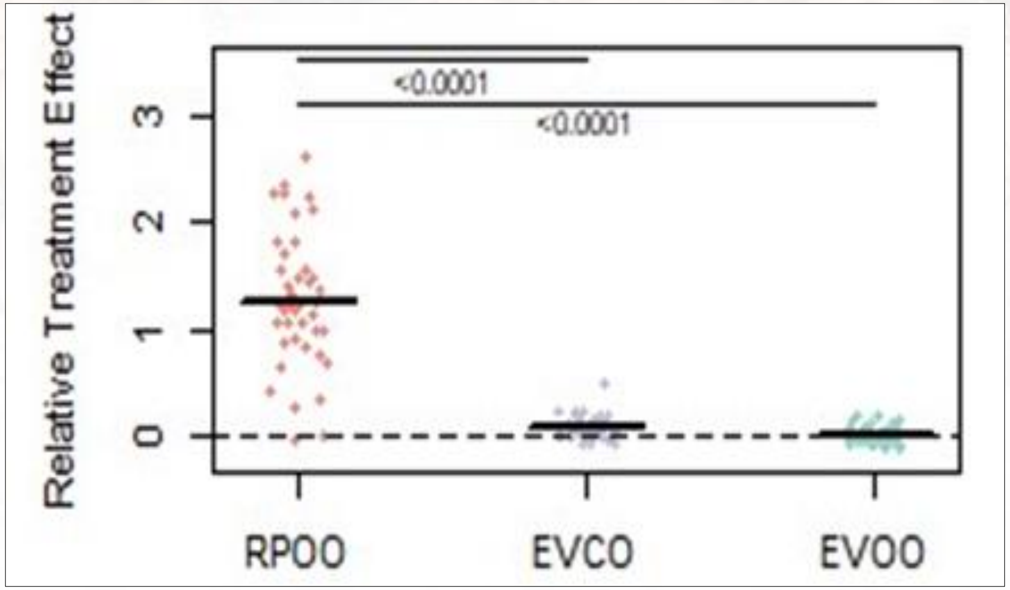
Table 5: Plasma and urine antioxidant markers in participants with central obesity who had completed a 12-week dietary intervention

Variables	RPOO diet (n=44)	EVCO diet (n=48)	EVOO diet (n=50)	Interaction effects	Main effects
Plasma antioxidants					
– **α-carotene (µg/mL)**	**1.55 (1.36,1.73)**	**0.32 (0.28,0.36)**	**0.27 (0.23,0.3)**	0.47	**<0.01***
– **β-carotene (µg/mL)**	**1.75 (1.56,1.94)**	**0.9 (0.77,1.03)**	**0.8 (0.69,0.91)**	0.53	**<0.01***
– **Retinol (µmol/L)**	1.29 (1.21,1.36)	1.29 (1.21,1.36)	1.21 (1.14, 1.29)	0.53	0.17
– **RBP4 (ng/mL)**	24899.43 (23030.85,26768.01)	24907.29 (23096.55,26718.03)	24300.1 (22305.27,26294.93)	0.25	0.32
– **α-tocopherol (µg/mL)**	**11.47 (10.76,12.18)**	**10.99 (10.38,11.59)**	**10.68 (10.08,11.28)**	0.34	**0.04***
Urine antioxidant					
– **Total phenolic content (GAE), mg/mL**	390.69 (313.35,468.03)	370.32 (322.63,418.01)	384.62 (330.34,438.9)	0.08	0.33

Abbreviation: EVOO, extra virgin olive oil; EVCO, extra virgin olive oil; GAE, gallic acid equivalent; RBP4, retinol binding protein 4;RPOO, red palm olein.
Summary statistics are presented in mean, with corresponding 95% CI. For each of these markers, an initial ANCOVA model with main and interaction effects was fitted; the smallest P value for the ANCOVA regression coefficients of interaction effects is given. If statistical significance ($P < 0.05$) is absent, then an ANCOVA model with only main effects was fitted; the smallest *P* value of the ANCOVA regression coefficients of main effects is given. Variables with statistically significant results are flagged by an asterisk. For these variables, pairwise group comparisons of the residuals of regressing the variable at the endpoint against baseline were done using the two-sample t-test.

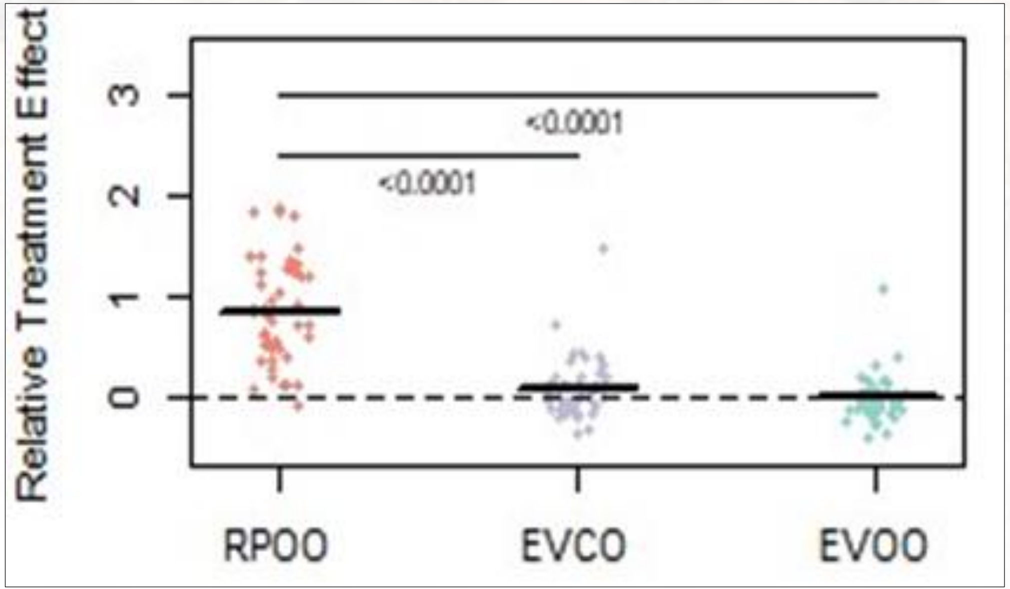
Antioxidants Markers : ↑ α- and β-carotenes with RPOO diet

(a) α-carotene



(µg/mL)	RPOO	EVCO	EVOO
Baseline	0.21 ± 0.11	0.18 ± 0.09	0.19 ± 0.12
Endpoint	1.55 (1.36,1.73)	0.32 (0.28,0.36)	0.27 (0.23,0.3)

(b) β-carotene



(µg/mL)	RPOO	EVCO	EVOO
Baseline	0.76 ± 0.35	0.66 ± 0.3	0.68 ± 0.34
Endpoint	1.75 (1.56,1.94)	0.9 (0.77,1.03)	0.8 (0.69,0.91)

Figure 5: Distribution of the relative treatment effect (a) α-carotene; and (b) β-carotene; in participants with central obesity who completed a 12-week dietary intervention with red palm olein (RPOO), extra virgin coconut oil (EVCO), or extra virgin olive oil (EVOO).

Statistically significant comparisons between two groups (two-sample t-tests) are indicated by a horizontal bar linking the two groups, with Benjamini-Hochberg adjusted P value given below the bar.

Lipid Profile : clinically insignificant changes on LDL and TC:HDL,

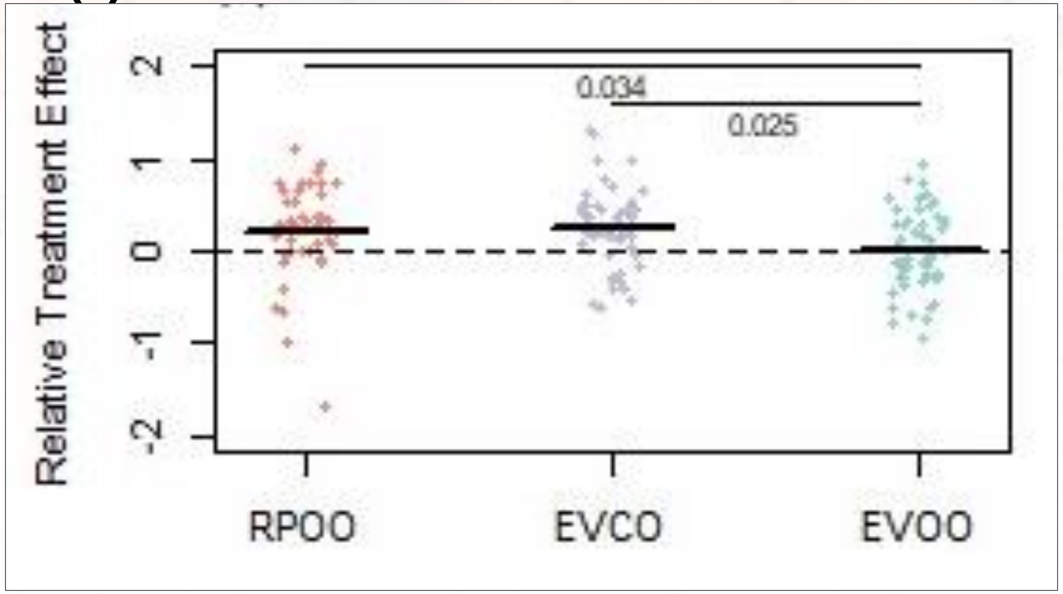
Table 6: Plasma lipid and lipoproteins in participants with central obesity who had completed a 12-week dietary intervention

Variables	RPOO diet (n=44)	EVCO diet (n=48)	EVOO diet (n=50)	Interaction effects	Main effects
Plasma lipid profile					
Total cholesterol (mmol/L)	4.67(4.41,4.93)	4.85 (4.6,5.1)	4.47 (4.25,4.69)	0.15	0.11
LDL cholesterol (mmol/L)	**2.91 (2.71,3.11)**	**3.0 (2.83,3.21)**	**2.6 (2.45,2.82)**	0.27	**0.02***
Mean LDL particle size (nm)	269.95 (268.47,271.44)	270.25 (269.29,271.21)	269.2 (267.77,270.63)	<0.01*	-
Small dense LDL (%)	2.22 (1.15,3.3)	1.8 (1.12,2.48)	2.47 (1.46,3.49)	<0.01*	-
HDL cholesterol (mmol/L)	1.24 (1.15,1.34)	1.3 (1.2,1.39)	1.2 (1.2,1.37)	0.24	0.64
HDL-2 (%)	11.67 (10.82,12.38)	11.16 (10.31,12.01)	11.34 (10.52,12.16)	0.15	0.23
HDL-3 (%)	9.45 (8.72,10.12)	9.15 (8.43,9.86)	9.2 (8.48,9.97)	0.27	0.48
Small HDL particle (%)	23.57 (20.99,26.15)	22.31 (20.91,23.72)	26.1 (23.37,28.83)	0.38	0.38
Intermediate HDL particle (%)	48.58 (47.67,49.49)	46.89 (44.53,49.24)	48.26 (47.38,49.14)	0.11	0.37
Large HDL particle (%)	29.15 (27.17,31.13)	28.19 (26.18,30.21)	25.05 (22.02,28.08)	0.17	0.46
Triacylglycerol (mmol/L)	1.13 (0.98,1.28)	1.18 (1.01,1.35)	1.21 (1.04,1.39)	0.77	0.62
Total: HDL cholesterol	**3.8 (3.63,4.14)**	3.86 (3.65,4.08)	**3.6 (3.36,3.83)**	0.39	**0.02***
VLDL cholesterol (mmol/L)	1.11 (1.04,1.18)	1.17 (1.1,1.24)	1.07 (1.01,1.13)	0.14	0.12
Apolipoprotein B-100 (g/L)	**0.99 (0.92,1.05)**	**0.98 (0.93,1.03)**	**0.91 (0.85,0.96)**	0.26	**0.02***
Apolipoprotein A-1 (g/L)	1.43 (1.35,1.5)	1.47 (1.39,1.54)	1.49 (1.4,1.57)	0.22	0.52
Apolipoprotein B-100: apo A-1	0.71 (0.66,0.75)	0.68 (0.64,0.72)	0.63 (0.58,0.67)	<0.01*	-

Abbreviation: EVOO, extra virgin olive oil; EVCO, extra virgin olive oil; RPOO, red palm olein. All data are presented in mean and 95% CI. For each of these markers, an initial ANCOVA model with main and interaction effects was fitted; the smallest P value for the ANCOVA regression coefficients of interaction effects is given. If statistical significance (P < 0.05) is absent, then an ANCOVA model with only main effects was fitted; the smallest P value of the ANCOVA regression coefficients of main effects is given. Variables with statistically significant results are flagged by an asterisk. For these variables, pairwise group comparisons of the residuals of regressing the variable at the endpoint against baseline were done using the two-sample t-test.

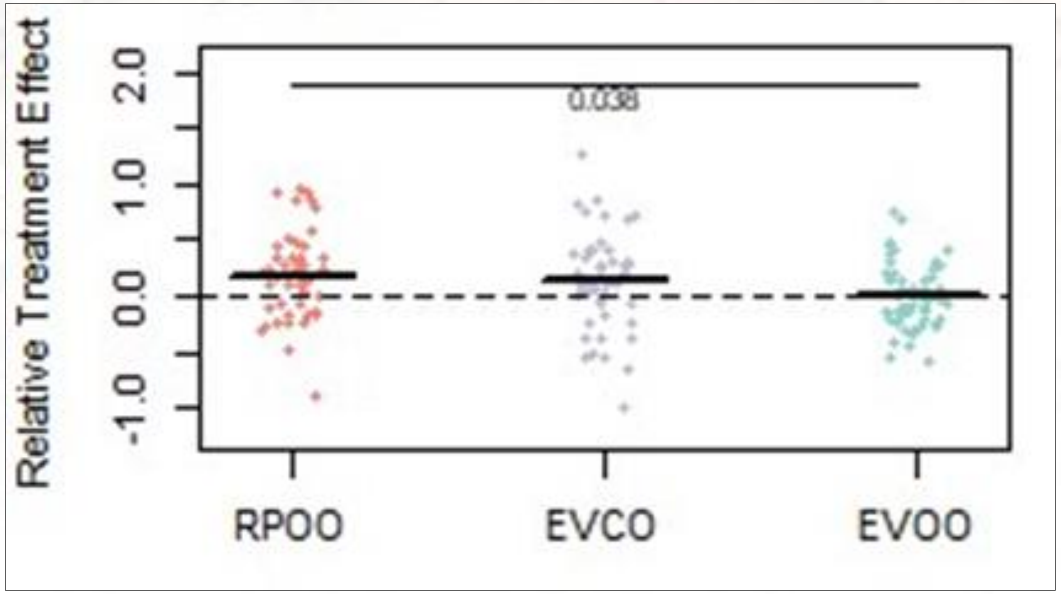
Lipid Profile : clinically insignificant changes on LDL and TC:HDL

(a) LDL cholesterol



(mmol/L)	RPOO	EVCO	EVOO
Baseline	3.25 ± 0.11	3.37 ± 0.09	**3.17 ± 0.11**
Endpoint	2.91 (2.71,3.11)	3.0 (2.83,3.21)	**2.6 (2.45,2.82)**
Δ Change	-0.34	-0.37	**-0.57**

(b) total: HDL cholesterol ratio



	RPOO	EVCO	EVOO
Baseline	**3.80 ± 0.12**	3.84 ± 0.10	**3.69 ± 0.12**
Endpoint	**3.8 (3.63,4.14)**	3.86 (3.65,4.08)	**3.6 (3.36,3.83)**
Δ Change	**0**	+0.02	**-0.09**

Figure 6: Distribution of the relative treatment effect (a) LDL cholesterol and (b) total: HDL cholesterol ratio in participants with central obesity who completed a 12-week dietary intervention with red palm olein (RPOO), extra virgin coconut oil (EVCO), or extra virgin olive oil (EVOO). Statistically significant comparisons between two groups (two-sample t-tests) are indicated by a horizontal bar linking the two groups, with Benjamini-Hochberg adjusted P value given below the bar.

Plasma Fatty Acid Composition and Dexa Scan : ↑ Oleate (EVOO)

Table 6: Plasma fatty acid profiles, bone mineral density and body fat measures in participants with central obesity

Variables	RPOO diet (n=44)	EVCO diet (n=48)	EVOO diet (n=50)	Interaction effects	Main effects
Plasma fatty acid composition (g/100 g total fatty acids)					
Palmitic acid (C16:0)	25.01 (24.56,25.47)	24.84 (24.38,25.3)	24.96 (24.54,25.39)	0.33	0.23
Palmitoleic acid (C16:1)	2.04 (1.64,2.43)	2.08 (1.69,2.48)	2.09 (1.68,2.49)	0.76	0.65
Stearic acid (C18:0)	6.39 (6.20,6.57)	6.40 (6.24,6.55)	6.48 (6.33,6.63)	0.64	0.99
Oleic acid (C18:1 *cis*)	**20.8 (20.24,21.36)**	**20.18 (19.43,20.93)**	**22.47 (21.74,23.2)**	**0.90**	**0.01***
Linoleic acid (C18:2n6 *cis*)	31.13 (29.92,32.34)	31.92 (30.65,33.19)	30.04 (28.91,31.16)	0.39	0.16
Linolenic acid (C18:3)	7.31 (6.91,7.71)	7.48 (7.04,7.91)	7.28 (6.88,7.69)	<0.01*	-
Behenic acid (C22:0)	2.89 (2.01,3.78)	3.07 (2.15,3.99)	2.61 (1.68,3.53)	0.81	0.98
Body fat and bone density measures					
Total body fat (%)	39.73 (35.78,43.68)	39.38 (35.55,43.21)	41.23 (38.43,44.04)	0.59	0.46
Total body fat (z-score) [1]	1.84 (1.43,2.25)	1.45 (0.72,2.17)	2.09 (1.53,2.65)	0.37	0.60
AP Spine (% fat) [1]	31.56 (28.42,34.69)	29.96 (25.67,34.24)	31.64 (28.7,34.57)	0.17	0.11
Left femur (% fat) [1]	27.61 (24.56,30.65)	28.15 (25.08,31.22)	29.29 (26.62,31.95)	0.11	0.17
BMD AP spine L1-L4 (g/cm^2)[1]	1.25 (1.19,1.31)	1.22 (1.16,1.28)	1.2 (1.14,1.25)	0.59	0.14
AP spine L1-L4 (z-score) [1]	0.01 (-0.7,0.71)	0.03 (-0.43,0.48)	-0.23 (-0.74,0.27)	<0.01*	-
BMD total femur (g/cm^2) [1]	1029.39 (953.22,1105.56)	969.61 (906.03,1033.19)	919.62 (843.05,996.2)	0.12	0.46
Plasma calcium (mmol/L)	2.25 (2.22,2.28)	2.29 (2.26,2.33)	2.28 (2.25,2.32)	0.02*	-

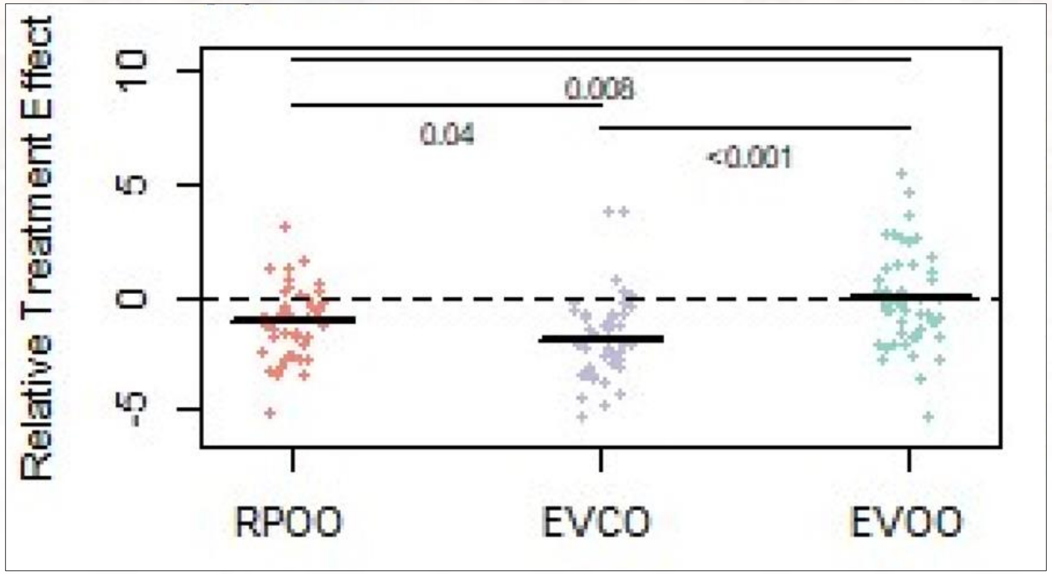
Abbreviation: AP anteroposterior BMD bone mineral density, EVCO extra virgin coconut oil, EVOO extra virgin olive oil, RPOO red palm olein.

All data are presented in mean and 95% CI. For each of these markers, an initial ANCOVA model with main and interaction effects was fitted; the smallest P value for the ANCOVA regression coefficients of interaction effects is given. If statistical significance (P < 0.05) is absent, then an ANCOVA model with only main effects was fitted; the smallest P value of the ANCOVA regression coefficients of main effects is given. Variables with statistically significant results are flagged by an asterisk. For these variables, pairwise group comparisons of the residuals of regressing the variable at the endpoint against baseline were done using the two-sample t-test. .

[1]Subset data analysed using dual-energy X-ray absorptiometry scans (DEXA) (RPOO, n = 18; EVCO, n = 18; EVOO, n = 16).

Plasma Fatty Acid Composition : ↑ Oleate with EVOO diet

Oleic Acid



(g/100 g total fatty acids)	RPOO	EVCO	EVOO
Baseline	20.29 ± 1.71	20.65 ± 2.25	21.28 ± 2.48
Endpoint	20.8 (20.24,21.36)	20.18 (19.43,20.93)	22.47 (21.74,23.2)

Figure 7: Distribution of the relative treatment effect oleic acid in participants with central obesity who completed a 12-week dietary intervention with red palm olein (RPOO), extra virgin coconut oil (EVCO), or extra virgin olive oil (EVOO).

Statistically significant comparisons between two groups (two-sample t-tests) are indicated by a horizontal bar linking the two groups, with Benjamini-Hochberg adjusted P value given below the bar.

Strengths & Limitations

Strengths

- fully controlled trial + standardised PUFA (changes in blood markers = major fatty acids and unique phytonutrients of the different experimental oil)
- Appropriate carbohydrate/fat intake = no sign lipogenesis (circulating SFAs) & no changes to cardiometabolic risk markers
- mixed model statistical approach (all possible confounders)
- low dropout rate
- the researchers were blinded to biochemical analyses
- statistical analyses performed by a third party (not involved in the study conduct)

Limitations

- single-blind study (comparison oils have a distinct colour)
- Did not mask the colour of the oil

Conclusion

- Inflammatory markers: no difference
- Endothelial function markers: no difference
- Lipid profile: no difference except for LDL (EVOO↓ than RPOO and EVCO)
- LDL and HDL subfractions: no difference
- All 3 diet groups had mostly large, buoyant LDL particles)
- Bone mineral density and body fat composition: no difference
- Antioxidants (α-carotene and β-carotene): RPOO ↑

Red Palm Oil as Premium Oil

~In par with extra virgin olive oil and coconut oil

European Journal of Nutrition
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ORIGINAL CONTRIBUTION

Check for updates

Diverse impacts of red palm olein, extra virgin coconut oil and extra virgin olive oil on cardiometabolic risk markers in individuals with central obesity: a randomised trial

Kim-Tiu Teng[1] · Radhika Loganathan[1] · Boon How Chew[2,3] · Tsung Fei Khang[4,5]

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Abstract

Purpose Dietary fats with an abundance of phytonutrients have garnered public attention beyond fatty acids per se. This study was set to investigate the impact of consuming diets with red palm olein (RPOO), extra virgin coconut oil (EVCO) and extra virgin olive oil (EVOO, as a control) on cardiometabolic risk biomarkers and lipid profile.

Methods We recruited a total of 156 individuals with central obesity, aged 25–45 years, with waist circumference ≥ 90 cm for men and ≥ 80 cm for women in a parallel single-blind 3-arm randomised controlled trial. The participants consumed isocaloric diets (~2400 kcal) enriched with respective test fats (RPOO, EVCO or EVOO) for a 12-week duration.

Results The mean of the primary outcome plasma high sensitivity C-reactive protein was statistically similar between the three diets after a 12-week intervention. EVOO resulted in significantly lower mean LDL cholesterol compared with RPOO and EVCO, despite similar effects on LDL and HDL cholesterol subfractions. The RPOO diet group showed elevated mean α and β-carotenes levels compared with EVCO and EVOO diet groups ($P < 0.05$), corresponding with the rich carotenoid content in RPOO.

Conclusion The three oils, each of which has unique phytonutrient and fatty acid compositions, manifested statistically similar cardiometabolic effects in individuals with central obesity at risk of developing cardiovascular diseases with distinct circulating antioxidant properties.

Clinical trial registration ClinicalTrials.gov (NCT05791370).

Keywords Red palm olein · Extra virgin coconut oil · Extra virgin olive oil · Hs-CRP · Obesity · Human study

Introduction

Substantial scientific debates surround the health effects of saturated fats on cardiovascular risk, against a background of equivocal findings from epidemiological and prospective studies [1–5]. The cardiometabolic impact of saturated fatty acids (SFA) intake is known to be affected by the food matrix and types of fatty acids, as well as the comparative nutrient (e.g. carbohydrates of interest) [1]. For instance, long-chain SFA such as palmitic acid (C16:0) is found to increase LDL cholesterol levels, whereas lauric acid (C12:0) is reported to increase both LDL and HDL cholesterol levels. However, both palmitic and lauric acids have a net neutral effect on the total: HDL cholesterol ratio [6]. Despite disagreements regarding the health benefits of dietary fatty acids, the consumption of RPOO [SFA: 42%; mainly (C16:0)—37%] and EVCO [SFA: 95%; mainly (C12:0)—52% and myristic acid (C14:0)—19%], both of which contain a substantial amount

Kim-Tiu Teng and Radhika Loganathan contributed equally to this work and shared the first authorship.

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Thank you

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Baseline Characteristics

Variables	RPOO (n=45)	EVCO (n=48)	EVOO (n=50)
Physical characteristics			
Total body (z-score) [3]	1.82 ± 0.18	1.63 ± 0.25	2.03 ± 0.26
AP Spine (% fat) [3]	31.56 ± 1.32	30.22 ± 1.72	32.21 ± 1.60
Left femur (% fat) [3]	27.77 ± 1.53	28.1 ± 1.11	29.34 ± 1.15
BMD AP spine L1-L4 (g/cm^2) [3]	1.24 ± 0.03	1.21 ± 0.03	1.19 ± 0.03
AP spine L1-L4 (z-score) [3]	-0.06 ± 0.34	-0.06 ± 0.21	-0.26 ± 0.25
BMD total femur (g/cm^2) [3]	1033.33 ± 34.49	912.33 ± 54.84	914.44 ± 32.52
Systolic blood pressure (mmHg)	114.88 ± 1.70	113.64 ± 1.68	115.75 ± 2.08
Diastolic blood pressure (mmHg)	79.81 ± 1.40	76.87 ± 1.27	77.49 ± 1.50
Plasma fatty acids (g/100 g total fatty acids) and antioxidants			
Palmitic acid (C16:0)	24.93 ± 1.49	24.71 ± 2.08	25.34 ± 1.74
Palmitoleic acid (C16:1)	1.76 ± 1.34	1.99 ± 1.42	2.07 ± 1.45
Stearic acid (C18:0)	6.35 ± 0.51	6.38 ± 0.54	6.43 ± 0.61
Oleic acid (C18:1 cis)	20.29 ± 1.71	20.65 ± 2.25	21.28 ± 2.48
Linoleic acid (C18:2n6 cis)	31.31 ± 3.44	31.22 ± 4.34	30.92 ± 3.23
Linolenic acid (C18:3)	6.97 ± 1.84	7.2 ± 1.23	7.31 ± 1.44
Behenic acid (C22:0)	3.1 ± 3.15	3.7 ± 4.08	2.77 ± 3.99
α-carotene (µg/mL)	0.21 ± 0.11	0.18 ± 0.09	0.19 ± 0.12
β-carotene (µg/mL)	0.76 ± 0.35	0.66 ± 0.3	0.68 ± 0.34
Retinol (µmol/L)	1.29 ± 0.32	1.32 ± 0.25	1.29 ± 0.25
RBP4 (ng/mL)	24936.48 ± 6820.04	26653.96 ± 7073.22	25241.7 ± 6790.15
α-tocopherol (µg/mL)	11.2 ± 2.16	11.15 ± 1.99	10.93 ± 2.34
Total phenolic content (GAE), mg/ml	308.47 ± 120.02	355.14 ± 171.64	384.83 ± 179.62

Mala

Baseline Characteristics

Variables	RPOO (n=45)	EVCO (n=48)	EVOO (n=50)
Biochemical profile			
hs-CRP (mg/L)	5.05 ± 1.11	4.64 ± 0.78	5.36 ± 1.11
IL-6 (pg/mL)	5.69 ± 0.95	10.19 ± 1.67	8.37 ± 1.06
IL-1b (pg/mL)	1.72 ± 0.24	2.38 ± 0.26	2.67 ± 0.30
TNF-α (pg/mL)	3.43 ± 0.44	4.18 ± 0.43	5.27 ± 0.57
sICAMs (ng/mL)	344.25 ± 17.28	323.2 ± 8.22	372.5 ± 19.81
sVCAMs (ng/mL)	699.64 ± 24.40	658.61 ± 15.87	735.56 ± 20.65
Total cholesterol (mmol/L)	5.13 ± 0.13	5.35 ± 0.10	5.15 ± 0.13
LDL cholesterol (mmol/L)	3.25 ± 0.11	3.37 ± 0.09	3.17 ± 0.11
Mean LDL particle size (nm)	270.39 ± 0.56	269.79 ± 0.58	269.52 ± 0.69
Small dense LDL (%)	1.88 ± 0.38	2.17 ± 0.41	2.38 ± 0.48
HDL cholesterol (mmol/L)	1.38 ± 0.04	1.43 ± 0.04	1.45 ± 0.05
HDL-2 (%)	11.88 ± 0.35	11.39 ± 0.44	11.92 ± 0.43
HDL-3 (%)	9.54 ± 0.30	9.31 ± 0.36	9.49 ± 0.36
Small HDL particle (%)	22.9 ± 1.29	22.24 ± 0.66	25.94 ± 1.38
Intermediate HDL particle (%)	48.39 ± 0.42	46.54 ± 1.17	47.5 ± 0.45
Large HDL particle (%)	30.09 ± 0.87	28.48 ± 1.00	26.03 ± 1.59
Triacylglycerol (mmol/L)	1.07 ± 0.06	1.19 ± 0.07	1.17 ± 0.08
Total: HDL cholesterol ratio	3.80 ± 0.12	3.84 ± 0.10	3.69 ± 0.12
VLDL cholesterol (mmol/L)	1.17 ± 0.04	1.25 ± 0.03	1.21 ± 0.04
Apolipoprotein B-100 (g/L)	1.02 ± 0.03	1.07 ± 0.03	1.00 ± 0.03
Apolipoprotein A-1 (g/L)	1.43 ± 0.03	1.46 ± 0.02	1.47 ± 0.02
Apolipoprotein B-100: apo A-1	0.72 ± 0.02	0.74 ± 0.02	0.71 ± 0.03

Types of Dietary Fats

Monounsaturated Fatty Acids (good fat)	Polyunsaturated Fatty Acids (good fat)		Saturated Fatty Acids (controversial fat)	Trans Fats (bad fat)
Omega-9 • **Oleic acid (OA):** avocados, olives and olive oil.	**Omega-3** • **Alpha-linolenic acid (ALA):** flaxseeds, walnuts • **Eicosapentaenoic acid (EPA):** seafood i.e. salmon, oysters, and crab. • **Docosahexaenoic acid (DHA):** seafood i.e. salmon, tuna and sardines.	**Omega-6** • **Linolenic acid (LA):** Nuts, seeds (flax and sunflower) and vegetable oils i.e. corn, soy, sunflower, groundnut, and safflower.	Red meat, cream, butter, ghee, lard, tallow, eggs, coconut oil and palm oil	Commercially-baked pastries, cookies, doughnuts, muffins, cakes, pizza dough, Packaged snack foods (crackers, microwave popcorn, chips), Stick margarine, Vegetable shortening, Fried foods (French fries, fried chicken, chicken nuggets, breaded fish), Candy bars
encourage intake	encourage intake	limit intake	limit intake	avoid int

		Effect on Cholesterol	Foods Sources
Lauric Acid	12:0	↑ LDL & HDL	Coconut oil
Myristic	14:0	↑ LDL & HDL	Palm kernel oil
Palmitic	16:0	↑ LDL & HDL	Animal Fats & Dairy
Stearic	18:0	↓LDL & HDL	Animal Fats & Dairy
Elaidic	Trans-18:1	↑LDL, ↓HDL	Partially hydrogenated oils
Oleic	Cis- 18:1	↓LDL, ↑HDL	Olive & canola oil, nuts, avocados
Linoleic	18:2n-6	↓LDL, ↑HDL	Many vegetable oils, walnuts
Linolenic	18:3n-3	↓LDL, ↑HDL	Flaxseed, walnuts, canola oil