Human health benefits of vaccenic acid

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Human health benefits of vaccenic acid

Catherine J. Field, Heather Hosea Blewett, Spencer Proctor, and Donna Vine

Abstract: The health risks associated with consumption of diets high in trans fats from industrially produced hydrogenated fats are well documented. However, trans fatty acids are not a homogeneous group of molecules, and less is known about the health effects of consuming diets containing vaccenic acid (VA), a positional and geometric isomer of oleic acid, the predominant trans isomer in ruminant fats. The presence of VA in industrial trans fats has raised the question of whether VA produces the same adverse health effects as industrially produced trans fats. VA is also the major trans fat in ruminant fats, and questions have arisen as to whether consuming this trans fat has the same effects on health risk. The purpose of this paper is to critically review the published studies in humans, animals, and cell lines. Epidemiological, but not rodent, studies suggest that VA intake or serum concentrations may be associated with increased cancer risk. However, epidemiological, clinical, and rodent studies to date have not demonstrated a relationship with heart or cardiovascular disease, insulin resistance, or inflammation. VA is the only known dietary precursor of c9,t11 conjugated linoleic acid (CLA), but recent data suggest that consumption of this trans fat may impart health benefits beyond those associated with CLA.

Key words: vaccenic acid, trans fat, cancer, insulin sensitivity, immune, inflammation, beef, dairy.

Résumé : Les problèmes de santé associés à la consommation d'aliments riches en gras trans provenant des graisses hydrogénées fabriquées industriellement sont bien connus. Néanmoins, les acides gras trans ne constituent pas un groupe homogène de molécules; en outre, on ne connaît pas bien les effets sur la santé des aliments contenant de l'acide vaccénique (VA), un isomère de position et de géométrie de l'acide oléique et qui est le principal isomère trans dans les graisses des ruminants. La question suivante s'impose : du fait que le VA est le principal gras trans contenu dans les graisses des ruminants, la présence de VA dans les gras trans industriels suscite-t-elle les mêmes problèmes de santé que les gras trans produits industriellement? Cet article a pour objet de faire l'analyse critique des études dans le domaine sur les humains, les animaux et les lignées cellulaires. À l'exception des études sur les rongeurs, les études épidémiologiques suggèrent que la consommation de VA de même que les concentrations sériques de VA seraient associées à un risque accru de cancer. Néanmoins, les études épidémiologiques, cliniques et sur les rongeurs ne démontrent pas une relation avec les maladies cardiaques ou cardiovasculaires, l'insulinorésistance et l'inflammation. Le VA est le seul précurseur alimentaire connu de l'acide linoléique conjuguée (« CLA ») c9,t11; des observations récentes suggèrent que la consommation de ce gras trans procureraient des bénéfices sanitaires au-delà de ce qu'apporte le CLA.

Mots-clés : acide vaccénique, gras trans, cancer, sensibilité à l'insuline, immune, inflammation, bœuf, laitier.

[Traduit par la Rédaction]

Introduction

There is considerable concern regarding the health risks associated with the consumption of trans fatty acids. Vaccenic acid (VA) (t11 octadecenoic acid; Fig. 1) is a positional and geometric isomer of oleic acid (c9-octadecenoic acid), and is the predominant trans monoene in ruminant fats (50%–80% of total trans content) (Lock et al. 2004). The major source of dietary VA is ruminant fats, produced by the incomplete biohydrogenation of the polyunsaturated fatty acids (PUFA), linoleic acid, and linolenic acid by microorganisms in the rumen (Fig. 2) (Lock and Bauman 2004). Dietary VA can be desaturated to *cis*-9,*trans*-11 conjugated linoleic acid (c9,t11-CLA) in ruminants, rodents, and humans (Santora et al. 2000; Turpeinen et al. 2002). Attempts to increase the c9,t11-CLA content of animal fats also increase the VA content in these fats (Aharoni et al. 2004; Fievez et al. 2003; Lynch et al. 2005; Mir et al. 2005). Hydrogenated plant oils are another source of VA in the diet, and it has been recently estimated that this source may contribute to about 13%–17% of total VA intake (Wolff et al. 2000). The presence of VA in industrial trans fats has raised the question of whether VA produces the same adverse health effects as industrially produced trans

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Fig. 1. Nomenclature for vaccenic acid (VA).

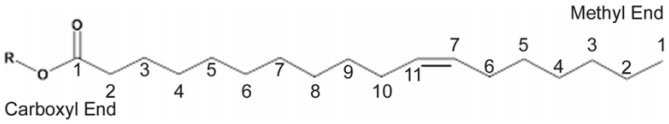
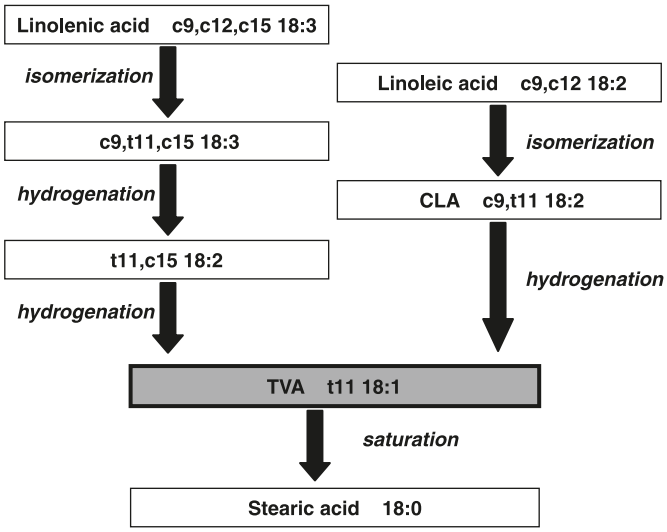


Fig. 2. Rumen synthesis of vaccenic acid (VA) from dietary fatty acids. TVA, *trans* vaccenic acid.



fats. The purpose of this paper is to critically review the published studies (Table 1) in humans, animals, and cell lines to determine the potential health impact of naturally occurring dietary VA derived from ruminant foods.

VA consumption and cancer

Five epidemiological studies have reported findings that imply that the intake (by estimating diet or measuring serum lipids) of VA may alter the risk of cancer; 4 of these examined breast cancer risk in women (Aro et al. 2000; Rissanen et al. 2003; Shannon et al. 2007; Voorrips et al. 2002), and 1 examined prostate cancer risk in men (King et al. 2005) (Table 1). The Kuopio Breast Cancer Study in Finland (Aro et al. 2000) estimated the average intake of VA by postmenopausal women to be 280 mg·day^{-1}, which did not differ between cases and controls. The average serum levels of VA were 0.26% (0.17%–0.40%) of total serum fatty acids, which were lower in cases than control subjects (Aro et al. 2000), resulting in an odds ratio for plasma VA of 0.3, which remained significant after adjustment for many known risk factors for breast cancer (Aro et al. 2000). Although the average intake of VA did not differ between those with and without cancer (Aro et al. 2000; Voorrips et al. 2002), individuals with higher intakes or blood lipid content of VA were found to have a higher risk of cancer in 4 of these studies (King et al. 2005; Rissanen et al. 2003; Shannon et al. 2007; Voorrips et al. 2002), suggesting that a higher VA intake may increase the risk of cancer. It was not possible to determine whether the source of VA in these studies was from hydrogenated fat or ruminant fat.

Some caution must be taken in applying conclusions from epidemiology studies that result from comparing the highest and lowest quintiles, quartiles, or tertiles of intake. This may be even more important in a case–control study when the there is no difference in the mean intake between cases and controls. These comparisons are more applicable if the appropriate covariables that cluster with the individuals in the intake extremes can be controlled. There is not sufficient evidence in these studies that important dietary factors associated with risk of cancer (AICR 2007) were measured and, therefore, were used in the analysis. Further, despite the association between VA and breast cancer risk, no relationship was found between the intake of the 2 major sources of this fatty acid in the diet (milk or milk products and meat from ruminants) and breast cancer incidence (Voorrips et al. 2002). Obtaining accurate estimates of the intake of these relatively minor lipids in the diet is difficult, and estimates can vary considerably depending on the tools used and the compositional data available. Similarly, the concentration of VA is very low in serum and serum lipids (used to estimate intake), and the resulting confidence interval for the measurement is large. There is currently no evidence to confirm that the intake of VA is relatively constant over a lifetime, an assumption made with the estimates and measures in epidemiological studies. In fact, with the changes in animal fat consumption, one would predict that the intake of VA may have actually decreased in the population.

In contrast to suggestions from the epidemiological studies, the majority of studies using cancer cell lines (Awad et al. 1995; Miller et al. 2003) or rodent tumors (Banni et al. 2001; Corl et al. 2003; Ip et al. 1999; Sauer et al. 2004) have demonstrated that VA reduces cell growth and (or) tumor metabolism. Animal and in vitro studies suggest that the anti-cancer properties of VA are due, in part, to the in vivo conversion of VA to c9,t11-CLA (Banni et al. 2001; Corl et al. 2003; Lock et al. 2004). However, several additional mechanisms for the anti-cancer effects of VA have been proposed, including changes in phosphatidylinositol hydrolysis (Awad et al. 1995), reduced proliferation (Sauer et al. 2004), increased apoptosis (Miller et al. 2003), and inhibition of fatty acid uptake (Sauer et al. 2004). In conclusion, although the epidemiological evidence of VA intake and cancer risk suggests a positive relationship, this is not supported by the few animal studies that have been performed. This area requires future investigation.

VA consumption and coronary heart disease

Five epidemiological studies have attempted to study the relationship between coronary heart disease (CHD) risk and estimated VA intake. Contrary to what has been reported for elaidic acid and total trans fatty acid intake, these studies have not found a convincing association between VA intake from animal fats and CHD (Ascherio et al. 1994; Clifton et al. 2004; Hodgson et al. 1996; Sun et al. 2007; Willett et al. 1993) (Table 1). The findings from the Nurses' Health Study were followed by a number of other case–control studies investigating a possible relationship between trans fatty acid intake and CHD. One cohort study initially reported a positive association with VA content in adipose tissue, but this association disappeared in the same cohort when it was reanalyzed after hydrogenated fats were removed from the market (Clifton et al. 2004). A nested case–control study performed on the Nurses' Health cohort found that total VA concentration in erythrocytes was significantly higher at

Table 1. Studies examining the effects of vaccenic acid (VA) on health.

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Human epidemiological studies					
Aro et al. (2000)	Nested case–control study using breast cancer cases (n = 68 premenopausal; n = 127 postmenopausal) and population-based controls (n = 75 premenopausal; n = 133 postmenopausal) from the Finnish breast cancer screening study 1992–1995.	1800 kcal; 67 g·d^{-1} fat; 27 g·d^{-1} SFA; 20 g·d^{-1} MUFA; 8.5 g·d^{-1} PUFA; 1.2 mg·d^{-1} *trans* C18:1; 0.28 g·d^{-1} VA; 0.13 g·d^{-1} CLA.	Average intake: 280 mg·d^{-1} in cases and controls.	Serum VA concentrations and dietary intake between cases and controls. Calculated odds ratios by separating serum fatty acids into quintiles.	In postmenopausal women: average serum concentrations of VA ↓ in cases vs. controls; no difference in dietary intake. Lowest quintile = 0.17; highest quintile (0.40) odds ratio = 0.3 (0.1–0.7); ↑ serum VA = ↓ breast cancer.
Voorrips et al. (2002)	Cohort study using breast cancer cases (n = 941) and controls (n = 1598) from the Netherlands Cohort Study on Diet and Cancer 1986–1992.	1680 kcal; 68 g·d^{-1} fat; 29 g·d^{-1} SFA; 22 g·d^{-1} MUFA; 15 g·d^{-1} PUFA; 1.2 g·d^{-1} *trans* 18:1; 0.8 g·d^{-1} VA; 0.2 g·d^{-1} CLA.[a]	Average intake (adjusted for energy): 800 mg·d^{-1} in cases and controls.	Dietary intake of fats, trans fatty acids, VA, and food sources of VA between cases and controls. Calculated rate ratios by separating fatty acid intake into quintiles.	Lowest quintile = 0.3 g·d$^{-1;}$ highest quintile (1.2 g·d^{-1}) rate ratio = 1.40 (1.05–1.86); ↑ serum VA = ↑ breast cancer. No relationship between breast cancer and other C18:1 trans fats (included t6 but would primarily be t9 *trans*).
Rissanen et al. (2003)	Nested-case–control study using breast cancer cases (n = 73 premenopausal; n = 54 postmenopausal) and controls (n = 138 premenopausal; n = 104 postmenopausal) from the Mobile Clinic Heath Examination Survey 1973–1991.	Diet not assessed	Mean serum concentration: 0.41% VA.	Serum VA concentrations between cases and controls at baseline and cancer diagnosis after 10-y follow-up. Total *trans* MUFA measured (assume the majority is elaidic acid). Calculated odds ratios by separating serum fatty acid concentrations into tertiles.	No significant differences between cases and controls in the mean serum concentration of total *trans* MUFA and VA. Highest tertile (>0.4) odds ratio = 3.69 (1.35–10.06); ↑ serum VA = ↑ breast cancer. Association clearer in postmenopausal women. No association between breast cancer and total *trans* MUFA.
Shannon et al. (2007)	Case–control study of 322 women with breast cancer and 1030 frequency age-matched control women in Shanghai, China.	Diet not assessed	Erythrocytes from cases (0.96% VA) vs. control women (0.93% VA).	Erythrocyte VA concentrations in women following histological confirmation of breast cancer, compared with erythrocyte VA concentrations from control women without breast cancer.	Erythrocyte VA concentrations were slightly but significantly higher among cases than controls.
King et al. (2005)	Nested-case–control study using prostate cancer cases (n = 272) and controls (n = 426) from the β-Carotene and Retinol Efficacy Trial 1985–1996.	Diet not assessed	VA intake not assessed.	Serum phospholipid concentration of VA and prostate cancer status. Calculated odds ratios by separating serum fatty acid concentrations into quartiles.	Highest quartile (0.55) odds ratio = 1.69 (1.03–2.77); ↑ serum VA = ↑ prostate cancer.
Willett et al. (1993)	Prospective study of 85 095 women (Nurses' Health Study 1980–1988). Nutrient intake estimated from the semi-quantified FFQ developed for this study.	Mean intakes not reported.	Intake of VA not reported. Total intake of trans fats ranged from an average of 1.3% of energy in the lowest quintile to 3.2% of energy in the highest quintile.	Calculated relative risk of fatal and nonfatal MI between the highest and lowest quintiles of estimated trans intake (total, hydrogenated vegetable oil sources, foods high in trans fatty acids, and animal sources of trans fatty acids).	Relative risk (highest quintile vs. lowest) = 1.50 (1.12–2.00). The association was stronger for women whose margarine consumption over the previous 10 years had been stable. Foods high in hydrogenated fat (margarine, cookies, and cake) were each significantly associated with higher risks of CHD. A nonsignificant inverse association was observed for the estimated intake of trans isomers from animal fats.

Table 1 (*continued*).

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Ascherio et al. (1994)	Case–control study using patients admitted to 1 of 6 Boston area hospitals with a first acute MI as cases (n = 239) and healthy controls (n = 282). Nutrient intake estimated from the semi-quantified food FFQ used in the Nurses' Health Study.	Intakes of cases vs. controls: 2507 vs. 2384 kcal·d^{-1}; 36.5% vs. 34.0% calories from fat; 37.3 vs. 33.2 g·d^{-1} SFA; 36.4 vs. 32.2 g·d^{-1} MUFA; 4.68 vs. 3.78 g·d^{-1} trans fatty acids.	VA intake not reported. Animal-derived trans fat was 36% of total fat. Mean intake of total trans fats: 4.36 g·d^{-1} for men and 3.61 g·d^{-1} for women.	Calculated relative risk of MI between the highest and lowest quintiles of estimated trans fat intake (total and vegetable oil vs. animal sources).	Intake of total trans fatty acids and trans fatty acids from hydrogenated vegetable oils was related to risk of MI. Relative risk (highest quintile vs. lowest quintile of intake) = 2.44 (1.42–4.19). No association was observed between intake of trans isomers from animal fats and MI risk.
Clifton et al. (2004)	Case–control study; men and women after first MI (cases; n = 209) and controls (n = 179). 300-item FFQ used to estimate intake of various trans fatty acids. Collected adipose tissue biopsy from most of the control subjects (n = 167) and about 30% of the cases (n = 79).	2600 kcal (case), 2300 kcal (control); 35% fat; 13.9% (case), 12.9% (control) SFA; 13% MUFA; 5.6% PUFA; 3.5% (case), 3.0% (control) total trans.[b]	Intake of trans fat from dairy and beef estimated at 1.1 g·d^{-1}. Adipose tissue content of VA estimated at approximately 0.68% of total fatty acids.	Compared estimated VA intake and adipose content of VA between cases and controls.	Cases ↑ trans intake vs. controls. The intake from margarines did not differ; however, the estimated intake of trans fat from dairy and beef was significantly ↑ in the cases. Lowest quintile = 1.55 g·d^{-1}; highest quintile (2.25 g·d^{-1}) relative risk = 2.25(1.16–4.32). ↑ trans intake = ↑ MI. Adipose VA was 26% higher in the cases vs. controls. Differences between cases and controls disappeared when samples were collected after trans-fat-containing margarines were removed from the market.
Hodgson et al. (1996)	Cross-sectional study of nondiabetic patients undergoing a coronary angiography procedure.	Diet not assessed.	Average platelet levels of VA were 0.5% *w/w* of total fatty acids.	Relationship between platelet concentration of VA and an angiographic score of severity of CHD.	No relationship between VA concentration and CHD severity. Positive relationship between elaidic acid, *trans*-10 C18:1, and degree of CHD.
Sun et al. (2007)	A prospective, nested, case–control study of incident cases of CHD (n = 166) and age-matched controls (n = 327) from the Nurses' Health Study. Blood collected in 1989–1990; follow-up in 1996. Nutrient intake estimated by semi-quantitative FFQ; VA was not reported.	3.0 g·d^{-1} trans fat.	Erythrocyte fatty acids at baseline 0.40% VA among cases vs. 0.38% VA among control women.	Erythrocyte VA concentrations were measured in blood samples taken from women free of cardiovascular diseases at baseline, compared with those from women who had and who had not developed or died from CHD over the 6-y follow-up period.	VA, % of total erythrocyte fatty acids: ↑ among CHD cases vs. controls at baseline. Total 18:1 trans isomers. Lowest quartile = 0.77; highest quartile (1.62) relative risk = 2.4 (1.4–4.3).
Human clinical trials					
Tricon et al. (2006)	A randomized, double-blind, placebo-controlled crossover trial using 32 healthy male volunteers 34–60 years old.	38% fat; 17% protein; 45% carbohydrates during the control and CLA/VA phases (6 wk each, separated by a 7 wk washout period).[b]	CLA/VA phase: 1421 mg·d^{-1} c9,t11-CLA + 4689 mg·d^{-1} VA. Control phase: 151 mg·d^{-1} c9,t11-CLA + 312 mg·d^{-1} VA.	Plasma lipids (TGs, cholesterol, HDL cholesterol, LDL cholesterol); insulin; glucose; VCAM-1; ICAM-1; E-selectin; IL-6; serum CRP; LDL subclass, LDL oxidation.	CLA/VA diet did not affect inflammatory markers; insulin; glucose; TGs; total, LDL, or HDL cholesterol; LDL particle size; or LDL oxidation. CLA/VA diet ↑ LDL/HDL.
Tholstrup et al. (2006)	A double-blind, randomized, 5-week, parallel-intervention study using 42 healthy young men 19–33 years old.	VA diet: 45% fat; 9% protein; 42% carbohydrate. Control diet: 42% fat; 10% protein; 46% carbohydrate.[b]	VA diet: 3.6 g·d^{-1} of VA. Control diet: 0.5 g·d^{-1} of VA.	Plasma lipids (TGs, cholesterol, HDL cholesterol, LDL cholesterol); serum insulin; glucose; CRP; urinary 8-iso-$PGF_{2\alpha}$.	VA diet had 6% ↓ total cholesterol and 9% ↓ HDL cholesterol. There were no differences between groups with respect to TG or LDL concentrations, serum insulin, glucose or CRP concentrations, or urinary 8-iso-$PGF_{2\alpha}$.

Table 1 (*continued*).

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Kuhnt et al. (2006)	A placebo-controlled 6-wk feeding study of 24 healthy male and female subjects 20–28 years old.	30% fat; 12% protein; 60% carbohydrates.[b]	Test group: 3 g·d^{-1} VA+3 g·d^{-1} *trans*-12 C18:1. Control group: control oil (1:1 palm kernel oil to rapeseed oil).	Urinary 8-iso-$PGF_{2\alpha}$ and 15-ketodihydro-$PGF_{2\alpha}$; plasma tocopherols and retinol.	Test group ↑ urinary 8-iso-$PGF_{2\alpha}$ excretion. Control group, no change. No differences between groups in 15-ketodihydro- $PGF_{2\alpha}$ levels. Test group ↓ β-tocopherol levels and ↑ retinol levels vs. experimental group.
Kuhnt et al. (2007)	A placebo-controlled 6-wk feeding study of 24 healthy males and females.	30% fat; 12% protein; 60% carbohydrates.[b]	Test group: 3 g·d^{-1} VA+3 g·d^{-1} *trans*-12 C18:1. Control group: control oil (1:1 palm kernel oil to rapeseed oil).	Peripheral blood immune cell phenotypes; peripheral blood leukocyte phagocytosis; plasma concentrations of IL-1β, IL-6, IL-8, IL-10, IL12p70, TNF-α, leptin, adiponectin, and CRP.	No differences in circulating immune cell phenotypes, phagocytic function, or plasma cytokine, adipokine, or CRP concentrations between groups.
Turpeinen et al. (2002)	30 healthy subjects fed a baseline diet for 2 wk, followed by a 9-d intervention.	54% carbohydrates; 15% protein; 30% fat; 12% of fat PUFA; 25% of fat SFA; 65% of fat MUFA; 0.5 P/S; <0.2 VA; <0.04 CLA.	Fed 3 levels of VA × 9 d: 1.7 g–0.7% kcal; 3.0 g–1.35% kcal; 4.4 g–2% kcal; PUFA, CLA, SFA content constant between diets.	VA and CLA concentrations in serum; urinary prostanes.	VA and CLA concentration ↑ in a dose-related manner (plateau at 4 d). All VA diets ↑ urinary excretion of 8-iso-$PGF_{2\alpha}$ vs. baseline diet.
Human and animal cell lines and primary cultures					
Awad et al. (1995)	Human cancer colon cells (HT-29) treated with 18:1 fatty acids for 9 d.	N/A	30 μmol·L^{-1} VA.	Tumor growth; PI hydrolysis.	VA ↓ tumor growth and ↑ PI hydrolysis vs. 18:0; VA ↓ PI hydrolysis vs. *cis* 18:1.
Miller et al. (2003)	MCF-7 (breast) and SW480 (colon) treated with VA for 4 d.	N/A	5–20 μg·mL^{-1} VA.	Cancer cell growth apoptosis; VA incorporation into cellular lipids, compared with equal amounts of CLA.	VA ↓ growth only at the highest concentration of VA (20 μg·mL^{-1}), while CLA ↓ growth even at the lowest dose (5 μg·mL^{-1}). VA modified cellular functions consistent with apoptosis (DNA fragmentation, depleted cytosolic glutathione, ras expression). VA and CLA incorporated into tissues in a dose-dependent manner. Estimated the conversion of VA to CLA as 44% in MCF-7 and 24% in SW480 cells. VA increased AA uptake into tumor cells, but CLA did not. Suggests other effects of VA, independent of CLA conversion.
Reynolds et al. (2008)	Human colon cancer cells (Caco-2) treated with VA or c9,t11-CLA.	N/A	50 μmol·L^{-1}.	IL12p70, TNFα, IL-6 protein concentrations in cell supernatants following 24 h stimulation with LPS; IL12p35, TNFα, IL-6, PPARγ, and PPARα mRNA levels in cells following 24-h stimulation with LPS	CLA but not VA ↓ mRNA levels of TNF-α, IL-12p35, and IL-6, compared with control cells.

Table 1 (*continued*).

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Animal feeding studies					
Banni et al. (2001)	Study 1: healthy rats fed diets containing 0%, 1%, 2%, and 3% VA. Study 2: MNU-induced mammary cancer in rats. Rats fed diets for 6 wk after tumor induction.	5% *w/w* butter; low in PUFA; 50% SFA; 50% MUFA.	Study 1: fed 1%, 2%, 3% *w/w* VA (purified fatty acid). This represents 16%–40% of fatty acids as VA. Study 2: fed 2% *w/w* VA vs. 1% c9,t11-CLA.	Study 1: tissue accumulation of c9,t11-CLA. Study 2: tumor growth.	Study 1: VA ↑ CLA (c9,t11) levels in mammary gland and liver; maximum CLA production at 2% *w/w*. Study 2: VA (2% *w/w*) ↓ mammary tumors = c9,t11-CLA (1% *w/w*).
Corl et al. (2003)	MNU-induced mammary cancer in rats. Fed 1 of 7 diets for 24 wk after tumor induction: (1) 0.3% VA+0.05% CLA; (2) 0.13% VA+0.18% CLA; (3) 0.13% VA+0.24% CLA; (4) 0.13% VA+0.37% CLA; (5) 0.73% VA+0.18% CLA; (6) 1.0% VA+0.24% CLA; (7) 1.6% VA+0.37% CLA.	20% from fat; 10% *w/w* butter fat; did not report PUFA content; 50% saturated; 50% unsaturated.	0.13%–1.6% *w/w*; VA (from butter).	VA and CLA concentrations in plasma, liver, mammary gland; tumor growth.	↑ tissue CLA content with ↑ dietary VA. Dose-dependent effect of VA+ CLA on carcinogenesis.
Ip et al. (1999)	MNU-induced mammary cancer in rats. Rats fed diets for 1 month: (1) control (0.1% CLA); (2) high CLA butter (0.8% CLA); (3) Matreya CLA (0.8% CLA); (4) Nu-Chek CLA (0.8% CLA).	20% *w/w* butter; 60% SFA; 24% MUFA; LA 3% of fat.	Control diet: 3.8% of fat. High CLA butter: 25% of fat.	CLA concentration in liver, mammary fat, peritoneal fat, and plasma; tumor number and proliferation; mammary epithelial mass per unit area of mammary fat pad.	All CLA diets ↓ tumor cell number and proliferation. CLA and CLA+VA diet changed mammary cell development (epithelial mass per unit area of mammary fat pad).
Sauer et al. (2004)	Buffalo rats implanted with a transplantable rodent hepatoma (7288CTC). Various fatty acids (linoleic acid, elaidic acid, VA, both major CLA isomers) were perfused.	4.2% of diet fat; 21% of fat palmitic; 11% of fat stearic; 34% of fat oleic; 28% of fat LA.	Plasma concentrations, 0.0–0.4 $mmol \cdot L^{-1}$.	Fatty acid uptake; fatty acid transporters; signaling by adipose tissue (inguinal fat pad) and tumor; estimation of tumor proliferation.	VA ↓ tumor fatty acid uptake and proliferation; more elaidic but less c9, t11-CLA. c9,t11-CLA effects in tumors are mediated by an inhibitory G-protein coupled folic acid receptor. VA and c9,t11-CLA had no effect on fatty acid metabolism in fat pad. t10,c12-CLA ↓ fatty acid metabolism in fat pad.
Lock et al. (2004)	MNU-induced mammary tumors in rats. Female rats injected at 50 d of age. Fed 1 of 4 diets for 6 wk: (1) 0.13% VA; (2) 0.4% VA; (3) 1.6% VA; (4) 1.6% VA+Δ^9 desaturase inhibitor.	Fed 100% butter at 10% *w/w*; 60% SFA; 24% MUFA; LA 3% of fat.	0.13%–1.6% VA.	Tissue VA and CLA content; tumor growth.	1.6% VA ↑ CLA content in tissues and ↓ tumor growth. 1.6% VA+Δ^9 desaturase inhibitor ↑ CLA liver and plasma concentrations vs. low VA groups. Inhibitor reversed effects of VA.
Loor et al. (2002)	Lactating mice and their pups; 3 diets (control, VA, or CLA) fed from days 3 to 14 postpartum.	10% *w/w* fat; constant LA content.	0.9% *w/w* VA; 0.5% mixed isomer CLA.	VAand CLA content in blood, liver, mammary gland tissue, and carcass; distribution of VA and CLA within lipid fractions; stearoyl-CoA desaturase activity.	VA contributed to c9,t11-CLA content of tissues. CLA is not converted back to VA. VA ↑ % of CLA in cholesterol esters vs. CLA, due to the ↓ specificity of the lecithin:cholesterol acyl transferase for this fatty acid. The same CLA in PL when fed VA or CLA.

Table 1 (*continued*).

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Meijer et al. (2001)	Hamsters randomly assigned to 1 of 5 test diets for 5 wk: (1) MCFA (30% C8:0+C10:0); (2) SFA (32% C16:0); (3) MUFA (+33% C18:1 9c); (4) elaidic (33%); (5) VA (34%).[c]	30% energy as fat.	34% of fat VA.	Lipid and lipoprotein profile, total and free cholesterol; lipid composition in a number of tissues.	VA compared with elaidic acid diet: ↑ LDL/HDL ratio; no difference in TG total or free cholesterol; elaidic acid more efficiently incorporated than VA into ns-2 position of platelet PL. VA compared with SFA diet: no difference in LDL, HDL, LDL/HDL, total, or free cholesterol. LDL TG content ↓ on VA diet. VA compared with oleic acid and MCFA diets: no difference in LDL or VLDL cholesterol, TG, total cholesterol, or free cholesterol.
Dupasquier et al. (2007)	LDLr$^{-/-}$ mice were fed 1 of 8 experimental diets for 14 wk: (1) regular fat; (2) elaidic shortening; (3) regular butter; (4) VA butter; (5) 2% cholesterol; (6) 2% cholesterol+elaidic shortening; (7) 2% cholesterol+regular butter; (8) 2% cholesterol+VA butter.	Not available.	VA-enriched butter.	Extent of atherosclerosis as quantified by en face examination of the dissected aortae; serum cholesterol; serum TGs.	Elaidic shortening diet was atherogenic. VA butter diet was not atherogenic. Cholesterol+VA diet ↓ atherosclerosis vs. cholesterol+regular butter diet. Cholesterol+VA diet ↓ serum cholesterol and TG levels vs. cholesterol+ regular butter diet.
Bauchart et al. (2007)	Male New Zealand white rabbits fed 1 of 3 diets for 12 wk: (1) *trans*-10 C18:1; (2) VA+CLA; (3) low in all 3 fatty acids.	12% *w/w* fat.	7% *w/w* VA; 2.6% *w/w* CLA.	Plasma lipids and apolipoproteins; plasma lipoprotein density.	VA+CLA ↓ VLDL vs. other groups. VA+CLA ↓ plasma total cholesterol, PLs, and apolipoprotein B (nonsignificantly).
Roy et al. 2007)	Male New Zealand white rabbits fed 1 of 3 diets for 6 or 12 wk: (1) *trans*-10 C18:1; (2) VA+CLA; (3) low in all 3 fatty acids.	12% *w/w* fat.	7% *w/w* VA; 2.6% *w/w* CLA.	Aortic lipid infiltration; plasma lipid and lipoprotein concentrations; liver lipid concentrations.	VA+CLA ↓ aortic lipid infiltration vs. *trans*-10 C18:1, but not control diet. VA+CLA ↓ plasma concentrations of total, VLDL, LDL, and HDL cholesterol vs. other diet groups (nonsignificantly). VA+CLA ↑ concentration of liver TG vs. other diet groups.
Santora et al. (2000)	Female C57BL/6 mice (6–7 weeks old) fed diets for 2 wk. Study 1: (1) control (no VA); (2) clofibrate ↑ Δ^9 desaturase activity (no VA); (3) PUFA (+10% corn oil) ↓ Δ^9 desaturase activity (no VA); (4) control (1% *w/w* diet VA); (5) clofibrate (1% *w/w* diet VA); (6) PUFA (1% *w/w* diet VA). Study 2: (1) stearic 1% *w/w* diet; (2) VA 1% *w/w* diet; (3) elaidic 1% *w/w* diet; (4) CLA 1% *w/w* diet.	Fat 5% *w/w* diet.	1% *w/w* of diet or 25% of the fat.	Study 1: food intake, body mass, carcass fatty acid composition (TG and PL); estimated the bioconversion of VA to CLA with and without a Δ^9 desaturase stimulator (cholfibrate) or inhibitor. Study 2: food intake, fat absorption, and incorporation into lipids.	Study 1: bioconversion of VA = 12%. Not influenced by cholfibrate. PUFA ↓ bioconversion of VA. In the tissues, 48% of VA was converted to CLA. Study 2: VA and CLA ↑ carcass CLA. Other diets had no carcass CLA. VA ↑ TG CLA, not PL. CLA ↑ TG and PL CLA. Bioconversion of VA occurs in AT (and maybe liver) in rodents. VA was digested better than stearic. VA not in carcass PL, but elaidic was. Elaidic acid ↓ docosahexaenoic and AA in carcass, but VA did not.

Table 1 (*concluded*).

Reference	Experimental design	Basal diet description (level and type of fat)	Amount of VA	Health effect measured	Result
Tardy et al. (2008)	Study 1: Male Wistar rats fed 1 of 3 diets for 8 wk: (1) control MUFA (oleic); (2) industrial (hydrogenated oil); (3) dairy fat diet (dairy fat).[d] Study 2: in vitro study using C2C12 myotubes	Study 1: 25% fat; 59% carbohydrates; 16% protein. Study 2: compared the effects of palmitic, oleic, elaidic, and VA acids on insulin signaling in C2C12 myotubes.	Study 1: 2.8% of total energy. Study 2: all fatty acids provided at 0.75 mmol·L^{-1}.	Study 1: intraperitoneal glucose tolerance test, muscle mitochondrial function. Study 2: Akt and phospho-Akt levels.	Study 1: No adverse effects of dairy fat diet and industrial fat diet on insulin or glucose responses to glucose tolerance test vs. control diet. Control group ↑ ATP and superoxide anion production in the soleus muscle vs. the 2 trans fatty acid groups. Study 2: VA and elaidic acid had no effect on Akt or phospho-Akt levels vs. control treatment (oleic acid).
Kanwar et al. (2008)	Male and female C57BL/6 mice fed diets for 6 wk. Milk fat study: replaced 0.5%, 2%, 5%, and 7% *w/w* soy bean oil with normal or enriched milk fat. Purified isomer study: (1) 2% *w/w* of total fat c9,t11CLA; (2) 3% *w/w* of total fat VA; (3) combination of both.	7% *w/w* fat.	Normal milk fat: 1.2% c9,t11-CLA; 4.7% VA. Enriched milk fat: 5% c9,t11-CLA; 23% VA. Purified isomer: 2% c9,t11CLA; 3% VA.	Immune response to intranasal ovalbumin challenge: BAL, leukocyte counts, IL-5, CCL11; levels of IgE and IgG1; airway histopathology.	Enriched milk fat diet ↓ total number of leukocytes, eosinophils, lymphocytes, and monocytes and macrophages, and IL-5 and CCL11 levels in BAL fluid vs. control diet and normal milk fat diet. Enriched milk diet ↓ serum IgE and IgG1 vs. control-fed and normal milk-fed animals. Enriched milk diet ↓ airway infiltration by leukocytes, goblet cell metaplasia, and mucus production vs. control-fed and normal milk-fed animals. Purified CLA and VA isomers ↓ immune parameters only when fed together; when fed individually, they were not effective.

Note: AA, arachidonic acid; BAL, bronchoalveolar lavage; CHD, coronary heart disease; CLA, conjugated linoleic acid; CRP, C-reactive protein; FFQ, Food Frequency Questionnaire; HDL, high-density lipoprotein; Ig, immunoglobulin; IL, interleukin; LA, linoleic acid; LDL, low-density lipoprotein; LPS, lipopolysaccharides; MCFA, medium-chain fatty acid; MI, myocardial infarction; MNU, *N*-methyl-*N*-nitrosourea; MUFA, monounsaturated fatty acid; N/A, not applicable; P/S, polyunsaturated to saturated fatty acid ratio of the diet; $PGF_{2\alpha}$, prostaglandin $F_{2\alpha}$; PI, phosphatidylinositol; PL, phospholipid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; TG, triglyceride; TNF, tumor necrosis factor; VLDL, very-low-density lipoprotein.

[a]Statistical analysis adjusted to energy intake.

[b]Values are expressed as percent of energy (or calories).

[c]Percentage reported is the percent of fat provided by each of the fatty acids in the diet.

[d]All diets in the study had a total fat level of 4% *w/w* of the diet.

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baseline in the cases than in the controls (Sun et al. 2007). This study reported a positive association between total trans fatty acid intake (but not VA intake) and CHD risk, suggesting that the higher VA content in erythrocytes was likely due to higher hydrogenated fat intake by the cases. This interpretation is supported by an earlier report on the same cohort, in which a nonsignificant inverse association was observed between CHD risk and the estimated intake of trans isomers from animal fats (Willett et al. 1993).

Surprisingly, based on the concern over hydrogenated fats and lipid risk factors for cardiovascular health, few studies have directly compared the effects of elaidic acid and VA. Only 1 published animal study, conducted prior to our work (Wang et al. 2008), could be found. Meijer et al. (2001) fed hamsters a diet that provided 30% of energy as fat for 4 weeks, exchanging 10% of the energy (one third of the fat component) with VA, elaidic acid, oleic acid, palmitic acid, or a combination of medium-chain fatty acids (C8:0 and C10:0), and determined the effects on blood lipids. The effect of VA on total blood cholesterol, free cholesterol, esterified cholesterol, or 2 lipid metabolizing enzymes (CETP and PLTP) did not differ from the effects of oleic acid (Meijer et al. 2001). Additionally, there was no significant effect of feeding VA on very-low-density-lipoprotein-, low-density-lipoprotein (LDL)-, and high-density-lipoprotein (HDL)-cholesterol concentrations. However, the LDL-/HDL-cholesterol ratio was significantly higher for the VA diet than for the elaidic acid diet. The authors concluded that consuming VA could have potential effects on CHD risk, although this was not supported by their data or consistent with studies done in humans or animal models genetically predisposed to dyslipidemia. Although the LDL-/HDL-cholesterol ratio was significantly higher in the hamsters fed VA than in those fed elaidic acid, the LDL-/HDL-cholesterol ratio in hamsters fed the elaidic acid diet was lower than in hamsters fed saturated fatty acid (SFA) diets (Meijer et al. 2001). Although the 2 SFA diets resulted in higher total plasma cholesterol than the c9-C18:1 diet, the elaidic acid diet did not (Meijer et al. 2001). This is contrary to what could be predicted from human trials, suggesting that the plasma lipid response, in this animal model, to dietary fatty acids may not be representative of human blood lipid effects. Preliminary data from another animal feeding study, presented at the 10th European Nutrition Conference (Paris, France 2007), indicated that consuming trans fatty acids sourced from elaidic-acid-rich hydrogenated vegetable shortening for 14 weeks was atherogenic in $LDLr^{-/-}$ mice, whereas consuming a butter rich in VA was not (Dupasquier et al. 2007). In addition, when mice were fed the VA butter in combination with atherosclerosis-promoting dietary cholesterol, serum cholesterol, triglycerides, and the extent of atherosclerosis was reduced, compared with mice fed dietary cholesterol plus regular butter. The authors concluded that, when fed in combination with dietary cholesterol, the VA butter diet protected mice against hyperlipidemia and atherosclerosis (Dupasquier et al. 2007). Consistent with this study, our work in the JCR-LA cp/cp rat has demonstrated that supplementing a diet with purified VA (by replacing oleic acid without changing the fat content or polyunsaturated to saturated-fatty-acid ratio) at 1.5% *w*/*w* (3% of energy) for 3 weeks significantly reduced triglyceride levels (by 50%) in this animal model of dyslipidemia and metabolic syndrome, without changing the elevated haptoglobulin concentrations in plasma (Wang et al. 2008). Contrary to the observations with dyslipidemic rodent models, 2 studies using a rabbit model to compare the effects of a VA and CLA-enriched diet to either a *trans*-10 C18:1 diet or a control diet low in these fatty acids reported a primarily neutral effect of VA plus CLA on the risk of atherogenesis (Bauchart et al. 2007; Roy et al. 2007).

Although clinical studies have not yet been conducted on purified VA, a number of studies have examined the effect of VA and c9,t11-CLA enriched diets. Tricon et al. (2006) reported that incorporation of VA and c9,t11-CLA in milk fat into the diet did not result in detrimental effects on most CHD risk parameters in healthy men. In a double-blind, randomized, parallel-intervention study, healthy young men who consumed a VA-rich diet (3.6 g VA·day^{-1}) for 5 weeks had 6% lower total-cholesterol and 9% lower HDL-cholesterol concentrations than men consuming a low VA diet (Tholstrup et al. 2006). However, the authors concluded that these effects may have been partly attributable to the higher monounsaturated fatty acid and lower SFA content of the high VA diet, rather than to the effects of VA alone. Kuhnt et al. (2006) looked at the effects of 6 g·day^{-1} of a mixture of VA and another trans fat (*trans*-12 C18:1) in a 6-week randomized clinical trial, and reported that the post-intervention concentration of urinary 8-iso-PGF_2 (free-radical-induced lipid peroxidation) in the test group was significantly higher than baseline and significantly higher than the control group. They concluded that, although this might be interpreted as a potential negative effect, the intake of VA in this study far exceeded that consumed by the population (Kuhnt et al. 2006). The minimal biological importance of this potential increase in a urinary marker of lipid peroxidation was confirmed in a subsequent report from the same cohort, in which the VA diet not affect any measured biomarker (interleukin (IL)-6, IL-8, tumor necrosis factor (TNF)α, C-reactive protein (CRP), intercellular adhesion molecule-1, or phagocytic function) of inflammation or immune function in these healthy men (Kuhnt et al. 2007). Similarly, Tholstrup et al. (2006) found no difference in serum CRP concentration among healthy subjects consuming a high vs. a low VA diet.

Thus, contrary to what has been reported for elaidic acid, there does not appear to be an association in epidemiological studies between VA intake from animal fats and CHD risk markers. Several studies have attempted to use adipose tissue fatty acid composition as a biomarker of VA intake. However, the extent to which this reflects long-term intake is not known, as there have been have been few studies on the incorporation and turnover of this fatty acid in fat depots. Although limited, the animal and human feeding trials also do not support adverse effects of VA on markers of CHD risk. In contrast, the animal studies using rodents with dyslipidemia suggest that supplementation with VA may improve dyslipidemia, particularly by lowering hypertriglyceridemia.

VA effects on insulin sensitivity

A recent study by Tardy et al. (2008) examined the effects of industrially produced vs. ruminant-derived dietary

trans monounsaturated fatty acid on insulin sensitivity in rats. For 8 weeks, Male Wistar rats were fed 1 of 3 diets: a control diet enriched in oleic acid; a diet containing 4% of total energy as trans fat derived from hydrogenated oil and containing mainly elaidic acid; or a diet containing 4% of total energy as dairy fat-derived trans fat containing mainly VA. Compared with the control treatment, there was no effect of elaidic acid or VA on the insulin or glucose response to an intraperitoneal glucose tolerance test. Consistent with this study, in our study using JCR-LA cp/cp lean and obese (insulin resistant) rats, a VA-supplemented diet (described above) did not affect fasting levels of insulin or glucose, or the response of these hormones to a meal challenge (Wang et al. 2008). To our knowledge, only 1 clinical study has examined the effects of VA consumption on serum insulin and glucose concentrations. In a double-blind, randomized, parallel-intervention study, no significant differences in serum insulin or glucose concentrations were observed between healthy young men who consumed either a VA-rich diet (3.6 g VA·day^{-1}) or a low VA diet for 5 weeks (Tholstrup et al. 2006). Although few in number, animal and human studies in healthy individuals, and our work in an animal model of insulin resistance, suggest that VA does not alter insulin sensitivity.

VA effects on immune function and inflammation

Kanwar et al. (2008) conducted a study using 8-week-old mice to determine the effects of feeding VA, c9,t11-CLA, or both in combination on the development of airway allergic responses. Mice were fed a diet of either normal or enriched milk fat, containing (as a percent of total milk fatty acids) either 1.2% CLA and 4.7% VA, or 5% CLA and 22.9%VA, respectively, for 42 days. In addition, some mice were fed a diet containing 2% *w*/*w* (of total fat) c9,t11-CLA or 3% *w*/*w* VA to investigate the effects of purified fatty acid individually or in combination. In response to an allergen challenge of intranasal ovalbumin, the enriched milk fat diet significantly reduced the numbers of total leukocytes, eosinophils, lymphocytes, and monocytes and macrophages in bronchoalveolar lavage fluid, compared with a control diet or the normal milk fat diet (Kanwar et al. 2008). Animals fed the enriched milk fat diet also had significantly lower IL-5 and CCL11 levels in bronchoalveolar lavage fluid, and lower serum concentrations of allergen-specific immunoglobulin E and immunoglobulin G1. Pathologic changes within the airways, such as mucus production and leukocyte infiltration, were reduced by enriched milk fat feeding, compared with control-fed or normal-milk-fed animals (Kanwar et al. 2008). Interestingly, the purified CLA and VA isomers inhibited these markers of airway inflammation only when fed together; when fed individually, they had no significant effect (Kanwar et al. 2008). A recent study by Reynolds et al. (2008) compared the effects of VA with those of c9,t11-CLA on markers of inflammation in Caco-2 intestinal epithelial cells. Despite significant conversion of VA to c9,t11-CLA in these cells, only the CLA treatment significantly reduced messanger RNA levels of TNF-α, IL-12, and IL-6, compared with control cells. In these models, VA does not appear to influence immune function.

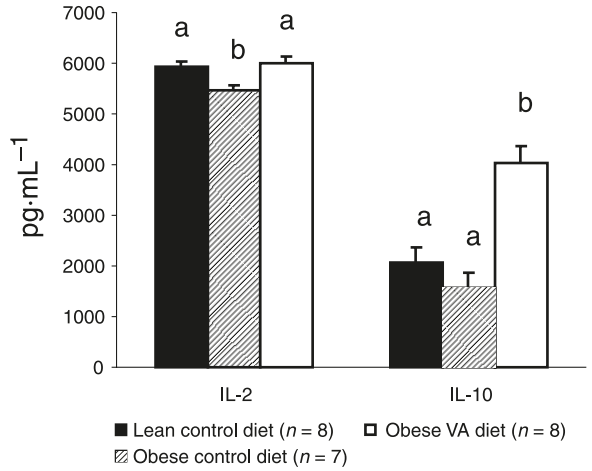
Only 2 published reports describing the effects of VA consumption on immune function or inflammation in humans could be found. As described above, Tholstrup et al. (2006) found no difference in serum CRP concentration among subjects consuming a high (3.6 g VA·day^{-1}) vs. a low VA diet. Kuhnt et al. (2007) measured a number of immune and inflammatory parameters in 24 healthy subjects consuming a diet containing equal amounts of VA and *trans*-12 C18:1 or a diet free of CLA and trans fatty acids for 6 weeks. The authors reported no significant differences between groups with respect to markers of inflammation in plasma (IL-6, IL-8, TNFα, CRP), phagocytic function, or circulating immune cell phenotypes (Kuhnt et al. 2007).

As a contrast to the short-term feeding studies in humans and animals, we recently completed a 16-week feeding trial in the JCR-LA cp/cp rat, a rodent model of obesity, insulin resistance, dyslipidemia, and chronic inflammation (Wang et al. 2008). Feeding a VA-enriched diet (1.0% *w*/*w*) for 16 weeks significantly improved the reduced ex vivo proliferative response (IL-2 production) by splenocytes stimulated with phorbol myristate acetate and ionomycin (Fig. 3). The production of IL-2 to this mitogen that stimulates immune cells via intracellular mechanisms was normalized in the cells from the obese JCR rat. This preliminary work suggests that feeding VA for longer periods of time may influence immune responses in an immunosuppressive condition, and future work is needed to understand the implications to health.

VA: potential mechanisms

The majority of the studies suggest that any health benefit of VA may be conferred by in vivo mammalian conversion of VA to c9,t11-CLA (Glaser et al. 2002; Loor et al. 2002; Salminen et al. 1998; Santora et al. 2000). Banni et al. (2001) were the first to demonstrate this conversion in a rodent model. Rats were fed diets containing 1%, 2%, or 3% *w*/*w* VA (representing 16%–40% of total fatty acids), and the levels of CLA and CLA metabolites were measured in several tissues. The production of c9,t11-CLA from VA in mammals occurs via the action of the Δ^9 desaturase enzyme. Thus, in the nonlactating human, the liver (with high Δ^9 desaturase activity) is likely the primary site of VA conversion to CLA (Turpeinen et al. 2002). Estimates for the rate of conversion of VA to c9,t11-CLA range in rodents from 5%–12% (Santora et al. 2000). In humans, the average conversion of VA to c9,t11-CLA was reported to be 19%, but conversion varied from 0% in a subject with a low intake (1.5 g·day^{-1}) of VA to over 30% in a subject with a high intake (4.5 g·day^{-1}) of VA (Turpeinen et al. 2002). The conversion rate may be influenced by differences in the level of PUFA in the diet, which reportedly affect the rate of conversion. For example, the activity of the Δ^9 desaturase enzyme is regulated by PUFA (Ntambi 1995); in adipocytes it is regulated by the t10,c12-CLA isomer (Lee et al. 1998). In mice, feeding a high PUFA diet was demonstrated to reduce the conversion of dietary VA (when fed at 1% *w*/*w* as a free fatty acid) to c9,t11-CLA (Santora et al. 2000). In this study, the bioconversion of VA to CLA in the high PUFA diet was 5.1%, compared with 12% in the low PUFA diet (Santora et al. 2000), supporting the inhibitory effects of PUFA on desaturase activity. In vitro work with mammary epithelial cells suggests that endogenous synthesis of CLA from VA in the mammary gland may be due to a greater

Fig. 3. Effect of feeding vaccenic acid (VA) on cytokine production by splenoctyes. Splenocytes (1.25×10^6 cells·mL^{-1}) were incubated for 48 h with 5% CO_2 in the presence of phorbol myristate acetate (20 ng·mL^{-1}) and ionomycin (0.5 nmol·L^{-1}). After 48 h, cells were centrifuged and supernatants were collected. The concentrations of interleukin (IL)-2 and IL-10 were determined in duplicate, using a commercially available ELISA kit (IL-2, Cedarlane, Hornby Ont.; IL-10, BD Biosciences, Mississauga, Ont.). Bars (mean ± SEM) that do not share a letter are significantly different ($p < 0.05$).



stearoyl-CoA desaturase activity (Loor et al. 2002), supporting the hypothesis that c9,t11-CLA made from VA is an important source of CLA for the suckling infant.

The metabolic fate of VA has not been extensively studied. It is well absorbed when fed in the diet (Emken et al. 1986; Santora et al. 2000), but plasma, liver, and other tissue levels are relatively low, even when VA is fed in levels many times higher than is normally consumed by humans (Adlof et al. 2000; Glaser et al. 2002; Herbel et al. 1998; Santora et al. 2000). This suggests that VA is either rapidly oxidized or metabolized to other lipids. There are no data available at this time to determine if VA is preferentially oxidized for energy.

Summary

Trans fatty acids are not a homogeneous class of fatty acids. Compared with industrially produced trans fats, there are relatively few studies that have investigated the effects of VA on health. The majority of VA in the human diet is from ruminant fats; however, it is also formed during the hydrogenation process, which may have, in previous years, contributed to total VA intake. Although there is an association with VA intake or serum concentration and cancer risk, the few animal studies that have been performed suggest a beneficial effect of VA in reducing tumour growth. Epidemiologic studies have not convincingly demonstrated a relationship between VA intake and the risk of myocardial infarction or CHD. Epidemiological studies suggest that the intake or plasma levels of VA may affect the risk of CHD in a beneficial manner. Data from animal models of dyslipidemia from our group and others support this suggestion. VA is the only dietary precursor to c9,t11-CLA and, in both rodents and humans, the intake of VA contributes to tissue levels of this isomer. More research should be encouraged to establish the health effects of consuming VA, as emerging data suggest that the consumption of this trans fat may impart health benefits beyond those associated with CLA.

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