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ScienceDirect
Food Chemistry 109 (2008) 670–674
FOOD CHEMISTRY
www.elsevier.com/locate/foodchem

Analytical Methods

Fatty acid composition of edible oils derived from certified organic and conventional agricultural methods

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Received 26 October 2007; received in revised form 10 December 2007; accepted 30 December 2007

Abstract

The objective of this study is to compare the fatty acid composition of commercially available edible oils derived from certified organic and conventional agricultural methods. A total of 59 certified organic and 53 conventional oils were purchased from retail markets in Sydney, Australia. Organic and conventional products were matched for comparison according to the description of production methods, labelled total fat content, brand name (wherever possible), and country of origin. Total fat was extracted and the fatty acid composition of the oils was determined by gas chromatography. No consistent overall trend of difference in the fatty acid composition was observed between organic and conventional oils. Saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids were all significantly different between types of oil ($P < 0.001$ in all three), and each had significant interaction between type and production method ($P = 0.002$, $P < 0.001$ and $P < 0.001$, respectively) indicating that organic and conventional oils differed in these components in an inconsistent fashion. Despite this, there were large differences particularly between MUFA and PUFA components in specific pairs of oils, especially in sunflower and mustard seed oils. The absence of an overall difference in the fatty acid composition of organic and conventional oils does not support the tenet that organic foods are of a higher nutritional quality than their conventional counterparts.

Keywords: Fatty acids; Oil; Organic; Conventional

1. Introduction

Organic agricultural practices aim to enhance biodiversity, biological cycles and soil biological activity so as to achieve optimal natural systems that are socially, ecologically and economically sustainable. Although there is no recognised worldwide standard for organic agriculture, a number of international organisations have developed basic frameworks against which organic production methods can be measured. The International Federation of Organic Agriculture Movements (IFOAM) has established standards for organic production, labelling, and certification procedures to be enforced by national organic associations (Australian Certified Organic, 2006). The Food and Agriculture Organization (FAO)/World Health Organization (WHO) (1999) Codex Alimentarius Commission has produced guidelines as a first step towards official international harmonisation of the requirements for organic products in terms of production and marketing standards, inspection arrangements and labelling requirements.

Consumer studies indicate that one of the primary reasons for purchasing organic food is the perception that it conveys nutritional advantages over conventional products (Bourn & Prescott, 2002; Magkos, Arvaniti, & Zampelas, 2003; Shepherd, Magnusson, & Sjödén, 2005; Williams, 2002). Reviews of the literature, however, have demonstrated few and inconsistent differences in the nutrient composition of organically produced foods compared to foods that have been produced by conventional methods (Bourn

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doi:10.1016/j.foodchem.2007.12.067

& Prescott, 2002; Magkos et al., 2003; Woese, Lange, Boess, & Bögl, 1997). Comparisons between studies are made difficult by the large variability in study design and methodology (Woese et al., 1997; Worthington, 2001). Nonetheless, there are indications that many organic food varieties have a lower nitrate content (Bourn & Prescott, 2002; Magkos, Arvaniti, & Zampelas, 2006; Siderer, Maquet, & Anklam, 2005; Worthington, 2001) and a higher vitamin C content (Magkos et al., 2003; Williams, 2002; Worthington, 2001) than their conventional counterparts.

A small number of studies have reported on the effect of agricultural methods on the fatty acid composition of meat and dairy products. Milk produced through organic practices has been shown in some instances to contain higher amounts of alpha-linolenic acid (ALA) (Bergamo, Fedele, Iannibelli, & Marzillo, 2003; Ellis et al., 2006; Fievez & Vlaeminck, 2006; Jahreis, Fritsche, & Steinhart, 1996) and conjugated linoleic acid (CLA) (Bergamo et al., 2003; Fievez & Vlaeminck, 2006; Jahreis et al., 1996); while other reports demonstrated no clear effect of local management practices on the presence of ALA (Toledo, Andrén, & Björck, 2002) or CLA (Ellis et al., 2006; Toledo et al., 2002). Organic milk has been found to contain a lower $n-6$:$n-3$ fatty acid ratio when compared with conventional milk (Ellis et al., 2006; Wong, Ahmad, Phuyal, & Samman, 2006). The fat quality of lamb is reported to reflect differences in the fatty acid composition of the animal feed rather than a specific metabolic impact of the production method (Nürnberg et al., 2006) and steers raised by organic or conventional methods showed no difference in the fatty acid composition of muscle tissue (Walshe, Sheehan, Delahunty, Morrissey, & Kerry, 2006). Organic chicken breast, based on a sample of 2 chickens, is reported to have lower ALA and higher linoleic acid (LA) compared to 2 conventionally produced chickens (Jahan, Paterson, & Spickett, 2004).

There is limited research comparing the effect of production methods on the fatty acid composition of edible oils. Perretti, Finotti, Adamuccio, Della Sera, and Montanari (2004) reported that the fatty acid composition of sunflower seed oil was unaffected by the method of production, whereas Gutierrez, Arnaud, and Albi (1999) found that the oleic acid concentration tended to be higher and the level of LA lower in organic compared to conventional virgin olive oil. The objective of the present analysis is to compare the fatty acid composition of a range of commercially available certified organic and conventionally produced edible oils.

2. Materials and methods

2.1. Sample collection

During the period from August to September 2006, samples of commercially available certified organic oil products were purchased from supermarkets, organic retail outlets and health food stores in the Sydney metropolitan region. The selected products were certified organic by accredited certifying organisations. Conventional products were purchased for comparison with their organic counterparts based on criteria that included, wherever possible, the description of the production methods, the labelled total fat content, brand name, and the country of origin. A total of 59 organic and 53 conventional samples were obtained of 10 different types of oil, comprising 51 organic-conventional pairs and 10 unpaired oils (8 organic and 2 conventional).

2.2. Lipid extraction and analysis

Lipids were extracted from duplicate samples of oil by chloroform/methanol (Bligh & Dyer, 1959). Fatty acid methyl esters (FAME) were prepared by direct transesterification (Lepage & Roy, 1986), and analysed by gas chromatography (Agilent 6850 series, Santa Clara, CA) with flame ionisation detection. FAME were analysed using a fused carbon–silica capillary column (phase: cyanopropylphenol, 25 μm; column: 30 m × 0.25 mm; type: DB-225, J & W Scientific, Folsom, CA). The flow rate of the hydrogen carrier gas was 1.0 ml/min, at a pressure of 500 kPa. The injector port and detector temperature were maintained at 300 °C. The oven temperature was programmed to maintain a temperature of 170 °C for 2 min, then rise to 190 °C at 10 °C/min and maintain for 1 min, before rising to a plateau of 220 °C at a rate of 5 °C/min. The total run time for one cycle was 25 min. Hewlett–Packard Chem Station Software (v 4.0.1.1) was used to calculate peak areas and retention times. FAME were identified by comparing retention times with a commercial standard mixture of 19 FAME (GLC 68, Nu-Check Prep, Elysian, MN).

2.3. Statistical comparison

The organic and conventional samples were compared with respect to classes of fatty acids (SFA, MUFA, PUFA) using an analysis of variance model with type of oil and method of production (organic or conventional) as fixed factors, and sample pair as a random factor. Preliminary analyses confirmed that fatty acid components were very different in terms of type of oil, but also different in terms of method and the interaction of type with method. Further analyses were conducted for each oil type separately. For those oils with a small number of pairs (that is, all except olive oil), non-parametric versions of the analyses were also conducted, and these results were preferred when they differed from the parametric versions: oils with fewer than three pairs were not compared statistically. All formal analyses were carried out using SPSS version 14 (Chicago, USA).

3. Results

A total of 59 certified organic and 53 conventional samples were available for analysis in the present study. Valid comparisons between organic and conventional products could not be carried out for avocado, macadamia, peanut, high oleic and high linoleic safflower, and pumpkin seed oils due to a small sample size or unavailability of conventional products for comparison.

The fatty acid composition of the oils and the $n-3/n-6$ ratios are shown in Tables 1 and 2. Overall results showed that for SFA, type of oil was the major determinant ($F = 994$ on 11,57 df, $P < 0.001$). Although method of production was non significant ($P = 0.40$), interaction between type and method was significant ($P = 0.002$). The significant interaction manifested itself in the fact that some oils had higher SFA in the organic version (e.g. coconut oil), while others had higher SFA in the conventional version (e.g. sesame oil). For monounsaturated fatty acids (MUFA), type of oil was also highly significant ($F = 28.7$ on 11,55 df, $P < 0.001$), with both the method of production ($P = 0.021$) and the interaction ($P < 0.001$) also reaching significance. For PUFA, type of oil was again significant ($F = 25.7$ on 11,56 df, $P < 0.001$), as were the method ($P = 0.032$) and the interaction ($P = 0.001$).

This pattern of results for classes of fatty acids was mirrored in the overall results for most individual fatty acids: in each case type of oil was highly significant, as was the interaction between type and method. Only palmitoleic acid (16:1) and arachidic acid (20:0) had type × method interactions that did not reach significance ($P = 0.49$, 0.07, respectively).

In terms of individual oil categories, results for sufficient pairs were available for canola (4 pairs), coconut (3 pairs), flaxseed (4 pairs), mustard seed (3 pairs), olive (23 pairs), sesame seed (4 pairs) and sunflower seed (5 pairs) oils. The results for olive oil were analysed using *t*-tests, while those for the other oils were carried out non-parametrically using Wilcoxon tests. None of the comparisons of the SFA, MUFA, PUFA and individual fatty acids shown in Tables 1 and 2 reached significance.

4. Discussion

The comparison between organic and conventional oil samples in the present study highlighted a high degree of variation in fatty acid profiles, with no consistent overall trends being observed.

A post hoc power investigation was carried out based on the olive oil results (the highest number of samples) ($n = 22$ pairs, with one outlier removed) which showed that this sample size had 97% power to pick up a 15% difference (71% power for 10% difference) in SFA. In addition, the study had essentially 100% power to pick up a 10% difference in MUFA, but only 36% power to pick up a 15% difference in PUFA. The power of the tests carried out on the other oils was much lower due to the smaller sample sizes ($n = 3$, 4 and 5 pairs) however, it was not possible to find more of these oils for purchase.

Table 1
Individual fatty acids and total SFA, MUFA, PUFA composition (mean ± standard deviation in percentage of total fatty acids) of organic and conventional coconut, olive, and canola oils

Fatty acid	Coconut oil		Olive oil		Canola oil	
	Organic ($n = 6$)	Conventional ($n = 3$)	Organic ($n = 23$)	Conventional ($n = 23$)	Organic ($n = 4$)	Conventional ($n = 4$)
12:0	42.64 ± 4.93	35.66 ± 4.53	ND	ND	ND	ND
14:0	22.89 ± 1.01	21.79 ± 0.91	ND	ND	ND	ND
14:1	ND	ND	ND	ND	ND	ND
16:0	14.03 ± 1.18	16.22 ± 1.46	10.42 ± 1.30	9.69 ± 1.83	3.97 ± 0.26	3.68 ± 0.17
16:1	ND	ND	0.77 ± 0.28	0.67 ± 0.34	ND	ND
18:0	6.11 ± 1.16	7.04 ± 0.82	2.56 ± 0.91	2.55 ± 1.11	2.43 ± 2.39	1.65 ± 1.1
18:1	11.71 ± 1.77	15.44 ± 2.11	75.23 ± 4.29	74.54 ± 9.17	65.57 ± 7.51	63.49 ± 1.34
18:2	2.63 ± 0.86	3.86 ± 0.46	9.73 ± 3.07	11.37 ± 9.74	19.46 ± 5.18	20.05 ± 0.48
18:3	ND	ND	0.85 ± 0.38	0.72 ± 0.18	6.27 ± 4.27	9.46 ± 0.26
20:0	ND	ND	0.44 ± 0.18	0.42 ± 0.23	0.65 ± 0.08	0.51 ± 0.34
20:1	ND	ND	ND	ND	0.98 ± 0.66	1.16 ± 0.12
20:2	ND	ND	ND	ND	ND	ND
20:3 ($n-6$)	ND	ND	ND	ND	ND	ND
20:4	ND	ND	ND	ND	ND	ND
20:3 ($n-3$)	ND	ND	ND	ND	ND	ND
22:0	ND	ND	ND	0.05 ± 0.23	0.67 ± 0.47	<0.1
22:1	ND	ND	ND	ND	ND	ND
22:6	ND	ND	ND	ND	ND	ND
24:0	ND	ND	ND	ND	ND	ND
24:1	ND	ND	ND	ND	ND	ND
SFA	85.66 ± 2.54	80.7 ± 2.54	13.42 ± 1.52	12.71 ± 1.72	7.72 ± 2.64	5.84 ± 0.99
MUFA	11.71 ± 1.77	15.44 ± 2.11	76 ± 4.13	75.2 ± 9.21	66.55 ± 6.87	64.65 ± 1.34
PUFA	2.63 ± 0.86	3.86 ± 0.46	10.59 ± 3.26	12.09 ± 9.6	25.73 ± 9.08	29.51 ± 0.53
$-n-6$	2.63 ± 0.86	3.86 ± 0.46	9.73 ± 3.07	11.37 ± 9.74	19.46 ± 5.18	20.05 ± 0.48
$-n-3$	ND	ND	0.85 ± 0.38	0.72 ± 0.18	6.27 ± 4.27	9.46 ± 0.26
$-n-3/6$	ND	ND	0.09 ± 0.03	0.08 ± 0.03	0.32 ± 0.21	0.47 ± 0.02

ND: not detected.

Table 2
Individual fatty acids and total SFA, MUFA, PUFA composition (mean percentage of total fatty acids ± SD) of organic and conventional mustard seed and sesame oils

Fatty acid	Mustard seed oil		Sesame oil	
	Organic ($n = 3$)	Conventional ($n = 3$)	Organic ($n = 4$)	Conventional ($n = 4$)
12:0	ND	ND	ND	ND
14:0	ND	ND	ND	ND
14:1	ND	ND	ND	ND
16:0	3.54 ± 0.54	2.30 ± 1.03	7.67 ± 0.6	8.01 ± 0.74
16:1	ND	ND	ND	ND
18:0	2.42 ± 0.16	0.69 ± 0.6	4.28 ± 0.54	5.92 ± 0.51
18:1	42.55 ± 2.91	27.47 ± 20.81	39.41 ± 0.28	41.30 ± 3.13
18:2	30.53 ± 1.44	16.76 ± 10.79	47.60 ± 1.06	43.89 ± 3.84
18:3	15.54 ± 1.66	11.17 ± 3.19	0.59 ± 0.06	0.29 ± 0.2
20:0	0.76 ± 0.06	0.82 ± 0.16	0.45 ± 0.32	0.59 ± 0.39
20:1	2.07 ± 0.75	5.67 ± 4.55	ND	ND
20:2	ND	0.27 ± 0.47	ND	ND
20:3 ($n-6$)	ND	ND	ND	ND
20:4	ND	ND	ND	ND
20:3 ($n-3$)	ND	ND	ND	ND
22:0	0.30 ± 0.26	0.88 ± 0.65	ND	ND
22:1	1.63 ± 1.42	31.71 ± 28.29	ND	ND
22:6	ND	ND	ND	ND
24:0	0.24 ± 0.2	0.32 ± 0.56	ND	ND
24:1	0.41 ± 0.36	1.93 ± 1.3	ND	ND
SFA	7.26 ± 0.37	5.02 ± 0.75	12.4 ± 1.14	14.52 ± 0.79
MUFA	46.66 ± 0.39	66.77 ± 13.44	39.41 ± 0.28	41.3 ± 3.13
PUFA	46.07 ± 0.45	28.21 ± 13.79	48.2 ± 1.09	44.18 ± 3.8
–$n-6$	30.53 ± 1.44	17.04 ± 10.61	47.6 ± 1.06	43.89 ± 3.84
–$n-3$	15.54 ± 1.66	11.17 ± 3.19	0.59 ± 0.06	0.29 ± 0.2
–$n-3/6$	0.51 ± 0.08	0.75 ± 0.22	0.01 ± 0.001	0.01 ± 0.005

ND: not detected.

A previous analysis of olive oils (Gutierrez et al., 1999) showed that the percentage of oleic acid tends to be higher, and the amount of LA lower, in organic compared to conventional virgin olive oil, with no other significant differences in fatty acid composition. In the present study, no differences in oleic acid and LA levels were observed between organic and conventional olive oils (22 of which were extra virgin out of a total of 23 samples, Table 1).

Organic coconut oils are observed to have lower palmitic acid than conventional ones but higher total SFA as a result of the relatively higher level of lauric acid (Table 1). The predominance of lauric acid is a known characteristic of coconut oil, as is the presence of a high level of other short chain fatty acids, such as caprylic (C8:0) and capric (C10:0) acids (Gunstone, 1996). Fatty acids with chain lengths shorter than lauric acid were not analysed in this study so potential differences in shorter chain fatty acids between organic and conventional coconut oils have not been investigated.

Organic mustard seed oil was found to contain a higher level of saturated fatty acids than conventional mustard seed oil. The difference can be attributed to the higher stearic acid content of the organic produce. In contrast to their unsaturated fatty acids content, mustard seed oils contain relatively low amounts of saturated fatty acids so the difference is unlikely to make a substantial change to the overall fatty acid composition of organic compared to conventional varieties (Table 2).

Although no significant differences were observed in the concentrations of MUFA or PUFA when comparing organic and conventional mustard seed oils, the levels of a number of specific fatty acids were found to fluctuate between individual samples. The major unsaturated fatty acid components of typical mustard seed oils are reported to be erucic acid (43%), oleic acid (23%), ALA (10%), LA (9%), and eicosenoic acid (8%) (Gunstone, 1996). In the present study, only 2 of the 3 conventional samples contained erucic acid as the predominant fatty acid, with the remaining one containing oleic acid in the greatest proportion. Among the corresponding organic samples, all were found to have oleic acid as their largest component. It is unclear from the present analysis whether the observed difference in the fatty acid composition of mustard seed oils is a result of the use of different cultivars of mustard seed, or other factors.

Organic sesame oils contain lower stearic acid and total saturated fatty acids content than their conventional counterparts. Similar to mustard seed oils, sesame oils are high in unsaturated fatty acids so the effect of the difference in SFA on the overall fat composition of organic and conventional sesame oils is less pronounced. Organic sesame oils were also found to contain more ALA than conventional sesame oils but the magnitude of the difference is small (0.3% of total fatty acids) and did not affect the $n-6$:$n-3$ ratio (Table 2).

There are various study methods available for investigating potential differences between organic and conventional products, each with associated advantages and disadvantages. The approach used in the present study is the compositional analysis of products purchased from retail markets. In broad terms, retail market studies differ from farm and cultivation studies in that little or no information is available regarding the specific environmental conditions under which the products were produced, including the time of harvest, variety, ripening, maturation and processing methods. Studies at the retail level are therefore less likely to be representative of the food production system as a whole (Magkos et al., 2006). A potential disadvantage of obtaining all the samples from retail outlets is the lack of a guarantee of authenticity. Nevertheless all organic samples were labelled as certified organic. Market-oriented studies do, however, reflect the quality of products in commercial outlets, and are therefore more applicable to the consumer. In the present study, sample size was limited by the number and variety of oils available for purchase. Among the 59 organic oils obtained, olive oils contributed 23 samples, compared to 1 each for avocado, peanut, macadamia and pumpkin seed oils. For some oils, few conventional samples were available for comparison with the organic varieties.

Recent studies have held that organic farming benefits biodiversity (Bengtsson, Ahnstrom, & Weibull, 2005; FAO/WHO Codex Alimentarius Commission, 1999; Hole et al., 2005), contributes to the empowerment of traditional farmers and local communities (Ramesh, Singh, & Subba Rao, 2005), and may increase yields while simultaneously increasing water use efficiency and potentially decreasing pesticide use and carbon sequestration (Pretty et al., 2006; Wood, Lenzen, Dey, & Lundie, 2006). An approach that minimises ecological damage is apposite to the sustainability of the food supply into the future (Solomons, 2002). In conclusion, although some differences were identified in specific oils, no consistent difference was observed between the overall fatty acid composition of commercially available certified organic and conventionally produced edible oils. Consumers and health professionals will need to prioritise factors other than nutrition in their decisions to recommend or to purchase organic produce.

Acknowledgements

This work was supported partly by the Sydney University Nutrition Research Foundation. SS designed the study, evaluated the data and wrote the manuscript; JWYC collected data and undertook a preliminary evaluation; MJF evaluated the data and assisted with drafting the manuscript; ZIA and JLP provided technical assistance; PP evaluated the data and assisted with drafting the manuscript.

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