Received: 29 July 2011 Revised: 12 October 2011 Accepted article published: 28 November 2011 Published online in Wiley Online Library: 19 March 2012

(wileyonlinelibrary.com) DOI 10.1002/jsfa.5639

Comparison of nutritional quality between conventional and organic dairy products: a meta-analysis

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Abstract

As a contribution to the debate on the comparison of nutritional quality between conventional *versus* organic products, the present study would like to provide new results on this issue specifically on dairy products by integrating the last 3 years' studies using a meta-analysis approach with Hedges' *d* effect size method. The current meta-analysis shows that organic dairy products contain significantly higher protein, ALA, total omega-3 fatty acid, *cis*-9,*trans*-11 conjugated linoleic acid, *trans*-11 vaccenic acid, eicosapentanoic acid, and docosapentanoic acid than those of conventional types, with cumulative effect size (±95% confidence interval) of 0.56 ± 0.24, 1.74 ± 0.16, 0.84 ± 0.14, 0.68 ± 0.13, 0.51 ± 0.16, 0.42 ± 0.23, and 0.71 ± 0.3, respectively. It is also observed that organic dairy products have significantly ($P < 0.001$) higher omega-3 to -6 ratio (0.42 vs. 0.23) and Δ9-desaturase index (0.28 vs. 0.27) than the conventional types. The current regulation on organic farming indeed drives organic farms to production of organic dairy products with different nutritional qualities from conventional ones. The differences in feeding regime between conventional and organic dairy production is suspected as the reason behind this evidence. Further identical meta-analysis may be best applicable for summarizing a comparison between conventional and organic foodstuffs for other aspects and food categories.

Keywords: nutrition; organic; comparison; dairy products; meta-analysis

INTRODUCTION

The organic food market is growing and expanding all over the world,[1] and it has been the fastest-growing market in the food sector over the last decade.[2,3] This market was estimated to reach US $55 billion in 2009.[1] As the third most important commodity after fruits and vegetables within the global organic food market, the organic dairy market is also increasing.[4] This suggests that the market players including consumers are becoming increasingly interested in this sector.

The lack of consumer confidence in conventional products due to issues such as mad cow disease, the dioxin scandal and effects of pesticide and antibiotic use is suspected as one of the driving forces of this trend.[5] Organic Monitor[6] reported that the sales growth of dairy products rose over 30% in some countries in Europe due to the BSE crisis. Apart from that, consumers are becoming more concerned about the health aspects.[7,8] It was shown that health is the second strongest consideration (after hedonism) for consumers in choosing organic dairy products, followed by animal welfare and environmental issues.[2,7,9] Consumers expect better quality in terms of health and nutritional properties from organic labelled products.[10,11]

On the other hand, consumers lack information beyond the food label. Scientific evidence is highly demanded in order to promote consumer confidence in organic foods.[5,10] However, the available evidence is not yet able to fill this lack.[12] There have been contrasting results among individual experiments. Furthermore, the final conclusions of some reviews are contradictory. Some of them inferred that organic products are healthier and have higher nutritional value than conventional ones,[13–16] but others argued against that.[2,17–19] Although systematic reviews have been conducted on this issue,[17,18] most of them did not apply meta-analysis.[19] Therefore, a valid conclusion from the various studies has not been possible so far.[20]

Therefore, based on the description above, the main objective of this study was to compare the nutritional quality between conventional and organic dairy products. This was conducted by summarizing the related studies for a period from March 2008 to April 2011, which is not covered by the previous reviews[17] (the period from January 1958 to February 2008 was reviewed by Dangour *et al*.[17]), using a meta-analytical technique. The outcome is expected to provide new, additional scientific references in the organic food quality area.

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EXPERIMENTAL

Literature search and selection method

Literature search was conducted through a literature database, i.e. ISI Web of Knowledge (http://apps.isiknowledge.com) and Science Direct (http://www.sciencedirect.com/) for a period from March 2008 to April 2011. The following keywords were used in the search: 'comparison', 'conventional', 'organic', 'milk', 'dairy', 'compare', 'label', 'claims', 'farm*management', 'production*management', 'nutrition', and 'quality'. An additional search was conducted using the names of the major authors in the field. These initial searches resulted in 994 potential references. Inaccessible full articles were obtained by direct correspondence to the authors. Further, the following criteria were used for literature selection: (1) published in English as full-text articles; (2) peer-reviewed published journals; (3) direct comparison between organic and conventional; (4) declared 'conventional' (reported as conventional, high-input, intensive, non-organic) and 'organic' product (reported as organic label, organic claim, organically certified, organically regulated, organic farm, organic supplier); (5) dairy products, including raw milk and milk-based product as well as milk from animals other than bovine; and (6) comparison of the nutritional quality aspect, including macro- and micro-nutrients.

According to the initial title screening, as many as 945 references were eliminated because the topic was irrelevant to the research. After reviewing the abstracts, 20 out of the 49 articles were selected. Then, seven articles were eliminated due to the irrelevant nutritional parameters used (four articles), author not replying to correspondence (two articles), and insufficient data for statistical meta-analysis (one article). In the end, the screening yielded 13 articles for use in subsequent data coding and statistical data analysis.

Studies coding

Some moderator variables were used for the studies coding and initial information. Those variables were place of research, type of survey, type of animal, type of product, processing unit, season, sample size of the conventional and organic groups, organic regulation used, and references. A total of 29 studies were derived from a comprehensive review of the 13 selected articles. The mean value and standard deviation from several parameters were recorded and tabulated, and the units of measurements were homogenized for further data analysis. Those parameters were: fresh forage in diet, yield, fat content, protein content, and some vitamins (α-tocopherol and β-carotene). Minerals were excluded from the parameters because there was a lack of available information. Some fat components were recorded in more detail owing to the essential parameters for defining the nutritional quality of the dairy product and the data availability from the selected articles. Those fat components were: total saturated fatty acid (SFA), total monounsaturated fatty acid (MUFA), total polyunsaturated fatty acid (PUFA), stearic acid (C18 : 0), oleic acid (C18 : 1 n-9), linoleic acid (C18 : 2 n-6), α-linolenic acid (ALA, C18 : 3 n-3), omega-3 fatty acid (n-3), omega-6 fatty acid (n-6), conjugated linoleic acid 9 (CLA9, *cis*-9,*trans*-11 C18 : 2), vaccenic acid (VA, *trans*-11 C18 : 1), eicosapentanoic acid C20 : 5 n-3 (EPA), and docosapentanoic acid C22 : 5 n-3 (DPA). Docosahexaenoic acid was excluded from the list because the number of studies (two) was too few for quantification. A minimum three studies was needed to quantify the cumulative effect size.[21] Additional parameters were calculated from the data available for better nutritional quality insight, i.e. ratio of omega-3 to omega-6 fatty acid (n-3/n-6) and Δ-9 desaturase index, which is derived from [CLA9]/([CLA9] + [VA]).[22] The common units that were used for uniformity were: g g^{-1} dry matter for fresh forage in diet; kg milk per head per day for yield; g kg^{-1} milk for fat and protein content; mg kg^{-1} milk fat for α-tocopherol and β-carotene; and g kg^{-1} fatty acid for the fat components.

Statistical analysis

Effect size as 'Hedges' *d*' was applied to quantify parameter distance between conventional and organic products. This method was selected because of its ability to calculate the effect size regardless the heterogeneity of sample size, measurement unit, and statistical test result, and also suitability for estimating the effect of paired treatments.[20,23] The conventional group was pooled into a control group (C) and the organic group was pooled into an experimental group (E). The effect size (d) was calculated as

$$d = \frac{(\bar{X}^{E} - \bar{X}^{C}}{S}J$$

where $\bar{X}^{E}$ is the mean value from the experimental group and $\bar{X}^{C}$ is the mean value of the control group. Therefore the positive effect size indicates that the parameter observed is greater in the organic group, and vice versa. J is the correction factor for small sample size, i.e.

$$J = 1 - \frac{3}{(4(N^{C} + N^{E} - 2) - 1)}$$

and S is the pooled standard deviation, defined as

$$S = \sqrt{\frac{(N^{E} - 1)(s^{E})^2 + (N^{C} - 1)(s^{C})^2)}{(N^{E} + N^{C} - 2)}}$$

where N^{E} is the sample size of the experimental group, N^{C} is the sample size of the control group, s^{E} is the standard deviation of the experimental group, and s^{C} is the standard deviation of the control group. The variance of Hedges' d (v_d) is described as

$$v_d = \frac{(N^{C} + N^{E})}{(N^{C}N^{E})} + \frac{d^2}{(2(N^{C} + N^{E}))}$$

Cumulative effect size (d_{++}) is formulated as

$$d_{++} = \frac{\left(\sum_{i=1}^{n} w_i d_i\right)}{\left(\sum_{i=1}^{n} w_i\right)}$$

where w_i is the inverse of the sampling variance: $w_i = 1/v_d$.

The precision of the effect size is described by using 95% confidence Interval (CI), i.e. $d\pm(1.96 \times s_d)$. All the above equations are derived from Rosenberg *et al.*[24] and Sanchez-Meca and Marin-Martinez.[20] The calculated effect size is statistically significant if the CI does not reach the null effect size.[20]

A fail-safe number (N_{ft}) is calculated to recognize the publication bias caused by the insignificant studies which are not included on the analysis. $N_{ft} > 5N + 10$ is considered to provide evidence of

Table 1. List of comparison studies used in meta-analysis

Study code	Place	Type of survey	Animal	Product	Processing	Season	N_c	N_o	Organic regulation	References
1	UK	Farm	Cow	Whole milk	Raw	W&S	24	34	Organic certified	22
2	UK	Farm	Cow	Whole milk	Raw	W	21	10		
3	Switzerland	Farm	Cow	Whole milk	Pasteurized	W&S	36	36	Organic farming Switzerland	42
4	Netherlands	Farm	Cow	Whole milk	Raw	W	5	5	Organic certified	11
5	UK	Farm	Cow	Whole milk	Raw	W&S	16	20	Organic certified	43
6	UK	Farm	Cow	Whole milk	Raw	S	4	5		
7	UK	Farm	Cow	Whole milk	Raw	W	4	5		
8	UK	Farm	Cow	Whole milk	Raw	W	4	5		
9	UK	Farm	Cow	Whole milk	Raw	S	4	5		
10	Italy	Farm	Cow	Whole milk	Raw	W&S	10	10	Organic milk supplier	44
11	Italy	Farm	Cow	Curd	Processed	W&S	10	10		
12	Italy	Farm	Cow	Curd	Cooked	W&S	10	10		
13	Italy	Farm	Cow	Grana Padano Cheese	Processed	W&S	10	10		
14	Denmark	Farm	Cow	Whole milk	Raw	W&S	75	50	Danish Ministry of Food, Agriculture and Fisheries Council Regulation No. 2092/91	45
15	Poland	Farm	Cow	Whole milk	Raw	W&S	21	21	EU Verordnung 1999	46
16	Poland	Farm	Cow	Whole milk	Raw	W	21	21		
17	Poland	Farm	Cow	Whole milk	Raw	S	21	21		
18	US	Basket	Cow	Whole milk	Pasteurized	W	111	99	USDA standards	47, 10
19	US	Basket	Cow	Whole milk	Pasteurized	W	82[a]	99	for organic production	
20	Sweden	Farm	Cow	Whole milk	Raw	W	10	10	Organic certified	48
21	Sweden	Farm	Cow	Whole milk	Raw	S	15	15		
22	Greece	Farm	Sheep	Whole milk	Raw	W	41	41	Greek Ministry of	49
23	Greece	Farm	Goat	Whole milk	Raw	W	40	40	Rural Development and Food	
24	UK	Basket	Cow	Whole milk	Pasteurized	W&S	48	40	Certified organic	50
25	UK	Basket	Cow	Whole milk	Pasteurized	S	12	10		
26	UK	Basket	Cow	Whole milk	Pasteurized	W	12	10		
27	UK	Basket	Cow	Whole milk	Pasteurized	S	12	10		
28	UK	Basket	Cow	Whole milk	Pasteurized	W	12	10		
29	Germany	Farm	Cow	Whole milk	Raw	W	30	5	Certified by Demeter	51

N_c, sample size from conventional group; N_o, sample size from organic group; W, winter/indoor feeding period; S, summer/outdoor feeding period; W&S, whole season.
[a] rbST-free *versus* organic milk with the same organic sample as study code 18.

a robust meta-analysis model. N_{ft} was calculated using Rosenthal *et al.*'s method.[24] The least sample size from individual studies was applied as *N*. Cohen's benchmarks are used as the standard judgment borders to indicate how large the effect size is. Those benchmarks are 0.2 for small, 0.5 for medium, and 0.8 for large effect size.[24] Additional cumulative effect size calculation was applied on the different clusters from some variables such as season, processing unit, and type of survey. This was applied to see the influence of the moderator variables on the final effect size. All of the above effect size-related calculations were calculated using MetaWin 2.0.[24] Weighted paired-samples *t*-test was applied for the parameters. Least sample size from individual studies was applied as the weighting factor. The mixed-effect model of analysis of variance (ANOVA) with Tukey's test was also applied to see the influence of the moderator variables to the parameters. These tests were conducted using SPSS software version 13.[25]

RESULTS

Profile of the selected studies

The selected studies originated from different countries, i.e. UK, Italy, Poland, USA, Greece, Sweden, Denmark, Germany, Netherlands and Switzerland (Table 1). All selected studies mentioned that, for the organic group, the samples were organically certified. The regulation or organic certification body used varied, i.e. organic farming Switzerland, Danish Ministry of Food, Agriculture and Fisheries Council Regulation no. 2092/91, EU Verordnung 1999, USDA standard for organic products, Greek Ministry of Rural Development and Food, and Demeter. The season and the period of research were encoded separately. Three season types were used here, i.e. whole season (W&S: 34.5%) if the whole season from at least one year's accumulated result was reported, summer (S: 20.7%) and winter (W: 44.8%). Some authors clearly mentioned whether they conducted the evaluation in summer, winter or whole year, but others did not. Unclear cases were

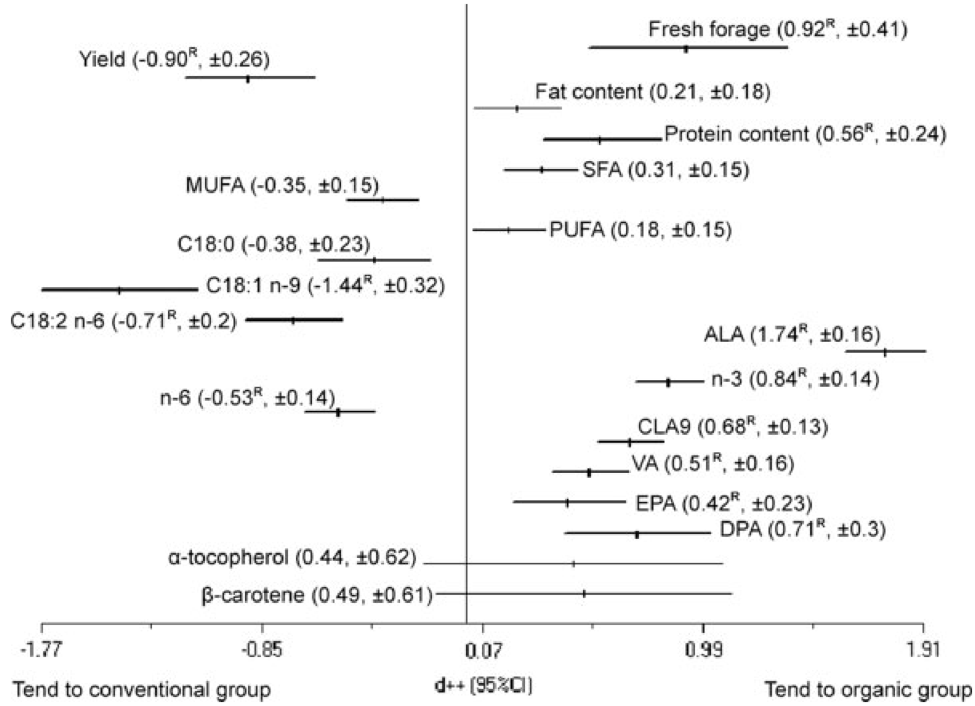

Figure 1. Forest plot of cumulative effect size (d_{++}) and 95% confidence interval (CI) of some nutritional parameters comparing conventional and organic dairy products. Bold lines indicate the robust model.

categorized according to the typical feeding management and research period presented. An outdoor feeding programme was categorized as summer, whereas an indoor feeding programme was categorized as winter. The sample size of the selected studies ranged widely, from four to 111 samples.

Organic *versus* conventional dairy products

The forest plot of cumulative effect size and 95% CI of all parameters (Fig. 1) illustrates the path of comparison of nutritional quality between conventional and organic dairy products. According to the cumulative effect size (d_{++}, ±95% CI), it is clear that organic dairy product contains significantly higher ALA (1.74 ± 0.16) and total omega-3 fatty acid (0.84 ± 0.14) with large effect size, higher protein (0.56 ± 0.24), CLA9 (0.68 ± 0.13), VA (0.51 ± 0.16) and DPA (0.71 ± 0.3) with medium effect size, and higher fat (0.21 ± 0.18), SFA (0.31 ± 0.15), PUFA (0.18 ± 0.15) and EPA (0.42 ± 0.23) with small effect size, compared to the conventional product. The result also indicated that organic dairy farming feeds cattle with significantly higher fresh forage than that the conventional one does, with large effect size, i.e. 0.92 ± 0.41.

Negative effect sizes were found in some parameters, which indicated that organic product contains smaller amount of the observed parameters. Those parameters are MUFA (-0.35 ± 0.15), stearic acid (-0.38 ± 0.23), oleic acid (-1.44 ± 0.32), linoleic acid (-0.71 ± 0.2) and omega-6 fatty acid (-0.53 ± 0.14). All except oleic acid (large effect size) were categorized as medium and small effect size. Insignificant cumulative effect size, which was shown if the ±95% CI was higher than or the same as the cumulative effect size, was also found. Accordingly, insignificant results were observed for the content of α-tocopherol (0.44 ± 0.62) and β-carotene (0.49 ± 0.61).

Not all of those results enabled us to make strong conclusions owing to the conflicting results among studies and the small study size. The fail-safe number (N_{fs}) briefly shows which one is appropriate to be pooled as the final strong conclusions. This number expresses how many sample study sizes should be added to the studies in order to change the initial effect size into a negligible effect size. If $N_{fs} > 5N + 10$, where N is the study effect size used for initial effect size calculation, then the result may be taken as the final robust conclusion.[24] According to these fail-safe number rules, robust parameters are fresh forage in diet, protein, ALA, omega-3 fatty acid, CLA9, VA, EPA, DPA (higher in organic dairy product), oleic acid, linoleic acid, and omega-6 fatty acid (lower in the organic product). These robust conclusions are clearly indicated by the bold lines in Fig. 1.

Further results on the cumulative effect size of milk yield show a negative and significant value, i.e. $-0.9^R \pm 0.26$ ($d_{++} \pm$ 95% CI). Moreover, according to the weighted *t*-test (Table 2), it was observed that organic dairy product had a significantly ($P < 0.001$) higher ratio of omega-3 to omega-6 (n-3/n-6) than that of conventional dairy product, with values of 0.42 and 0.23, respectively. Also it had a significantly ($P < 0.001$) higher Δ9-desaturase index (0.28 vs. 0.27).

Seasonal factor

A forest plot of ALA, n-3, CLA 9 and VA from different seasons (Fig. 2) illustrates that season significantly influenced the cumulative effect size of omega-3 fatty acid. According to the ANOVA and Tukey's test, the seasonal factor significantly ($P < 0.05$) influenced the Δ-9 desaturase index and n-3/n-6 ratio. Both for conventional and organic dairy products, the n-3/n-6 ratio was higher in summer than that in winter, with the mean value always significantly higher in the organic product (Fig. 3). Similarly, the mean value of the Δ-9 desaturase index was higher in summer, both for conventional and organic dairy products. However, no difference in the respective parameter was found between organic *versus* conventional products during the summer season.

Table 2. Cumulative effect size, weighted mean value and weighted *P*-value from all parameters

Parameters	Unit	Cumulative effect size (d_{++})	± 95%CI	Studies size (N)	N_{fs}	x_c	x_o	SEM	P-value	N_p
Fresh forage in diet	$g\ g^{-1}$ dry matter	0.9198*	0.4076	4	80.1^R	0.33	0.60	0.014	***	279
Yield	kg milk cow^{-1} day^{-1}	−0.9028*	0.2636	7	154.9^R	18.74	15.51	0.154	***	285
Fat content	$g\ kg^{-1}$ milk	0.2143*	0.1797	8	18^{NR}	35.90	36.90	0.081	***	331
Protein content	$g\ kg^{-1}$ milk	0.5626*	0.2409	5	43.6^R	31.70	32.50	0.026	***	271
SFA	$g\ kg^{-1}$ fatty acid	0.3121*	0.1490	10	39^{NR}	667.61	675.58	0.933	***	483
MUFA	$g\ kg^{-1}$ fatty acid	−0.3481*	0.1496	10	53.6^{NR}	270.29	259.06	0.765	***	483
PUFA	$g\ kg^{-1}$ fatty acid	0.1794*	0.1500	10	46.9^{NR}	43.89	45.39	0.309	***	483
C18:0 (stearic acid)	$g\ kg^{-1}$ fatty acid	−0.3798*	0.2347	5	14.8^{NR}	106.57	101.33	0.370	***	278
C18:1 n-9 (oleic acid)	$g\ kg^{-1}$ fatty acid	−1.4439*	0.3228	4	266.7^R	227.81	209.42	0.743	***	273
C18:2 n-6 (linoleic acid)	$g\ kg^{-1}$ fatty acid	−0.7151*	0.1998	6	125.4^R	27.26	21.60	0.204	***	404
C18:3 n-3 (ALA)	$g\ kg^{-1}$ fatty acid	1.7444*	0.1622	16	2875.8^R	4.79	7.61	0.048	***	529
n-3	$g\ kg^{-1}$ fatty acid	0.8435*	0.1373	18	1786.4^R	5.61	9.20	0.050	***	574
n-6	$g\ kg^{-1}$ fatty acid	−0.5283*	0.1418	14	89.3^R	27.64	23.42	0.197	***	539
n-3/n-6	ratio	–	–	–	–	0.23	0.42	0.004	***	539
CLA9	$g\ kg^{-1}$ fatty acid	0.6851*	0.1346	17	686.6^R	6.59	8.38	0.061	***	585
VA	$g\ kg^{-1}$ fatty acid	0.5147*	0.1562	9	163.8^R	18.78	22.82	0.157	***	478
Δ9-desaturase index	$g\ kg^{-1}$ fatty acid	–	–	–	–	0.27	0.28	0.001	***	478
EPA	$g\ kg^{-1}$ fatty acid	0.4244*	0.2318	6	325.1^R	0.37	0.64	0.005	***	283
DPA	$g\ kg^{-1}$ fatty acid	0.7120*	0.3009	4	202.2^R	0.66	1.04	0.011	***	257
α-tocopherol	$mg\ kg^{-1}$ milk fat	0.4452^{NS}	0.6227	3	8.5^{NR}	21.04	23.39	0.334	***	84
β-carotene	$mg\ kg^{-1}$ milk fat	0.4914^{NS}	0.6148	3	10.9^{NR}	4.38	5.29	0.048	***	84

CI, confidence interval; *N*, study size for effect size calculation; N_{fs}, fail-safe number; $\bar{x}_c$, weighted mean value from conventional group; $\bar{x}_o$, weighted mean value from organic group; SEM, standard error of the mean; N_p, cumulative sample size for *t*-test; Yield, calculated from cow only; SFA, total saturated fatty acid; MUFA, total monounsaturated fatty acid; PUFA, total polyunsaturated fatty acid; n-3, total omega-3 fatty acid including long- and medium-chain fatty acid; n-6, total of omega-6 fatty acid including long- and medium-chain fatty acid; n-3/n-6, ratio of total omega-3 fatty acid and total omega-6 fatty acid; CLA9, conjugated linoleic acid 9 (C18:2 c9t11); VA, vaccenic acid (C18:1 t11); Δ 9-desaturase index, estimated based on [CLA9]/([VA] + [CLA9]); R, model is robust ($N_{fs} > 5N + 10$); NR, model is not robust ($N_{fs} \leq 5N + 10$); NS, not significant.
* *P*-value < 0.05;
** *P*-value < 0.01;
*** *P*-value < 0.001.

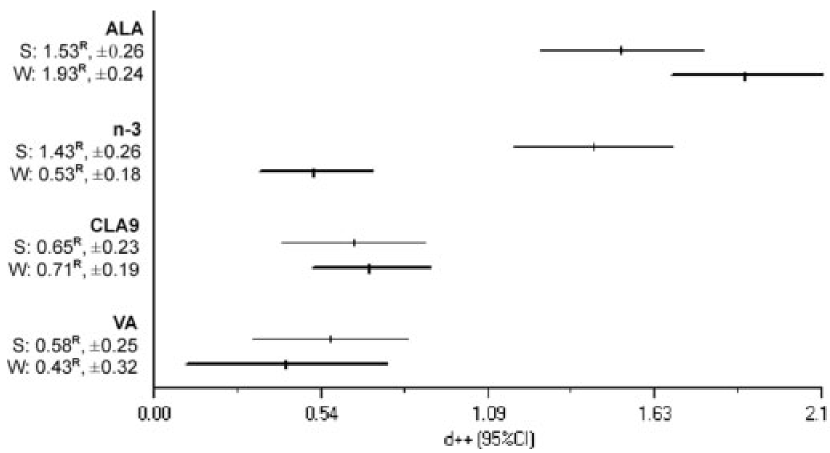

Figure 2. Forest plot of cumulative effect size (d_{++}) and 95% confidence interval (CI) of ALA, n-3, CLA9 and VA from different seasons. Bold lines indicate the winter season.

DISCUSSION

Defining the 'premium' nutritional quality of dairy product

According to Kahl *et al.*,[12] there are two important steps in constructing evidence in the food quality area to 'define' the substance that is going to be proved and then to 'prove' it using appropriate tools. A product is considered to have better nutritional quality than others if it contains higher amounts of some valuable nutrients. It is true that nutritional claims can be made if only a significant amount can be proved[12] but, unfortunately, in most cases significant amounts of valuable milk nutrients have not yet been recognized. 'Significant' amount means the amount which enables significant support of human health.

Comprehensive reviews from Huth *et al.*[26] and Haug *et al.*[27] enable some estimations to be given concerning a rule for

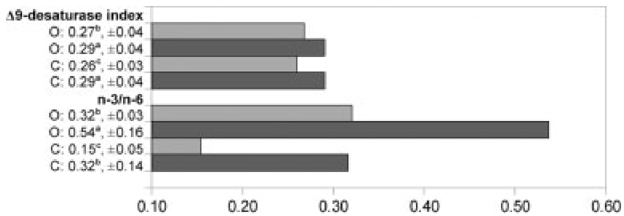

Figure 3. Mean value (± standard deviation) of Δ-9 desaturase index and n-3/n-6 for different seasons. Note: Δ9-desaturase index = [CLA9]/([VA] + [CLA9]); n-3/n-6, omega-3/omega-6 ratio; C, conventional group; O, organic group; dark grey bars, summer; light grey bars, winter; Mean values with superscript letters (a–c) are significantly different (*P*-value <0.05) according to Tukey's honestly significant difference test.

premium nutritional quality of dairy products. Although Huth *et al.*[26] provides a recommendation specifically for the Norwegian case, it may be used as an initial reference to define the premium dairy product worldwide, since references concerning this issue are limited. The premium nutritional quality of dairy product is applied if it enables the following list to be fulfilled:

1. High omega-3 to omega-6 ratio, close to 1:2.[27]
2. High CLA9 content,[26,27] with a significant amount of CLA9 of about 140 to 420 mg d^{-1}.[26]
3. High VA content.[26] However, Haug *et al.*[27] stated that a low proportion of VA is preferable. To cover instances that are both high in CLA9 and with quite a low proportion of VA, the Δ-9 desaturase index is applied. The Δ-9 desaturase index = [CLA9]/([CLA9] + [VA]).[22]
4. At least secure the level of 14 selected key compounds, i.e. protein, vitamins A, D, E, C, B_1, B_2, B_{11} and B_{12}, calcium, zinc, iron, potassium and essential oils.[28]
5. Using energy content as the basis for calculation is preferable.[29]

Not all of the above points can be covered by the current meta-analysis. However, a synthesis review should be able to bridge the update concept and the results available from primary studies. Therefore, an optimum method would be to adapt the above definition of nutritional quality of dairy product according to the results available from the selected studies, with only significant and robust results acceptable for the final conclusion. Thus the current study takes particular interest in certain parameters, i.e. protein, ALA, omega-3/omega-6 ratio (n-3/n-6), CLA9, Δ9-desaturase index, EPA and DPA.

The evidence and a plausible explanation

Significantly higher amounts of protein, ALA, n-3, CLA9, VA, EPA and DPA in organic dairy products than in conventional products, as well as a higher ratio of n-3 to n-6 (approximately twofold) and Δ9-desaturase index, indicate that the organic dairy product may have a premium nutritional quality. The current meta-analysis also shows that organic dairy farming feeds cattle with higher fresh forage levels than does conventional farming, with a large effect size. This provides evidence that, although the regulation and also the implementation of organic dairy farming vary among countries,[30] it seems sufficient to guarantee that dairy farms feed the cattle a higher fresh forage level than on conventional farms. The evidence seems able to answer scepticism among the players in the organic dairy market that the current regulation on dairy farming indeed drives organic farming to produce an enhanced nutritional quality of organic dairy product.

It appears that the most plausible reason from this evidence is the difference in feeding regime between organic and conventional dairy production systems. Higher fresh forage intake, as observed in organic dairy production, is associated with higher intake of PUFA, including ALA.[31,32] This is due to the high amount of unsaturated fatty acids, especially ALA and other omega-3 fatty acids in fresh forage, and it is more prominent in the early stage of maturity.[27] These omega-3 fatty acids cannot be synthesized in the mammary glands of dairy animals[33] since Δ-9 desaturase enzyme is not able to make a double bond at the omega-3 position.[27] Therefore the contents are highly dependent on the intake of the respective compounds in the diet. However, PUFA, including omega-3 fatty acids, may undergo transformation processes in the rumen of ruminants through the action of microbes. The transformation processes are through lipolysis and biohydrogenation of fatty acids.[34,35] Unsaturated fatty acids including ALA are hydrogenated into various isomers of PUFA and MUFA, particularly *trans* and conjugated fatty acids, and end up as stearic acid (C18 : 0), which is the ultimate product of the biohydrogenation process.[34] Inhibition of the biohydrogenation process, at least partially, may occur as indicated by higher CLA9 and VA, and lower C18 : 0 in the organic dairy product in relation to the higher fresh forage intake. Plant secondary compounds, particularly the phenolic compounds present in forages, may contribute to this inhibition. Accordingly, phenolic compounds have been reported to reduce PUFA biohydrogenation, accumulate VA and/or decrease concentration of C18:0.[36–38] The effects seem to be related to the phenolic toxicity to microbial species that are involved in fatty acid biohydrogenation, either in the initial steps of biohydrogenation by inhibiting *Butyrivibrio fibrisolvens* and/or in the terminal step by inhibiting *Clostridium proteoclasticum*.[36,39] Further, higher VA supply to the mammary gland may enhance the content of CLA9 through the action of Δ-9 desaturase.[33]

Influence of seasonal factor

The availability and variability of feed vary with the season, which then indirectly influences the nutrient composition of milk.[30,40] Normally, the nutritional quality of milk, especially the ratio n-3 to n-6, is reduced during wintertime due to the shifting of the feeding system from outdoors (normally in summer) to indoors (normally in winter), which then alters the feed from fresh forage to concentrate and conserved forage.[27] An open question may then arise as to whether the organic dairy product is enabled to secure its 'premium' nutritional quality during the whole season. The result presented shows that the effect sizes of some variables observed, i.e. ALA, n-3, CLA9 and VA, are always positive and robust both during summer and winter. The result also shows that the ratio of n-3 to n-6 and Δ-9 desaturase index are always significantly higher in organic dairy product than in conventional product, both in winter and summer periods. This evidence may suggest that organic dairy product seems able to maintain its 'premium' nutritional quality during the whole season.

Suitability of meta-analysis as a tool for comparing organic *versus* conventional foods

Meta-analysis, especially the Hedges' effect sizes technique, seems to be among the best choices for the current review. This technique is suitable for comparing two or more groups and thus might be used for further investigation in comparing conventional and organic foodstuffs other than dairy products or even for wider meta-analysis. Moreover, this technique has been shown to enable small-size studies to be tackled. Furthermore, this meta-analysis may offer more objective and repeatable results. Appropriate presentation of data and results may give opportunities for the next analyst to reuse information needed for further investigation. On the other hand, this technique is relatively time consuming. Furthermore, it is limited in that only studies which clearly mention the exact values of sample size, mean and standard deviation are eligible for selection. In the case that standard deviation values are not given in the papers, mixed models of ANOVA or paired (weighted) *t*-test, as also done in the present study, may provide an alternative method for conducting meta-analysis studies.[41]

CONCLUSIONS

Current meta-analysis of studies conducted over the last 3 years presents arguments that the current regulation on dairy farming indeed enables the driving of organic farming to produce organic dairy products with different nutritional quality from conventional products. The difference in feeding regime between conventional and organic dairy production is suspected to be the reason behind this evidence. Further identical meta-analysis may be best applicable for evaluating and summarizing the comparison of conventional and organic foodstuffs for other aspects and for food categories other than dairy products.

ACKNOWLEDGEMENTS

JK thanks the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) for financial support within project 2810OE096.

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