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Comparison of Organic and Conventional Raw Milk Quality in The Netherlands

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ABSTRACT

Organic production methods have in the past been shown to have benefits for the environment, biodiversity, soil quality, animal welfare and reduced pesticide residues. In addition to these qualities they may also contribute directly to human health. In an exploratory study, raw (bulk) cow's milk from five organic and five neighbouring conventional farms were compared at the end of the winter housing period. Farm management clearly differed; e.g. organic cows ate less concentrates and forage maize, and more silage of grass clover and hay. The levels of CLA (conjugated linoleic acid) and omega 3 fatty acids were significantly higher in the organic milk. No clear difference in taste was observed: the organic milk was generally considered creamier and tended to taste more of hay and grass than conventional milk. An indication of the health status of the cows was obtained by immunological research. In the organic milk the lymphocyte rest value tended to be lower and after stimulation the cells from organic milk had a higher stimulation index than those in conventional milk. In addition to the more conventional milk analysis two experimental holistic methods were used as an indicator of milk quality: biophoton emission and biocrystallization. These methods showed that organic milk was systematically more 'balanced': it had a more 'ordered structure' and showed better 'integration and coordination'. From this pilot study it can be concluded that overall the organic milk scored better than the conventional milk for both the conventional and holistic measures. Whether these results have an impact on human health needs to be explored in other studies.

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INTRODUCTION

In the organic farming system animal well being is an important issue. Organic milk production can be more beneficial to both animals and the environment than conventional production (Nicholas *et al*., 2004). For many people this is an important consideration for buying organic milk. However, for others the main reason for buying organic is the idea that organic food is more healthy. The call for scientific evidence increases. Therefore, a pilot study was performed to investigate whether organic milk differs from conventional milk and whether these differences could potentially enhance health in humans. This pilot research is modest in design and aims to investigate which parameters are useful to distinguish organic from conventional milk and to obtain an insight into the amount of variation within and between farms. Parameters were chosen that were expected to be relevant for human health in general or to the human immune system. Specific fatty acids are associated with a potential role in strengthening immune defences and preventing asthma, allergies and cardio-vascular disease (Simopoulos, 2002; McLeod *et al*., 2004; Prescott & Calder, 2004; Frischke, 2006; Jacobson, 2006) and the development of the nervous system and eyes in young children (Richardson, 2004; Jensen *et al*., 2005). Immune cell activity reflects primarily the health status of the udder, but it is also related to the general health of the cow, producing healthy milk, which ultimately leads to a healthy consumer. The "organic chain" implies that a healthy soil leads to healthy cattle feed, which in turn leads to healthy cows with healthy milk, which lead to healthy consumers.

MATERIALS AND METHODS

Sampling

For this study five organic dairy farms were selected in different regions in The Netherlands. Farms which play a pioneering role aiming at the improvement of the quality of the organic system (Adriaansen-Tennekes *et al.*, 2005) were selected. The feeding of the cows was based on home-grown fodder and mainly grass and grass-clover products. Five conventional farms were selected in the area near the organic farms, in order to enable a pair wise comparison of farms in the same region with comparable soils. In February 2005 two milk samples were taken from each farm at a one week interval to get insight into the variation within individual farms. The sampling took place in February, at the end of the winter housing period for the cows. Farm characteristics, including management systems, were recorded by means of a questionnaire taken during the initial farm visit.

The research was carried out on raw (bulk tank) milk to exclude the influence of different processing methods (standardization, homogenization and pasteurization). The sampled milk was divided into sub samples and cooled (ca. 4°C). On the same day samples were sent in glass bottles to the different laboratories. Milk intended for aroma and flavour evaluation was transported in bottles wrapped in aluminium foil, to avoid any adverse effects of light on the flavour. All the measurements were single blind measurements.

Choice of parameters

Parameters were chosen which are suited for the product milk and which may be relevant for the human immune system. Investigated were: (1) fatty acids, i.e. the polyunsaturated fatty acids conjugated linolenic acid (CLA) and omega 3 fatty acids, (2) immune cell activity, (3) flavour, (4) biophotons and (5) biocrystallizations. The lymphocyte stimulation index was calculated as an experimental measure of the responsiveness of the cells in the cow's milk. The number of lymphocytes in the milk is a measure of the current health state of the cow: high numbers of lymphocytes indicate a possible local inflammation. Biophoton and biocrystallization analyses relate to the hypothesis that the structure (the 'order') of food is at least as important to human health as the physical composition. The biophoton measurement is based on the 'long-term delayed luminescence' as a measure of the micellar structure of a living system. Biocrystallization pictures of milk suggest the inner structure of a product in terms of coherence, harmoniousness and expansiveness. The hypothesis is that a stronger order or coherence of a product contributes to human health.

No measurements were made of residues of antibiotics or pesticides in milk, because Dutch standards for these aspects are already very strict. Due to budget limitations, other evaluations, such as beta-carotene and vitamin E measurements, which showed up differences (or a tendency to differ) in previous trials (Jensen *et al.*,1999; Browning *et al.*, 2005) were also omitted.

Methods

The analyses of fatty acids were carried out on frozen milk samples by the Institute of Grassland and Environmental Research (IGER, U.K.) using the Kramer bimethylation method. Gas chromatography was used to reveal the full fatty acid pattern of the milk. The determination of the immune response of cells in milk was carried out by the Cell Biology and Immunology Group of the Wageningen University and Research Centre (WUR) (Boonstra *et al.*, 2000). The lymphocyte stimulation index is calculated as the number of white blood cells grown with a stimulant (mitogen) divided by the number of white blood cells grown without stimulation, thus on medium alone. The flavour evaluation was carried out by the Flavour Research Centre (Centrum voor Smaakonderzoek) in Wageningen. An expert panel of 10 regular milk drinkers marked the milk for 13 properties and one overall flavour experience. Biophoton measurements were performed by briefly irradiating milk with light. Then the emission of photons was measured for at least 3 min. The quantity and slowness of photon emission characterizes the micellar structure, whereby high emissions in the period from 100 to 200 s. indicate an ordered structure, and are therefore more desirable. These tests were developed and performed by MeLuNa in the Netherlands (Van Wijk, 2001; Popp, 2002; Saaman, 2004; Strube & Stolz, 2004). For the biocrystallization, milk was crystallized in a copper chloride solution in round glass dishes in a controlled climatic environment (Andersen, 2001). The method was developed around 1930 by Ehrenfried Pfeiffer and further refined for milk (Engquist, 1970; Schmidt, 1985; Balzer-Graf & Balzer, 1991). The crystalline pictures were visually assessed in a blind test for six morphological criteria (Huber *et al*., 2007). For these criteria, the pictures were scored in a scale of 1 to 9. Computerized image analysis was used to assess the needle density of the pictures from the second round of samples. The assays in this research were carried out by the Louis Bolk Institute (Driebergen, The Netherlands).

Statistical processing

An analysis of variance (ANOVA) was used to investigate whether the time of sampling or the region had any effect. For measurements unaffected by time or region, all the results were taken together in a paired sample t-test to determine the difference between organic and conventional milk. For measurements where there was timing or regional effect, two separate paired sample t-tests were carried out. The biophotons were also tested with a Wilcoxon Signed Rank test. ‘GenStat’ was used to calculate the correlations between the various parameters.

RESULTS

Differences in farm management

The organic farms selected were all pioneering farms, which aim at a further development of the organic system. Neighbouring conventional farms were selected to present a good cross-section of conventional livestock farming. The organic farms were situated in five different areas of the Netherlands. Soil types in these areas were clay and peat, marine clay, sand, river clay and loamy sand.

TABLE 1

Summary of farm characteristics, mean (range).

	Conventional N = 5	Organic (3 × EKO; 2 × BD)
Dairy cows per farm	90 (62–116)	51 (33–65)
Age of cows (years)	4.1 (4.1)	4.9 (4.1–5.1)
Cow breed	95% Holstein Frisian (HF)	Many different breeds: MRIJ, Montbeliard, Brown Swiss, Jersey, Holstein Frisian.
Milk (kg cow^{-1} $year^{-1}$)	8000 (7400–9000)	5900 (4650–7090)
Concentrate (kg cow^{-1} $year^{-1}$)	1950 (1200–2700)	900 (400–1460)
Type of roughage	Only grass silage and forage maize or maize.	Grass/clover silage, supplemented with small amounts of forage fodder beets, sometimes hay.
Straw in stable (%)	0	40
Cows with horns (%)	0	70
Cell count (× 1000) of milk	193 (140–299)	225 (140–302)
Farmer's idea of good milk quality	Factory requirements, low cell count, 'Food-Chain-Quality-Milk'-requirements.	Diversity in herd, consumer demand, harmonizing different elements of the farm.
Farmer's idea of healthy milk	Disease-free cows, aroma and flavour.	Resistant cows, no residues or allergens, vitality, aroma and flavour.
Farmer's idea of human and animal health	Absence of symptoms, feeling well.	Resistance, self-reliance, mental and physical wellbeing

The organic farms differed in many aspects from the conventional systems. Although there were considerable individual differences in farm management. The average farm characteristics are shown in Table 1. Organic farms had fewer cows with a higher average age. The organic cows produced less milk. Organic farms were not as strongly geared to high milk production through breed selection and their farming systems were far less intensive. The five organic farms keep a range of breeds (MRIJ, Montbeliard, Brown Swiss, Jersey) and the percentage of Holstein Frisian blood was limited (20% HF), while the conventional farms had almost exclusively HF cows (95% blood). Organic cows were fed more roughage and less concentrate, ate grass and clover silage more regularly, less silage maize and often more hay than cows on the conventional farms. The cows on the conventional farms were all housed in cubicle housing systems and were de-horned. On the organic farms (3 × EKO, 2 × Demeter) the cows more often had horns, and were more often housed in stalls with straw litter.

For conventional farmers, good milk quality is largely defined by external quality requirements imposed by the dairy plant or the government. Organic farmers describing good milk quality refer to aspects of their farm, their herd and the consumer. Both organic and conventional farmers consider aroma, flavour and the cows' health important in terms of a high milk quality. The organic farmers add that good milk is free of residues, is non-allergenic and has vitality.

With regard to human and animal health, conventional farmers focus on the absence of disease in combination with cows welfare. Organic farmers add terms such as resistance, self-reliance and wellbeing. Livestock farmers' attitudes to health determine the direction of their farm management practices.

Differences in milk quality

In Table 2 the results of the quality measures are presented as average values of the two repeated measures per farm. The pairs of farms 1 to 5 are placed together to enable pair wise comparison between the neighbouring farms. There is clearly a considerable variation between the farms. Also within one farm the results of the quality measures can vary between the two consecutive measurements. This was particularly the case for taste, immunology and biophoton measurements.

While the average fat content is similar between the two types of milk, the level of omega 3 fatty acids is clearly higher in organic milk ($p < 0.001$). This tendency is also present for the total CLA-fatty acid content, though this was not significantly different ($p = 0.067$). The cell count of the organic milk is on average slightly higher than that of the conventional milk. This is attributed to the litter in the stalls, not using drying-off preparations and using few, if any,

TABLE 2

Results of the main milk parameters for the individual farms (presented pair wise per region) and average over farm type.

		Region					
		1	2	3	4	5	Mean
Fat (%)	C	4.2	3.9	4.6	4.1	4.3	4.2
	O	4.0	4.0	4.1	4.0	4.9	4.2
CLAs (mg g^{-1} fat)	C	4.7	5.0	4.3	5.1	6.5	5.1
	O	8.0	6.0	4.6	7.7	5.1	6.3
Omega 3 (mg g^{-1} fat)	C	4.5	4.5	4.4	5.6	5.7	4.9***
	O	10.2	14.6	9.6	10.4	8.3	10.6
Lymphocyte (rest value)	C	1771	1704	1809	1766	1767	1763
	O	1231	1029	1049	1024	1016	1069
Lymphocyte (stimulation index)	C	21	23	22	21	19	21***
	O	29	30	35	33	37	33
Flavour							
Overall	C	69	67	69	72	69	69
	O	71	63	67	71	74	69
Creamy	C	53	54	53	51	58	54
	O	55	54	53	54	63	56

C = conventional, O = organic, ***$p < 0.001$.

antibiotics (Smolders & Baars, 2005). Whereas the organic cows have slightly more lymphocytes (= white blood cells) in their milk (cell count), these cells did not respond as strongly in rest in the absence of a mitogen (Table 2). When the white blood cells were cultured with the addition of a mitogen, then those of the organic cows showed a higher response to the mitogen, expressed in the lymphocyte stimulation index ($p < 0.001$). These differences warrant further investigation, because they potentially could indicate the cows' health status.

On average, conventional milk was found to taste just as good as organic milk, sometimes slightly better, sometimes slightly weaker (Table 2). The organic milk had a tendency to taste more of grass and hay than the conventional milk ($p = 0.059$). Organic milk was often characterized as slightly creamier by the tasters, although it was not systematically fattier.

The higher biophoton figures after exposure to light (average of counts s^{-1} in emissions after 100–200 s) show that the milk from organic farms can retain the light longer. On average the figures were 21376 and 23025 counts s^{-1} for conventional and organically produced milk, respectively. This is taken to mean that there is more order in the organic milk (Figure 1). Since all the values were systematically higher in the case of the second sampling than that of the first, no real significant differences were found between all the absolute values. However, when pairs of farms were compared, the organic milk scored higher, significantly more often, than conventional milk (Wilcoxon test, $p = 0.005$).

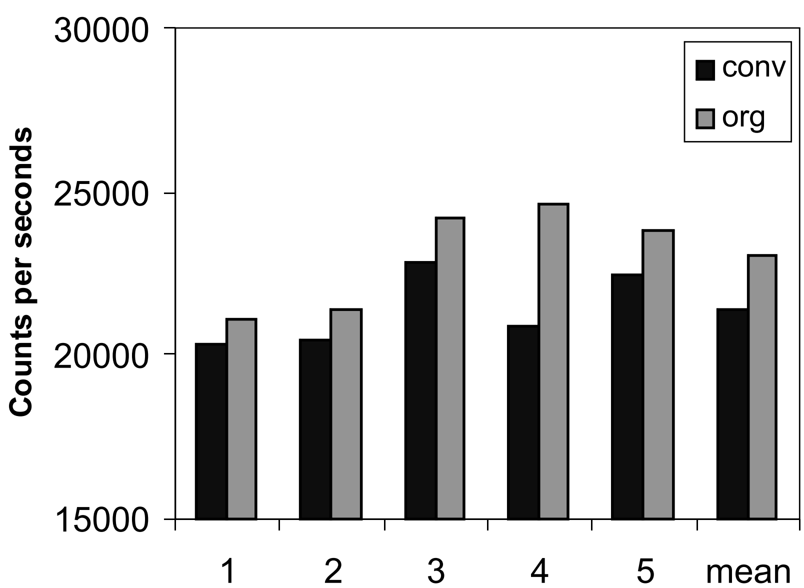

FIGURE 1. Biophoton emission (after 100–200 s), farms presented pair wise per region.

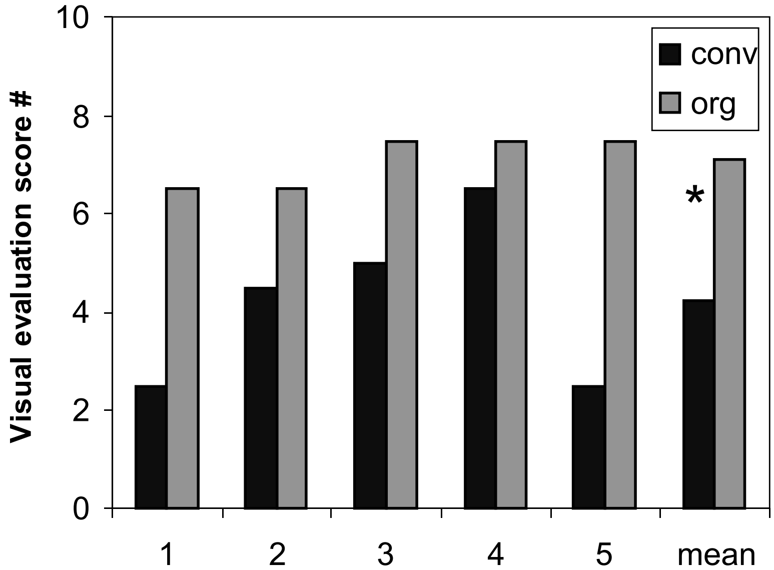

FIGURE 2. Biocrystallisation scores of integration, farms presented pair wise per region. *p < 0.001, # scored on the scale 0–9.

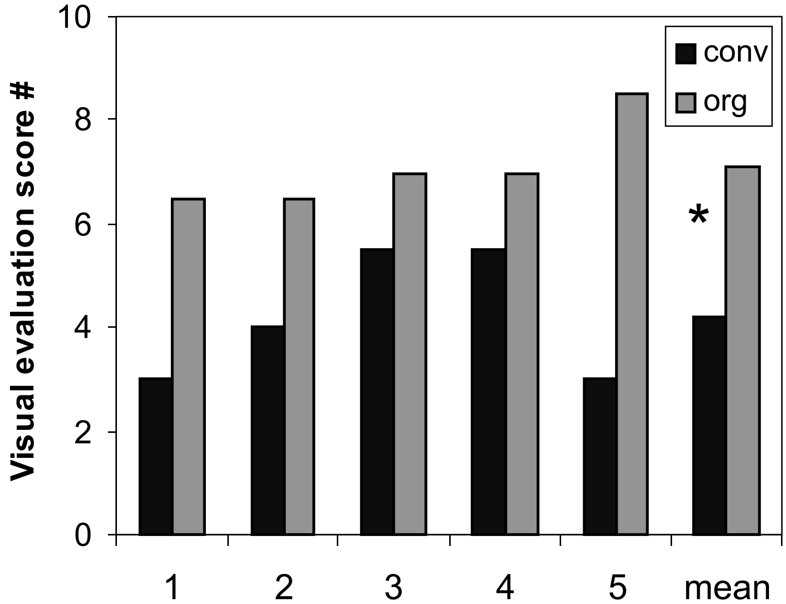

FIGURE 3. Biocrystallisation scores of coordination, farms presented pair wise per region. *p < 0.001, # scored on the scale 0–9.

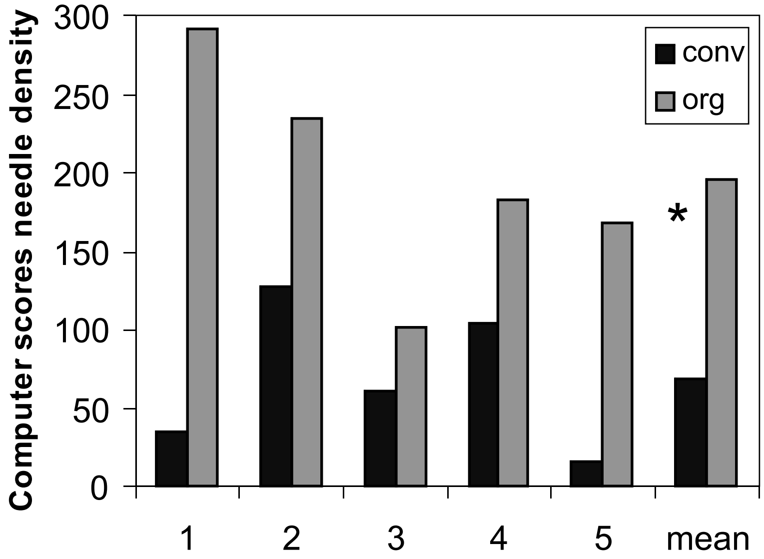

FIGURE 4 Biocrystallisation: Computer analysis of needle density. *p < 0.01.

The biocrystallization pictures were first scored visually. In the visual evaluation organic milk showed more integration (Figure 2, $p < 0.001$) and better coordination (Figure 3, $p < 0.001$). All organic milk pictures also showed stronger perradiation ($p < 0.001$), less degraded 'wickerwork' lattice ($p < 0.001$) and longer 'side needles' ($p = 0.012$). The computer image analysis indicated that all organic milk samples had a denser needle structure than the conventional milk ($p = 0.027$) (Figure 4).

Remarkably good correlations were found between the different experimental parameters: biocrystallization (coordination) and biophotons, $r = 0.54$ and biocrystallization (coordination) and lymphocyte rest value, $r = -0.93$. The correlation between the visual and computer evaluation of the biocrystallization pictures was $r = 0.79$.

DISCUSSION

This research was relevant to investigate the potential of organic dairy production in terms of pioneering farming. Results were based on a set of quality parameters within a framework, where differences in quality might be expected. There was wide variation between the farms. Based on paired comparisons, the differences between organic and conventional bulk tank raw milk samples were significant for several parameters. If only the group average values are assessed, the differences are less clear.

Some parameters showed a wide variation between two successive samplings taken a week apart. The age of the milk in the tank may have played a role here. A refrigerated tank is emptied about three times a week by the dairy processor. The milk in the tank may therefore range from half a day to three and a half days old. However, analysis of the results showed that there is no correlation between the findings and the age of the milk in the tank. The greatest differences between the two sampling dates were seen in the biophoton assessment. The least differences were in the fat content and fatty acid pattern.

Similar levels of total fat, but higher levels of omega 3 fatty acids and a tendency to higher CLA levels in organic milk were found. The higher levels of CLA and omega 3 fatty acids have been found before in organic milk (Flachowsky, 2000; Bergamo *et al*., 2003; Rist, 2004; Browning *et al*., 2005). Previous research showed that milk produced in the grazing season had a higher level of CLA's than milk in the stabling period (Jahreis, 1997, Jahreis *et al*., 1997; Dhiman *et al*., 1999; Geschie & Thomas, 2002; Dewhurst *et al*., 2003; Weller & Davies, 2004). Therefore it is remarkable that higher levels in organic milk were found in this study, which was performed in February, at the end of the winter housing period of the cows, when these levels are usually low.

The higher levels of CLA's and omega 3 fatty acids in organic milk can be explained by the relationship between feed and fatty acids (Dhiman *et al*., 1999; Jahreis *et al*., 1997; Sait & Brunetti, 2003; Dewhurst *et al*., 2003, Witkowska, 2004). The higher values found here are probably due to the high percentage of grass and red clover silage (Dewhurst *et al*., 2003), slightly more hay and the low percentage of concentrate and silage maize in the ration of organic cows. The highest omega 3 values were found in the milk from a biodynamic farm which fed its cows almost exclusively on red clover silage.

A Swiss research project (Rist *et al*., 2007) and a major population screening in the Netherlands (Kummeling *et al*., 2005) showed that the more organic dairy products a mother consumes the higher the level of rumenic acid (the main CLA) in her milk. This cow milk research, combined with the research on mothers' milk, leads to the supposition that the higher CLA levels continue throughout the food chain. They are passed on from the clover-rich feed via the cow, its milk and the human mother's milk to the child. Furthermore CLAs are not very sensitive to heat (Bergamo *et al*., 2003), so that consumers of pasteurized organic milk may also benefit. The CLAs are thus passed down the entire food chain. Conventional farmers and feed suppliers are now also in the process of adapting farming methods and feeds to raise the CLA content in conventional milk to create a 'healthy' product such as 'CLA cheese' which can be marketed separately (Scheeder *et al*., 2002; Geschie & Thomas, 2002). Higher health-promoting fatty acid content is thus unlikely to continue to provide organic milk with a unique added value in future. It is even conceivable that a high CLA and omega 3 content in milk can be achieved more quickly and easily on conventional farms, by buying specifically enriched feed, than by the more closed-cycle organic farming methods.

As in this trial with raw bulk tank milk, Lössl (2002) found that biodynamic pasteurized milk tasted creamier than conventional pasteurized milk. There is little correlation between fat content and creamy flavour (r = 0.58). A slightly stronger hay or grass flavour has also been found before, and is strongly influenced by the type of feed (Oortwijn, 1983; Lössl, 2002; Toledo-Alonzo, 2003).

Relevance for health

Much work has already been published about fatty acids and their relationship with health (Hayek *et al*., 1999; Hoffman *et al*., 2000; Ishiguro, 2002; Albers, 2003). Additionally, several researchers (Jensen *et al*., 1999; Robertson & Fanning, 2004; Nielsen & Lund-Nielsen, 2004; Browning *et al*., 2005) have found higher levels, or a tendency towards them, of a number of other health-promoting substances in organic milk, such as vitamin E (alpha tocopherol), beta-carotene (vitamin A precursor) and other antioxidants (lutein and zeaxanthine). These are also fairly well known to enhance human health. Two Dutch studies reported a direct effect of milk products on health. In a recent Dutch prospective study in children, a lower risk of eczema was observed in those children consuming exclusively organic instead of conventional milk (Kummeling *et al*., 2008) and also the consumption of full fat milk products has been associated with a reduced asthma risk (Wijga *et al*., 2003).

As far as is known, no milk quality research has been carried out in which all the links in the food chain have been investigated in succession, from higher levels of healthy substances in organic products right through to consumers of these organic products. By placing different research projects in succession this link can be made, although, with the associated uncertainty.

In this experiment it is surprising that the experimental methods, in 9 out of 10 cases, show that there is a difference between organic and conventional milk. All the differences found in this pilot study suggest that organic milk is healthier. The experimental methods offer good prospects for a complementary vision on health. The impact of higher contents of beneficial milk components and the higher coherence as seen in biophoton and biocrystallization assessment for human health need further exploration.

With only two milk samplings shortly after each other in the stabling period and only five pairs of organic and conventional farms it is not possible to produce any generally valid evidence that all organic milk is healthier than all conventional milk. There were too few sampling points in respect of the considerable differences between and within the farms. However, the organic farms were chosen in such a way that their management, housing, feeding and animal breeding reflected the aims of organic farming in terms of closed production cycles, roughage feeding without maize silage, low levels of concentrates and more robust cow breeds. By selecting farms in this way it was possible to show a clear differentiation between organic and conventional milk quality.

CONCLUSION

From this pilot study it can be concluded that in this pair wise comparison the organic milk generally scored better than the conventional milk for both the conventional and holistic measures. Statistically significant differences were seen in the amount of omega 3 fatty acids, the lymphocyte stimulation index, the biophoton emission and crystallization pictures. Whether these results have an impact on human health needs to be explored in other studies.

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