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REGULAR ARTICLES

Fatty acid content, health and risk indices, physicochemical composition, and somatic cell counts of milk from organic and conventional farming systems in tropical south-eastern Mexico

Claudia Delgadillo-Puga · Bernardo Sánchez-Muñoz · José Nahed-Toral · Mario Cuchillo-Hilario · Margarita Díaz-Martínez · Roman Solis-Zabaleta · Aurora Reyes-Hernández · Rosa Maria Castillo-Domíguez

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Abstract Organic agriculture and livestock farming is claimed to promote animal welfare and can offer animal products with better hygienic-sanitary quality, based on principles of health, ecology, fairness, and care. However, no clear advantages of organic milk (OM) versus conventional milk (CM) from tropical conditions are available. The aims of the study were to determine fatty acid profile, health-promoting (HPI) and thrombogenic (TI) indices, physicochemical composition, and somatic cell counts (SCC) of OM and CM in tropical south-eastern Mexico. Female cross-breed cows (400–600 kg) were employed. CM had larger values of saturated fatty acids (SFA) and polyunsaturated fatty acid (PUFA) (63.6 %; 4.57 %) than OM (61.48 %; 4.22 %), while OM resulted in a larger value of monounsaturated fatty acid (MUFA) (34.3 %) than CM (31.7 %). HPI and TI showed that OM was more favorable than CM. Milk production and physicochemical composition (PC) as well as density had no significant difference, while SCC was significantly lower in OM than in CM on a monthly basis. These results showed that OM promotes a healthful and balanced diet, and is already produced by sustainable ecologic technologies employing traditional agrosilvopastoral management, which is more environmentally friendly and promotes ecological resilience.

Keywords Organic milk · Fatty acid · CLA · Somatic cells · Agrosilvopastoral

Introduction

In recent years, concern about sustainability of natural resources on agriculture is taking relevance owing to the rise of the awareness related to the effects of climate change, environmental pollution, and the rapid loss of biodiversity (Pimentel et al. 2005; Wrage et al. 2011). In response to this ecological trend, organic agriculture was born and centered its philosophies on health, ecology, fairness, and care (International Federation of Organic Agriculture Movements (IFOAM) 2013). To preserve environmental characteristics while they are producing is the target of current organic farms (OF) devoted to produce with alternative approaches to maintain negative effects for environment at a minimum. In the current situation of agriculture, OF are also challenged to hold or improve yields obtained by conventional production (Nauta et al. 2006; Butler et al. 2009); some other benefits of OF are that they promote animal welfare and offer products with hygienic-sanitary quality and lower contamination of pesticides. Nevertheless, no evidence on nutritional aspects has been found to demonstrate that organic products are superior

C. Delgadillo-Puga (✉) · M. Cuchillo-Hilario · M. Díaz-Martínez · R. M. Castillo-Domíguez
Nutrición Animal INCMNSZ, Vasco de Quiroga 15, 14000 Mexico, Distrito Federal, Mexico
e-mail: claudia.delgadillop@quetzal.innsz.mx

B. Sánchez-Muñoz · R. Solis-Zabaleta
FMVZ-UACH, Tuxtla Gutiérrez 29000, Chiapas, Mexico

J. Nahed-Toral
ECOSUR, San Cristobal de Las Casas, Chiapas 29290, Mexico

M. Cuchillo-Hilario
CIAT, A.A. 6713, Cali, Valle del Cauca, Colombia

A. Reyes-Hernández
FQ-UNAM, Coyoacán 04510, Distrito Federal, Mexico

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to conventional products (Nahed-Toral et al. 2013; Smith-Spangler et al. 2012).

Dairy foods have proved to be an excellent source of beneficial metabolites as conjugated linoleic acid (CLA), *n*-3 and *n*-6 fatty acids, antioxidants, phenols, flavonoids, and bioactive peptides (Dewhurst et al. 2006; Cuchillo et al. 2010; Prandini et al. 2011). However, some studies have discouraged consumption of foods of animal origin because of the feasibility to ingest large amounts of saturated fatty acids (SFA) and cholesterol. Thus, some indices have been developed to better describe the benefits and risks of foods for human consumption, calculated from the fatty acid (FA) profile and SFA and cholesterol content (Connor et al. 1986; Ulbricht and Southgate 1991; Chen et al. 2004).

Milk production, physicochemical composition (PC), and somatic cell counts (SCC) are regularly analyzed to allow the evaluation of milk quality, and this last as an indicator for inflammatory processes of cow udder as well (Nauta et al. 2006). It has been suggested that OF and conventional farm (CF) systems differ mainly in the sanitary quality of milk (Smith-Spangler et al. 2012); however, no data is available to describe this effect in organic milk (OM) in tropical conditions. The aims of this work were to determine fatty acid profile, health and risk indices, PC, and SCC of OM and conventional milk (CM).

Materials and methods

The experiment was carried out in south-eastern Mexico (93° 15′–93° 52′ W, 16° 59′–17° 23′ N) where the climate is warm and humid with abundant summer rains. Total annual precipitation is 1,932 mm; average altitude is 320 m, with a rough topography. Biodiversity is reflected by the presence of many species and the predominant vegetation includes pastures, trees, and live fence-posts.

The study included 750 Zebu-Holstein, Zebu-American Swiss, and American Swiss cross-bred cows, weighing 400–600 kg, aged 3–10 years, with 2–8 parturitions. Farms were classified into two groups: organic (OM) and conventional (CM) milk production systems. OF were in complete compliance with the organic livestock proximity index (OLPI) recommended by Mena et al. (2012) and Nahed-Toral et al. (2013). The farms were located in three rural areas: (1) Grijalva (farms 35, OM 17, CM 18), (2) Pomarroza (farms 22, OM 11, CM 11), and (3) Malpaso (farms 18, OM 9, CM 9). Cows per farm ranged between 8 and 12 (303 and 447 total, in OM and CM system, respectively). The organic production units did not use external inputs; they employed agricultural residues and grazing swards: from open areas to completely forested grazing pastures with *Cynodon plectostachyus* (8,300±640 kg DM/ha), *Brachiaria brizantha* (9,200±1,100 kg DM/ha), and *Panicum máximum cv. mombasa* (20,500±2,600 kg DM/ha); these values are means of five samples collected along 7.5 months. OF used a stocking rate of 1.8±1.5 AU/ha. Animals in CF were supplemented with a mix which consisted in rolled corn 57 %, wheat bran 17 %, barley 15 %, soybean 9 %, and vitamins and minerals 2 %. Animal management in both systems included hand-milking once in the morning. Milk production was registered in the milk-recording scheme (15 days/month).

During January to June of 2009, three milk samples (200 ml each) of OM and CM systems were taken from the bulk tank on day 5, 15, and 25 every month from three randomly selected farms, resulting in 54 samples per system. One hundred milliliter of fresh milk were used for physicochemical analyses (Lacticheck-LC 01RR) and SCC which were determined using a portable DeLaval cell counter DCC, and remaining milk was freeze-dried and stored at 4 °C for later analyses. All determinations were done in triplicate.

Hexane and sodium hydroxide methanol solutions were used to obtain lipids from milk samples. FA profile and conjugated linoleic acid (CLA) were determined as before (Cuchillo et al. 2010). Health-promoting index (HPI) was calculated according to Chen et al. (2004), considering monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and other fatty acids content: HPI=(*n*-6PUFA+*n*-3PUFA+MUFA)/[(C12:0+(4×C14:0)+C16:0)]. Thrombogenic index (TI) was estimated using the formula from Ulbricht and Southgate (1991): TI=(C14:0+C16:0+C18:0)/[(0.5MUFA)+(0.5*n*-6PUFA)+(3*n*-3PUFA)+(*n*-3PUFA/*n*-6PUFA)].

Results per sample were averaged for completely random variance analysis. Days of sampling were treated as repeated measurements. Comparison of the means required a P value <0.05 to establish a significant difference by Tukey's test. All data were analyzed using the GLM (SAS., Statistical Software. SAS. Institute Inc 2008).

Results

Milk production, PC, and SCC are presented in Table 1. Milk production in OM from January to June was 4.8, while CM was 4.4 kg/cow/day. PC did not present significant differences along the study between systems. SCC (×1,000/ml) in OM was 220 while in CM was 456. A significant difference between systems was observed in January, March, April, and June with OM showing lower SCC than CM.

Six-month analysis of FA profile in OM (Table 2) showed that saturated fatty acid (SFA) concentration increased, while PUFA showed a reduction as well as CLA (C18:2 (*cis*-9, *trans*-11)). Values of MUFA were not different along the trial as well as *n*-6:*n*-3 ratio. HPI had the largest value in January,

Table 1 Production, physicochemical composition, and somatic cell count (SCC) of milk from cows managed in organic milk (OM) and conventional milk (CM) systems from tropical south-eastern Mexico

Parameters	January		February		March		April		May		June	
	OM	CM	OM	CM	OM	CM	OM	CM	OM	CM	OM	CM
Milk production, kg/cow/day	3.8	3.5	4.3	4.0	4.8	4.5	5.2	4.8	5.2	4.7	5.3	4.7
Nonfat solids, %	9.9	9.9	9.4	9.1	9.2	9.1	9.0	9.0	9.0	8.8	9.0	9.1
Fat, %	4.0	4.3	4.1	3.6	3.7	3.5	3.5	3.4	4.2	4.0	3.5	4.0
Protein, %	3.6	3.6	3.5	3.4	3.4	3.4	3.3	3.3	3.4	3.3	3.4	3.4
Lactose, %	5.2	5.4	5.2	5.0	5.1	5.0	5.0	4.9	5.0	4.9	4.9	5.0
Density, g/ml	33.3	32.9	28.3	27.6	27.9	27.5	29.0	28.7	32.0	31.2	32.6	32.1
Freezing point, °C	63.9	63.5	60.9	59.7	60.1	59.6	59.3	58.2	59.2	57.6	59.3	59.2
SCC, 1,000 cells/ml	186b	472a	166a	290a	156b	464a	276b	511a	309a	413a	225b	588a

Values are means from three determinations in three samples (at day 5, 15, and 25 each month) from a milk bulk tank. Means with different letters indicate difference between systems in the month of sampling (P<0.05)

while TI presented the smallest values in January, February, and June.

In CM (Table 3), SFA showed a trend to increase their concentration along the study with the highest value in March. MUFA reduced significantly its concentration; for instance, C18:1 (*cis*-9) resulted in lower values in June than in January. In PUFA, no differences were found, although C18:2 (*cis*-9, *trans*-11) increased at the end of the study; *n*-3 FA were not different, while *n*-6:*n*-3 ratio presented irregular values along the trial. HPI presented the highest value in January and February, and TI showed the lowest values the same months.

When comparing systems, CM presented larger values of SFA than OM. C10:0 and C18:0 were larger in OM than CM. For MUFA, OM had larger values than CM, for instance, C16:1 and C18:1 (*cis*-9). PUFA values in CM were larger than in OM, e.g., C18:2 (*cis*-9, *cis*-12) and C20:3 (*cis*-11-14-17); however, for CLA (C18:2 (*cis*-9, *trans*-11)), no differences were observed between systems. The *n*-6:*n*-3 ratios were not different, while total *n*-6 was larger in CM than OM.

Discussion

As in previous studies, these results show higher milk production in conventional than in organic systems (Müller and Sauerwein 2010; Fall and Emanuelson 2011). Since the mammary gland of dairy cows is particularly susceptible to infection, the use of antibiotics is an option; although it is prohibited in OF, exceptions can be made when diseases cannot be cured otherwise. Roesch et al. (2007) reported a SCC of 45,000 and 38,000 cells/ml for OM and CM, respectively. Later, Müller and Sauerwein (2010) compared SCC values in two studies: study I (15 OM and 13 CM, by 17 months), SCC was higher than 250 and lower than 200, respectively; study II (20 OM and 20 CM, by 25 months), both systems presented counts ranged 200–250. In the present study, there was a difference between systems, which suggests that management in organic farming according to OLPI contributes to reach international standards.

OM had lower values of SFA (61.5 %) than CM (63.7 %). However, SFA values of both production systems are smaller than those reported by Fall and Emanuelson (2011) in a study carried out in OF and CF (69.5 vs 70.1 %, respectively). In the same line, SFA values are smaller than the other two studies, which evaluated retail milk and milk collected in bulk tanks of dairy farms (Ellis et al. 2006; Butler et al. 2009), which showed 68–70 and 67–71 % for OM and CM, respectively. This could be due to the use of traditional grazing as a main source of forages in tropical south-eastern Mexico, which exert the synthesis of more desirable FA, e.g., MUFA rather than SFA. This must be clearly confirmed since consumers commonly perceive a high SFA concentration as negative. However, it is important to consider each SFA concentration rather than the sum, since some indicators (Ulbricht and Southgate 1991; Chen et al. 2004) consider individual fatty acid concentrations as discussed below.

Results of MUFA in both systems (34 and 32 %) are higher than those reported by Fall and Emanuelson (2011) who found values of 28.9 and 27.8 %; whereas Butler et al. (2009) reported values of 26.1 and 26.2 % for OM and CM, respectively. Likewise, Ellis et al. (2006) and Prandini et al. (2011) found lower means than us for organic (26.2 and 27.1 %) and conventional (27.6 and 27.0 %) milk. Differences among studies could be a result of animal feed as well as geographical location.

Even in the low SFA and the large MUFA amounts in milk from the current study, PUFA values (4.2 vs 4.6 %) were similar to those obtained by Prandini et al. (2011) (4.3 vs 4.2 % for OM and CM, respectively), who investigated milk used for Grana Padano cheese, which is characterized by higher amounts of CLA than conventional products. An organic diet based on fresh forage, and rich in PUFA, could

Table 2 Fatty acids profile (%) and health/risk indices in organic milk system from tropical south-eastern Mexico

Fatty acids (FA)	January	February	March	April	May	June
C10:0	1.0b	1.2ab	1.4ab	1.3ab	1.4ab	1.7a
C12:0	2.2ab	2.0b	2.5a	2.2ab	2.5a	2.6a
C14:0	10.0a	10.3a	10.9a	10.1a	11.1a	10.6a
C15:0	1.7a	1.6a	1.7a	1.8a	1.6a	1.6a
C16:0	29.1bc	28.7c	30.5ab	30.1abc	31.0a	29.9abc
C16:1	1.4a	1.6a	1.6a	1.4a	1.4a	1.3a
C17:0	1.5abc	1.6a	1.5ab	1.6a	1.4bc	1.4c
C17:1	0.43b	0.50a	0.44ab	0.50a	0.46ab	0.43b
C18:0	13.9ab	13.9ab	14.1a	14.1a	13.2ab	12.8b
C18:1 (*cis*-9)	33.4a	33.2ab	30.0b	31.9ab	31.0ab	32.9ab
C18:2 (*cis*-9, *cis*-12)	1.4ab	1.4ab	1.5a	1.4ab	1.2b	1.2ab
C18:2 (*cis*-9, *trans*-11) (CLA)	1.2a	1.1ab	1.0abc	1.0abc	0.9c	0.9bc
C18:3*n*-3	0.65a	0.59a	0.67a	0.55a	0.61a	0.64a
C18:3*n*-6	0.17a	0.18a	0.20a	0.04b	0.16a	0.15a
C20:0	0.30a	0.31a	0.31a	0.31a	0.27a	0.25a
C20:1	0.26a	0.24a	0.24a	0.23a	0.23a	0.22a
C20:2	0.04ab	0.06a	0.05ab	0.04b	0.04ab	0.03b
C20:3*n*-6	0.04ab	0.05ab	0.04ab	0.04a	0.06a	0.04ab
C20:3 (*cis*-11-14-17)	0.09a	0.08a	0.09a	0.09a	0.08a	0.07a
C20:4	0.10bc	0.10c	0.13ab	0.11abc	0.14a	0.10c
C20:5	0.08b	0.12ab	0.13a	0.13a	0.13a	0.10ab
C22:5	0.17a	0.16a	0.16a	0.17a	0.16a	0.17a
C22:6	0.02a	0.02a	0.03a	0.03a	0.02a	0.03a
Σsaturated FA (SFA)	59.9b	59.9b	63.2a	61.9ab	62.8ab	61.1ab
Σmonounsaturated FA (MUFA)	35.6a	35.6a	32.3a	34.1a	33.2a	34.9a
Σpolyunsaturated FA (PUFA)	4.5a	4.4a	4.4a	4.0ab	3.6b	3.6b
Σ*n*-6	1.89a	1.94a	2.11a	1.77a	1.71a	1.74a
Σ*n*-3	0.8a	0.8a	0.9a	0.8a	0.8a	0.8a
n-6:*n*-3ratio	2.2a	2.4a	2.3a	2.2a	2.0a	2.1a
Health-promoting index (HPI)	0.54a	0.53a	0.46c	0.50b	0.46c	0.50b
Thrombogenic index (TI)	2.4c	2.4b	2.7a	2.6ab	2.7a	2.5bc

Means with different letters indicate differences ($P<0.05$) among months. ΣSFA=C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0. ΣMUFA=C16:1, C17:1, C18:1, C20:1. ΣPUFA=C18:2, C18:2 (CLA), C18:3*n*-3, C18:3*n*-6, C20:2, C20:3*n*-6, C20:3, C20:4, C20:5, C22:5, C22:6. Σ*n*-6=C18:2, C18:3*n*-6, C20:3*n*-6, C20:4, C22:5. Σ*n*-3=C18:3*n*-3, C20:3, C20:5, C22:6. HPI=(*n*-6PUFA+*n*-3PUFA+MUFA)/[(C12:0+(4×C14:0)+C16:0)]. TI=(C14:0+C16:0+C18:0)/[(0.5MUFA)+(0.5*n*-6PUFA)+(3*n*-3PUFA)+(*n*-3PUFA/*n*-6PUFA)]

increase CLA content in milk fat and thus improve nutritional quality of organic dairy products. Content of PUFA in this study is higher (4.0 and 4.5 %) than values reported by Ellis et al. (2006) (3.9 vs 3.3 %) and Butler et al. (2009) (3.9 vs 3.2 %) for OM and CM, respectively. PUFA and *n*-3 FA tended to be higher in OM. Moreover, Ellis et al. (2006) found no differences between OM and CM in CLA content (0.65 vs 0.58 %, respectively), while Fall and Emanuelson (2011) found that CLA in OM was higher than in CM (0.63 vs 0.48 %, respectively). This was also observed on *n*-3 (1.44 vs 1.04 %) and conversely for PUFA (3.6 vs 4.3 %) for OM and CM, respectively. The likely explanation is related to the difference between feedstuffs on offer. As shown in earlier studies, type of feeding is capable of modifying PUFA, CLA, and total fat content (Dewhurst et al. 2006). Changes of SFA on a monthly basis are due to the presence of metabolic precursors, mostly modulated by fiber ingestion and PUFA in fresh forage (Ellis et al. 2006). Seasonal transition, sampling period, animal breed, herd size, milk production, and total mixed ration utilized could impact FA profile (Butler et al. 2009). Grazing when summer is approaching is expected to increase PUFA of milk. This was true for CLA in CM and may correspond to the green herbage allowance even at an early stage of the year. This is consistent with the lack of variation of PUFA.

Table 3 Fatty acids profile (%) and health/risk indices in conventional milk from tropical south-eastern Mexico

Fatty acids (FA)	January	February	March	April	May	June
C10:0	1.0bc	1.2ab	0.7c	0.9c	1.4a	0.8c
C12:0	2.3a	2.3a	1.5b	2.5a	2.1a	2.3a
C14:0	10.2ab	9.9b	7.6c	12.2a	10.4ab	11.2ab
C15:0	1.7a	1.5ab	1.3b	1.8a	1.7a	1.8a
C16:0	29.7a	29.7a	23.1b	32.1a	31.0a	33.9a
C16:1	1.1a	1.3a	1.1a	1.4a	1.2a	1.4a
C17:0	1.4a	1.4a	1.3a	1.4a	1.5a	1.6a
C17:1	0.48a	0.41a	0.41a	0.47a	0.38a	0.42a
C18:0	11.8ab	12.7ab	10.5b	12.8ab	14.0ab	14.7a
C18:1 (*cis*-9)	35.2a	33.8ab	20.7c	28.9b	30.8ab	28.8b
C18:2 (*cis*-9, *cis*-12)	1.2a	1.6a	1.6a	1.5a	1.6a	1.6a
C18:2 (*cis*-9, *trans*-11) (CLA)	1.1ab	1.0b	0.91b	1.0b	1.1ab	1.4a
C18:3*n*-3	0.66a	0.70a	0.63a	0.66a	0.67a	0.68a
C18:3*n*-6	0.090c	0.180ab	0.140bc	0.170abc	0.175ab	0.220a
C20:0	0.33a	0.30ab	0.25b	0.32a	0.33a	0.34a
C20:1	0.21a	0.24a	0.21a	0.26a	0.27a	0.27a
C20:2	0.03b	0.04ab	0.04ab	0.05ab	0.03b	0.05a
C20:3*n*-6	0.04a	0.07a	0.05a	0.06a	0.05a	0.06a
C20:3 (*cis*-11-14-17)	0.11a	0.09ab	0.07b	0.10ab	0.08ab	0.10ab
C20:4	0.08b	0.13a	0.11ab	0.14a	0.11ab	0.14a
C20:5	0.08c	0.12abc	0.12ab	0.13ab	0.10bc	0.15a
C22:5	0.13a	0.16a	0.15a	0.18a	0.16a	0.18a
C22:6	0.02ab	0.02ab	0.01b	0.02ab	0.03a	0.02ab
Σsaturated FA (SFA)	58.7d	59.3cd	73.3a	64.3bc	61.0bcd	65.3b
Σmonounsaturated FA (MUFA)	37.0a	35.9ab	22.5d	31.1bc	34.1abc	29.7c
Σpolyunsaturated FA (PUFA)	4.2a	4.7a	4.2a	4.5a	4.8a	4.9a
Σ*n*-6	1.6ab	2.2a	2.0ab	2.1ab	0.87c	1.5bc
Σ*n*-3	0.87a	1.0a	0.83a	0.91a	0.87a	0.93a
n-6:*n*-3ratio	1.9ab	2.2ab	2.4a	2.3ab	1.0c	1.6bc
Health-promoting index (HPI)	0.54a	0.54a	0.46b	0.41c	0.48b	0.40c
Thrombogenic index (TI)	2.3c	2.3c	2.7ab	2.9a	2.6b	3.1a

Means with different letters indicate differences ($P<0.05$) among months. ΣSFA=C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0. ΣMUFA=C16:1, C17:1, C18:1, C20:1. ΣPUFA=C18:2, C18:2 (CLA), C18:3*n*-3, C18:3*n*-6, C20:2, C20:3*n*-6, C20:3, C20:4, C20:5, C22:5, C22:6. Σ*n*-6=C18:2, C18:3*n*-6, C20:3*n*-6, C20:4, C22:5. Σ*n*-3=C18:3*n*-3, C20:3, C20:5, C22:6. HPI=(*n*-6PUFA+*n*-3PUFA+MUFA)/[(C12:0+(4×C14:0)+C16:0)]. TI=(C14:0+C16:0+C18:0)/[(0.5MUFA)+(0.5*n*-6PUFA)+(3*n*-3PUFA)+(*n*-3PUFA/*n*-6PUFA)]

However, the tendency towards a decrease of PUFA in OM and MUFA in CM should be further evaluated to explain this apparent contradiction.

There is an increased interest from consumers concerning the reduction of SFA consumption, since it is associated with the incidence of heart and brain strokes (Ulbricht and Southgate 1991). Therefore, strategies aimed to reduce SFA content in OM should be taken into consideration, mainly in March, April, and May when the largest values of TI were reached. In the same line, the attempt to decrease the TI would increase the HPI. In temperate regions, the inclusion of legumes has been promoted to increase the CLA and other desirable FA content in milk (Dewhurst et al. 2006), which may have positive effects on human health (Smith-Spangler et al. 2012). TI average (up to 2.7) in CM was higher than the 2.0 value, found by Ulbricht and Southgate (1991), meaning a larger risk of a thrombogenic event. PUFA and MUFA content makes it impossible to get a lower TI. Therefore, it would be prudent to increase desirable FA such as isomers CLA, α-linolenic, EPA, and DHA (Cuchillo et al. 2010; Bhat and Bhat 2011). These findings could contribute to the perception that organic dairy products offer benefits to human health. Search and incorporation of tropical vegetation species in animal feedstuff are recommended in order to raise availability of PUFA and thus enhance healthy value of milk.

Conflict of interest The authors state that there is no conflict of interest associated with the results showed in this manuscript.

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