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Comparison of chemical composition of organic and conventional Italian cheeses from parallel production

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ABSTRACT

Although there are several studies comparing organic and conventional milk characteristics, very few focused on dairy processed products such as cheese. Thus, this study aimed for a detailed controlled examination of gross composition, minerals, and the fatty acid profile of organic (ORG) and conventional (CON) Italian cheeses from parallel production. Four Italian cheese types were analyzed: Latteria (ORG, n = 9; CON, n = 10); Asiago Protected Designation of Origin (PDO) fresco (ORG, n = 9; CON, n = 9); Caciotta (ORG, n = 8; CON, n = 8); and Mozzarella Traditional Specialty Guaranteed (TSG; ORG, n = 14; CON, n = 14). Cheese samples were collected from September 2020 to August 2021. Gross composition, minerals, and fatty acids were determined using infrared spectroscopy. Within each cheese type, paired ORG and CON samples were compared using a nonparametric Wilcoxon signed-rank test. Latteria showed lower PUFA, n-3, and n-6 content, and greater Fe, K, C10:0, C12:0, and C16:0 content in ORG than in CON. Asiago PDO fresco showed lower protein and Zn content and greater salt, ash, and Na content in ORG than in CON. Caciotta showed lower ash, n-3, and n-6 content and greater K, C4:0, C8:0, C10:0, C14:0, and C16:0 content in ORG than in CON. Mozzarella TSG showed lower fat and, therefore, fatty acid content, and greater moisture, ash, and Mg content in ORG than in CON. In conclusion, few significant differences in chemical composition were observed between ORG and CON cheeses, regardless of the type considered. Moreover, Asiago PDO fresco showed fewer significant differences between ORG and CON compared with Latteria, Caciotta, and Mozzarella TSG.
Key words: low-input system, product quality, PDO food, quality control

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INTRODUCTION

Cheese production from whole cow milk has been steadily increasing in the last 5 yr in the European Union (**EU**) up to 7.8% (FAOSTAT, 2022). Italy is one of the Top-3 cheese producing countries in the EU, with a 14.6% share, after France and Germany (FAOSTAT, 2022). Asiago Protected Designation of Origin (**PDO**) fresco (>20 d of ripening) or stagionato (>90 d of ripening) is produced from cow milk in Northeastern Italy, being the fourth most produced cheese type in that country (CLAL, 2022). Mozzarella Traditional Specialty Guaranteed (**TSG**) is a soft cheese from cow milk. Caciotta is an aged or semi-aged soft cheese in a cylinder shape from cow's, sheep's, goat's, and buffalo's milk or a mix of these milks. Latteria is a general term to describe a semi-hard cheese from cow milk made in the Veneto region in Northern Italy. In contrast, all organic (**ORG**) retails sales in the EU continued its growth in 2020, where Italy is among the Top-3 countries after Germany and France with 3,872 million €, and is the country with the largest number of ORG producers (>70,000) and ORG processors (>22,000) considering all goods (Willer et al., 2022). These data support the relevance of Italy as a cheese producer as well as an ORG producer in the EU considering all goods. The difference between ORG and conventional (**CON**) cheese making procedure is only related to the different type of milk at beginning of cheese making. The cheese making conditions (e.g., temperature, time, operation), the type of rennet, and bacteria are the same between ORG and CON cheeses. Thus, ORG cheese should be made from ORG milk and manufactured avoiding cross-contamination with CON cheese (i.e., produce first on the morning after the machinery was clean the day before). The ORG milk comes from ORG farms which mainly differ from CON ones on feed (ORG feed), stocking density, and veterinary treatments while all other inputs and management remain unchanged.

Research found that people with university education and greater concern about environmental sustainability are the consumer group with the highest willingness to pay more for ORG than CON food (Gracia and de-Magistris, 2016). For ORG cheese it was found a greater expected liking score that CON cheese, probably due to a satisfactory consumer trust in ORG legislation (Napolitano et al., 2010). Consumers perceive ORG being better (i.e., healthier and better quality) than CON products (Rodríguez-Bermúdez et al., 2020), but there is a lack of studies on the intrinsic quality traits of cheese comparing both production systems. Studies are usually conducted in fluid milk rather than in processed dairy products (Średnicka-Tober et al., 2016). The very few studies on ORG cheese used samples from different dairy producers for the CON cheese (da Silva Cândido et al., 2020; da Silva Abreu et al., 2021) or focus only on ORG cheese (Popovic-Vranjes et al., 2016; Łepecka et al., 2022). In particular, da Silva Cândido et al. (2020) and da Silva Abreu et al. (2021) focused on the isolation of *Staphylococcuss* sp. and the bacterial diversity from ORG and CON fresh minas cheese, respectivily, and did not evaluate cheese chemical composition. Those authors concluded that the microbiological differences observed cannot be attributed to the production system itself –i.e., being ORG or CON– because the cheesemaking process was different (da Silva Cândido et al., 2020; da Silva Abreu et al., 2021). To the best of our knowledge, there are not further studies comparing ORG and CON cheese. Therefore, the aim of this study was to evaluate compositional (gross composition, and mineral and fatty acid content) differences between ORG and CON Italian cow cheeses Latteria, Asiago PDO fresco, Caciotta, and Mozzarella TSG from parallel production. Variation do to different processing and milk sourcing regions were removed by our research design using the same processing plant, cheese types, and milk source in the region, however differently produced on ORG or CON farms.

MATERIALS AND METHODS

Sample Collection

Because no human or animal subjects were used, this analysis did not require approval by an Institutional Animal Care and Use Committee or Institutional Review Board.

Respecting the mandatory rules reported by organic standards (e.g., separation of milk, traceability of batch and wheels), samples (100 g) of ORG and CON cheese of each type paired by factory, production day, batch, cheesemaking process, and ripening time were collected. Because of ORG cheese processing regulation for what is called parallel production ORG and CON processing on the same factory line, the ORG cheese was always made first after cleaning the line the day before. Cheeses were sampled almost monthly across 1 yr (September 2020 to August 2021). Cheese types included in the present study were as follows: Latteria (ORG, n = 9; CON, n = 10); Asiago PDO fresco (ORG, n = 9; CON, n = 9); Caciotta (ORG, n = 8; CON, n = 8); and Mozzarella TSG (ORG, n = 14; CON, n = 14).

Based on the moisture content of the samples, cheeses were classified as soft (>45% water), semi-hard (35–45% water), and hard (<35% water; CLAL, 2018). Therefore, samples from Latteria and Asiago PDO fresco included hard (n = 16 and n = 3, respectively) and semi-hard cheeses (n = 3 and n = 15, respectively), and Caciotta included hard (n = 1), semi-hard (n = 14), and soft (n = 1) cheeses. Mozzarella TSG samples were all classified as soft cheese. All cheese types were manufactured with whole pasteurized cow milk, salt, and rennet. The ripening time indicated by the manufacturer for Asiago PDO fresco was 20 d, for Caciotta between 14 d and 3 mo, and for Latteria between 10 and 60 d. Mozzarella TSG does not undergo a ripening process.

Samples arrived refrigerated (4°C) at the laboratory of the Department of Agronomy, Food, Natural resources, Animals, and Environment of the University of Padova (Legnaro, Italy) and 1.5 cm of the rind were removed in Latteria, Asiago PDO fresco, and Caciotta samples. Each cheese sample was homogenized with a knife mill Retsch Grindomix GM200 (Retsch GmbH and Co, Haan, Germany) and the ground cheese was kept in a sealed plastic bag at 4°C and analyzed within 2 h to avoid variations in cheese composition depending on moisture loss.

Chemical Analyses

Samples were analyzed using a near-infrared spectrophotometer in transmittance mode FoodScan Dairy Analyzer (Foss Electric A/S) which worked at room temperature (20°C). A 50-g ground sample of each cheese was placed in the cup glass of FoodScan (diameter 140 mm, depth 20 mm) assuring that the sample covered all the bottom surface of the plate without leaving empty spots, and was scanned from 850 to 1,050 nm every 2 nm. Each spectrum was the average of 16 subspectra collected during the automatic rotation of the cup and recorded as log(1/transmittance) using ISIscan Nova and Mosaic software (Foss Electric A/S).

Cheese moisture, fat, protein, salt, and ash percentages as sampled were determined using FoodScan Dairy Analyzer (Foss Electric A/S) through commercial FOSS Artificial Neural Networks Dairy Calibration. Moreover, prediction models for minerals (Na, Ca, P, K, S, Mg, Zn, and Fe; mg/kg), individual fatty acids (C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C15:0, C16:0, C18:0; g/100 of cheese), and groups of fatty acids (SFA, UFA, MUFA, PUFA, n-3, and n-6; g/100 of cheese) were applied. Briefly, those prediction models were developed by Franzoi et al. (2021) using partial least squares regression analysis on 158 cheese samples of mozzarella, burrata, caciotta, mozzarella for pizza, milk ricotta, whey ricotta, and scamorza cheese. The reference analysis for minerals was obtained using inductively coupled plasma optical emission spectrometry (ICP-OES) Arcos EOP (SPECTRO Analytical Instruments GmbH) after mineralization of the sample according to AOAC method #2015.06 (Pacquette and Thompson, 2018). For the reference analysis for fatty acid profile, total lipids were extracted by an accelerated solvent extraction method using a Dionex ASE 350 system (Thermo Scientific) with petroleum ether as solvent. Fatty acid methyl esters of total lipids were prepared with an internal method adapted from Christie (1993). More details about the reference analysis can be retrieved from De Marchi et al. (2021). The prediction models were validated through leave-one-out cross-validation. Coefficients of determination (and standard error between brackets) in cross-validation for minerals were as follows: Na, 0.93 (725.91 mg/kg); Ca, 0.91 (692.31 mg/kg); P, 0.92 (492.70 mg/kg); K, 0.85 (183.95 mg/kg); S, 0.85 (136.16 mg/kg); Mg, 0.92 (34.27 mg/kg); Zn, 0.92 (2.50 mg/kg); and, Fe, 0.39 (0.44 mg/kg). Coefficients of determination (and standard error between brackets) in cross-validation for individual fatty acids and groups of fatty acids were as follows: C4:0, 0.81 (0.07 g/100 of cheese); C6:0, 0.84 (0.05 g/100 of cheese); C8:0, 0.76 (0.04 g/100 of cheese); C10:0, 0.76 (0.10 g/100 of cheese); C12:0, 0.77 (0.12 g/100 of cheese); C14:0, 0.71 (0.47 g/100 of cheese); C15:0, 0.77 (0.03 g/100 of cheese); C16:0, 0.85 (0.75 g/100 of cheese); C18:0, 0.40 (0.80 g/100 of cheese); SFA, 0.89 (1.48 g/100 of cheese); UFA, 0.81 (1.11 g/100 of cheese); MUFA, 0.80 (1.01 g/100 of cheese); PUFA, 0.76 (0.20 g/100 of cheese); n-3, 0.63 (0.05 g/100 of cheese); and, n-6, 0.52 (0.20 g/100 of cheese).

Statistical Analysis

Compositional data for all cheese varieties were not normally distributed (Shapiro-Wilk test) and it was not possible to normalize the data using Box-Cox transformations (Box-Cox and Cox, 1964; Osborne, 2010). Therefore, differences in composition between ORG and CON within each cheese type were tested pairwise using the nonparametric Wilcoxon Singed-Rank test through the UNIVARIATE procedure of SAS ver. 9.4. (SAS Institute Inc., Cary, NC). Results are reported as median and 95% confidence interval of the estimate (**95% CI**). Significance was established at $P < 0.05$ unless otherwise stated.

RESULTS

Gross Composition

Latteria gross composition of 5 traits (moisture, protein, fat, ash, and salt content in percentage as sampled) was similar between ORG and CON cheese. However, Latteria tended to a lower ash content and a greater protein content in ORG than CON ($P < 0.10$; Table 1). Asiago PDO fresco showed lower protein content, and greater salt and ashes content in ORG than CON cheese ($P < 0.05$; Table 1). Caciotta presented greater protein and lower ashes content in ORG than CON cheese ($P < 0.05$; Table 1). However, Caciotta tended to a lower moisture content in ORG than CON ($P < 0.10$; Table 1). Mozzarella TSG had lower fat content, and greater moisture and ash content in ORG than CON cheese ($P < 0.05$; Table 1).

Mineral Profile

Among all the mineral evaluated, few differences were observed (Table 2). Latteria had ($P < 0.05$) greater K and Fe, and tended ($P < 0.10$) to lower Mg content in ORG than CON cheese (Table 2). Asiago PDO fresco showed greater Na and lower Zn content in ORG than CON ($P < 0.05$). Caciotta presented greater K content in ORG than CON cheese ($P < 0.05$), and tended to lower Na and greater S content in ORG than CON cheese ($P < 0.10$). Mozzarella TSG revealed greater Mg content in ORG than CON cheese ($P < 0.05$), and tended to greater Ca and lower K content in ORG than CON cheese ($P < 0.10$).

Fatty Acid Profile

The fatty acid profile of ORG and CON cheeses is reported in Table 3 and Table 4 for individual and fatty acid groups, respectively. Latteria had lower PUFA, n-3, and n-6 and greater C10:0, C12:0, and C16:0 content in ORG than CON cheese ($P < 0.05$). Also, Latteria tended to a lower UFA and a greater C14:0 content in ORG than CON cheese ($P < 0.10$). Asiago PDO fresco tended to a lower UFA content in ORG than CON cheese ($P < 0.10$). Caciotta presented lower n-3 and n-6, and greater C4:0, C8:0, C10:0, C14:0, and C16:0 content in ORG than CON cheese ($P < 0.05$). Also, Caciotta tended to a lower PUFA and a greater C12:0 content in ORG than CON cheese ($P < 0.10$).

Table 1. Gross composition (% as sampled) of organic and conventional cheeses

Trait[1]	Organic cheese		Conventional cheese		
	Median	95% CI[2]	Median	95% CI[2]	*P*-value
Latteria	n = 9		n = 10		
Moisture	30.91	29.59–34.29	31.65	29.54–37.01	0.820
Fat	38.38	37.09–39.91	38.20	35.38–40.11	1.000
Protein	26.35	24.02–26.93	25.09	23.76–26.27	0.074
Salt	3.23	2.95–3.64	3.14	2.85–3.99	0.910
Ash	4.82	4.56–5.46	5.58	5.06–6.22	0.074
Asiago PDO fresco	n = 9		n = 9		
Moisture	38.37	36.92–40.47	36.99	35.82–39.69	0.203
Fat	34.74	33.12–35.73	35.69	33.82–36.18	0.129
Protein	22.72	21.19–23.09	23.54	22.89–24.09	0.008*
Salt	2.55	2.17–3.18	2.29	1.90–2.54	0.020*
Ash	4.82	4.57–5.28	4.56	4.17–4.81	0.027*
Caciotta	n = 8		n = 8		
Moisture	39.80	38.52–45.47	42.72	40.18–44.76	0.055
Fat	34.37	31.54–37.42	32.42	31.29–34.48	0.148
Protein	23.23	21.92–25.52	21.89	21.16–22.68	0.039*
Salt	2.12	1.94–2.35	2.23	2.07–2.40	0.195
Ash	3.92	3.83–4.95	4.45	4.02–5.09	0.039*
Mozzarella TSG	n = 14		n = 14		
Moisture	61.96	59.74–64.05	61.02	59.44–61.92	0.005*
Fat	18.86	17.54–20.85	20.90	20.56–23.25	<0.001*
Protein	15.91	14.74–16.61	15.56	15.43–15.60	0.502
Salt	1.01	0.93–1.19	1.05	1.01–1.23	0.104
Ash	2.27	2.16–2.49	2.06	1.83–2.18	0.002*

[1]PDO = Protected Designation of Origin; TSG = Traditional Specialty Guaranteed.

[2]95% CI = 95% confidence interval of the estimate.

*Significant difference ($P < 0.05$) between gross composition of organic and conventional cheese.

Mozzarella TSG revealed lower SFA, UFA, MUFA, and all identified individual fatty acids in ORG than CON cheese ($P < 0.05$). However, those results in Mozzarella TSG should be interpreted, considering that fat content was lower in ORG than CON cheese ($P < 0.05$).

DISCUSSION

Milk composition is often affected by factors over which the cheesemaker has no control at all. Such are animal feeding, breed, and season (Law and Tamime, 2011). Moreover, due to the requirements established by the ORG regulation (EU, 2018), ORG farms usually have different management and feeding practices than CON farms. To standardize the cheese manufacture and ripening process, the cheesemaker standardizes milk composition by adding milk solids or removing cream to give continuity in composition and protect consumers and the manufacturing process (Law and Tamime, 2011). Thus, the cheesemaker has complete control on the cheesemaking process and ripening (Law and Tamime, 2011). However, milk standardization is not allowed in the production of PDO cheese. To be sure that the cheesemaking process and the ripening time were the same for both ORG and CON samples from each cheese type, they were collected from the same factory through a complete year. Therefore, in our study results in the end product mirror milk origin (animals' management practices, breed, and so on) and not the cheesemaking process and ripening time. We are not aware of previous studies comparing ORG and CON cheese composition, thus results will be discussed in relation to milk differences between both systems.

Before discussing the results of ORG versus CON cheese, we would point-out that values of gross composition, minerals, and fatty acids for both ORG and CON cheese (Tables 1 to 4) were in line with those reported by Manuelian et al. (2017). Those authors characterized the mineral profile through ICP-OES after mineralization with nitric acid, and the fatty acid profile using GC of 18 varieties of commercial cheeses including soft, semi-hard, and hard products. The comparable results of the present study with those obtained by Manuelian et al. (2017) are supportive of the adequacy of infrared prediction models used in our study for the quantification of mineral and fatty acid contents.

Differences reported in the literature between ORG and CON milk are related to several factors which are known to affect milk quality such as feeding, breed, and stage of lactation (Schwendel et al., 2015). However, studies related to the evaluation of ORG and CON products often neglect to consider other factors beyond

Table 2. Mineral composition (mg/kg) of organic and conventional cheeses

	Organic cheese		Conventional cheese		
Trait[1]	Median	95% CI[2]	Median	95% CI[2]	*P*-value
Latteria	n = 9		n = 10		
Ca	7,865	7,581–8,226	7,935	7,752–8,084	1.000
Na	6,382	5,386–7,500	6,303	5,489–7,524	0.910
P	5,838	5,015–6,512	5,937	5,709–6,430	0.570
S	1,645	1,532–1,762	1,636	1,541–1,669	0.734
K	1,065	984.1–1,142	967.3	925.5–976.4	0.004*
Mg	267.1	247.2–318.8	319.0	291.5–334.0	0.098
Zn	32.25	31.43–32.89	32.60	31.87–33.07	0.250
Fe	1.63	1.26–2.16	1.14	0.94–1.41	0.020*
Asiago PDO fresco	n = 9		n = 9		
Ca	7,358	6,817–7,557	7,331	6,928–7,532	0.820
Na	4,862	4,541–6,985	4,019	3,516–5,138	0.020*
P	4,939	4,058–5,447	4,421	4,100–5,021	0.359
S	1,492	1,366–1,608	1,438	1,405–1,491	0.426
K	946.1	905.2–967.4	975.6	906.1–1,000	0.496
Mg	273.0	239.7–287.2	252.5	244.8–279.7	0.359
Zn	30.86	29.92–31.91	31.42	31.04–32.33	0.012*
Fe	1.40	1.15–1.67	1.44	1.24–1.56	0.426
Caciotta	n = 8		n = 8		
Ca	7,324	7,065–7,937	7,314	7,095–7,649	0.742
Na	3,770	3,235–4,973	4,457	4,021–5,104	0.078
P	5,138	4,613–6,138	4,866	4,684–5,559	0.641
S	1,625	1,532–1,768	1,542	1,511–1,682	0.078
K	1,012	956.0–1,098	912.9	861.3–975.2	0.039*
Mg	248.9	226.4–332.6	267.6	233.9–293.3	0.461
Zn	30.66	30.00–31.59	30.25	30.18–31.51	0.844
Fe	1.47	1.39–1.91	1.39	1.31–1.97	0.641
Mozzarella TSG	n = 14		n = 14		
Ca	4,358	3,848–4,951	4,185	4,059–4,379	0.079
Na	2,003	1,664–2,235	1,821	1,660–2,347	0.217
P	2,746	2,547–2,939	2,624	2,504–2,843	0.194
S	1,186	1,147–1,242	1,158	1,140–1,241	0.626
K	340.0	253.1–409.4	377.8	346.3–426.7	0.091
Mg	128.3	109.3–133.2	111.6	95.93–115.9	0.007*
Zn	25.15	23.46–27.29	24.71	23.58–25.65	0.426
Fe	1.18	1.07–1.31	1.20	1.16–1.27	0.502

[1]PDO = Protected Designation of Origin; TSG = Traditional Specialty Guaranteed.
[2]95% CI = 95% confidence interval of the estimate.
*Significant difference ($P < 0.05$) between gross composition of organic and conventional cheese.

the farming system (Schwendel et al., 2015). A clear example is when milk fatty acid composition is evaluated, because the fatty acid profile responds to the farming practices (e.g., high input versus low input) rather than being the milk ORG or CON (Schwendel et al., 2015).

Gross Composition

None or up to 3 traits significantly differed between the ORG and CON cheese samples and, despite being significant, those differences represented <11%. The literature reports contradictory results regarding milk fat (Schwendel et al., 2015), protein (Schwendel et al., 2015; Średnicka-Tober et al., 2016), and lactose (Schwendel et al., 2015) content, which could explain the different trends observed across the cheese types we analyzed. Some studies reported greater fat content (% or g/kg of milk) in ORG than CON milk (Butler et al., 2011; Schwendel et al., 2015), whereas other observed lower content in ORG, or no differences at all (Schwendel et al., 2015; Średnicka-Tober et al., 2016). The diversity of results related to fat content can be explained by the different breeds used by ORG (often non-Holstein-Friesian breeds) and CON (often Holstein-Friesian) farmers, the greater use of starch-based concentrated and fat supplements (which increase milk fat content) in CON (Schwendel et al., 2015), and the sampling season (minimum in summer for ORG) and year (Butler et al., 2011; Schwendel et al., 2015). In fact, Butler et al. (2011) reported that season (winter > summer), sampling year (2006/2007 > 2007/2008), and the interaction category of milk × season effects were also significant for total milk fat (g/kg milk) when analyzing whole fresh milk at retail level. Moreover, those

Table 3. Fatty acid groups (g/100 g of cheese) of organic and conventional cheeses

	Organic cheese		Conventional cheese		
Trait[1]	Median	95% CI[2]	Median	95% CI[2]	*P*-value
Latteria	n = 9		n = 10		
SFA	27.35	26.81–30.09	28.07	24.67–30.25	0.910
UFA	11.06	10.72–11.64	12.19	11.09–13.86	0.074
MUFA	9.92	9.78–10.68	10.74	9.87–12.15	0.164
PUFA	1.09	0.97–1.41	1.53	1.20–1.78	0.004*
n-3	0.21	0.19–0.26	0.32	0.26–0.38	0.004*
n-6	0.83	0.77–0.91	0.98	0.93–1.16	0.004*
Asiago PDO fresco	n = 9		n = 9		
SFA	25.00	24.12–25.53	25.32	24.34–26.06	0.496
UFA	11.12	10.81–11.52	11.69	11.29–11.98	0.074
MUFA	9.91	9.52–10.31	10.33	10.04–10.49	0.129
PUFA	1.493	1.35–1.58	1.488	1.37–1.57	0.570
n-3	0.28	0.25–0.31	0.25	0.24–0.27	0.359
n-6	0.86	0.76–0.95	0.81	0.74–0.82	0.250
Caciotta	n = 8		n = 8		
SFA	22.60	20.86–24.94	21.43	20.57–23.01	0.148
UFA	9.29	8.82–11.28	9.98	9.35–10.69	0.313
MUFA	8.48	8.11–9.97	8.71	8.35–9.35	0.547
PUFA	1.06	0.86–1.40	1.32	1.12–1.46	0.078
n-3	0.19	0.17–0.26	0.24	0.22–0.27	0.016*
n-6	0.68	0.64–0.82	0.78	0.72–0.82	0.016*
Mozzarella TSG	n = 14		n = 14		
SFA	11.86	10.95–13.41	13.24	12.85–15.09	<0.001*
UFA	5.84	5.34–6.24	6.16	5.94–6.94	0.030*
MUFA	5.28	4.67–5.60	5.49	5.35–6.30	0.011*
PUFA	0.77	0.66–0.83	0.75	0.70–0.82	1.000
n-3	0.123	0.09–0.16	0.118	0.11–0.14	0.856
n-6	0.34	0.25–0.39	0.35	0.31–0.38	0.173

[1]PDO = Protected Designation of Origin; TSG = Traditional Specialty Guaranteed.

[2]95% CI = 95% confidence interval of the estimate.

*Significant difference ($P < 0.05$) between gross composition of organic and conventional cheese.

authors also observed that the interaction category of milk × season was significant and category of milk × year tended to be significant, even if the main effect of being ORG or CON was not significant for milk protein (g/kg milk).

Mineral Profile

Regarding the mineral profile, we also obtained very few significant differences between the ORG and CON cheese samples. Only 1 or 2 minerals differed in each cheese variety. Nevertheless, those differences were greater than the ones observed for gross composition as they ranged from 9% (K) to 30% (Fe). The significant difference for Zn content in Asiago PDO fresco represented <2%. The review of Średnicka-Tober et al. (2016) reported greater Fe content in ORG than CON milk, which agrees with our findings for Latteria cheese. Those authors also observed similar Ca, Na, P, K, Mg, and Zn milk content, whereas Rodríguez-Bermúdez et al. (2018) indicated a lower Zn concentration associated with the mineral supplementation adopted in CON systems. Moreover, in a previous study on Holstein-Friesian (Manuelian et al., 2022), only Fe, K, Mg, and S content in bulk milk differed between farming system for some specific months. All of which partially agrees with the limited differences detected in all 4 cheese types we investigated. López-Alonso et al. (2017) suggested that the ingestion of soil during grazing could affect the trace element status of ORG animals, which could partially explain the greater mineral content in ORG than CON cheese type of our study.

Fatty Acid Profile

Asiago PDO fresco did not reveled differences on their fatty acid profile due to being ORG, probably because as being a PDO cheese it should follow the PDO guidelines. The other cheese varieties evaluated significantly differed between the ORG and CON cheese samples up to 46% for fatty acid groups. In contrast, the differences for the determined individual fatty acids were in general <11%.

Milk fatty acids are the main compounds evaluated in ORG milk, as they are influenced by the diet (including pasture), stage of lactation, and season (Schwendel

Table 4. Individual fatty acids (g/100 g of cheese) of organic and conventional cheeses

	Organic cheese		Conventional cheese		
Trait[1]	Median	95% CI[2]	Median	95% CI[2]	*P*-value
Latteria	n = 9		n = 10		
C4:0	0.95	0.87–0.99	0.89	0.84–0.99	0.652
C6:0	0.61	0.59–0.67	0.62	0.58–0.66	0.734
C8:0	0.334	0.328–0.350	0.332	0.327–0.339	0.164
C10:0	0.90	0.89–0.92	0.87	0.82–0.89	0.027*
C12:0	1.14	1.11–1.19	1.04	0.99–1.06	0.004*
C14:0	3.19	3.13–3.49	3.17	3.11–3.23	0.098
C15:0	0.394	0.374–0.439	0.392	0.375–0.436	1.000
C16:0	9.22	8.82–10.19	8.95	8.67–9.22	0.004*
C18:0	3.41	2.60–3.50	3.04	2.84–3.19	0.426
Asiago PDO fresco	n = 9		n = 9		
C4:0	0.83	0.79–0.87	0.85	0.79–0.87	1.000
C6:0	0.60	0.54–0.63	0.57	0.55–0.61	0.301
C8:0	0.3345	0.326–0.362	0.3336	0.328–0.350	0.910
C10:0	0.89	0.83–0.92	0.86	0.82–0.90	0.203
C12:0	1.064	1.008–1.102	1.056	1.011–1.094	0.652
C14:0	3.15	3.10–3.47	3.24	3.11–3.43	0.426
C15:0	0.37	0.35–0.40	0.36	0.34–0.39	0.230
C16:0	8.92	8.59–9.53	9.11	8.81–9.64	0.301
C18:0	3.11	2.88–3.57	3.33	2.76–3.56	0.910
Caciotta	n = 8		n = 8		
C4:0	0.83	0.73–0.89	0.75	0.74–0.80	0.039*
C6:0	0.57	0.52–0.61	0.54	0.52–0.58	0.109
C8:0	0.33	0.32–0.34	0.32	0.32–0.33	0.023*
C10:0	0.87	0.85–0.96	0.84	0.83–0.87	0.023*
C12:0	1.04	1.01–1.18	1.01	0.99–1.04	0.055
C14:0	3.14	3.07–3.28	3.05	3.02–3.17	0.008*
C15:0	0.35	0.32–0.38	0.34	0.33–0.36	0.641
C16:0	8.98	8.66–9.59	8.61	8.51–8.89	0.008*
C18:0	2.72	2.55–3.12	2.83	2.67–3.23	0.313
Mozzarella TSG	n = 14		n = 14		
C4:0	0.49	0.47–0.55	0.54	0.53–0.56	<0.001*
C6:0	0.34	0.32–0.38	0.38	0.37–0.40	0.004*
C8:0	0.24	0.23–0.25	0.25	0.24–0.27	0.005*
C10:0	0.51	0.47–0.54	0.55	0.54–0.63	0.002*
C12:0	0.63	0.59–0.68	0.68	0.67–0.78	0.002*
C14:0	2.33	2.12–2.48	2.40	2.30–2.58	0.002*
C15:0	0.22	0.22–0.26	0.25	0.24–0.28	<0.001*
C16:0	6.11	5.81–6.86	6.76	6.58–7.18	0.001*
C18:0	2.58	2.06–3.11	2.67	2.36–3.24	0.005*

[1]PDO = Protected Designation of Origin; TSG = Traditional Specialty Guaranteed.

[2]95% CI = 95% confidence interval of the estimate.

*Significant difference ($P < 0.05$) between gross composition of organic and conventional cheese.

et al., 2015). It has been reported that minor dietary differences can modify the fatty acid profile of both ORG and CON milk (Schwendel et al., 2015) without affecting the total SFA percentage (Średnicka-Tober et al., 2016). In the current study, few differences in the fatty acid composition between ORG and CON cheeses were observed, and the majority of those differences were detected in Caciotta and Mozzarella TSG. In fact, Caciotta and Mozzarella TSG were the only cheese types that tended to present lower moisture content in ORG than CON cheese. Moreover, Mozzarella TSG had lower fat content in ORG than CON cheese which explains the lower amount of several individual and groups of fatty acids in the former than the latter. Thus, our results partially agreed with previous results in bulk milk collected in the same area where the fatty acid profile was almost identical in ORG than CON milk (Manuelian et al., 2022). The similarity of the fatty acid content is mainly related to the animals' feeding regimens (Manuelian et al., 2022). The cheese factories involved in the present study collect milk from the wider Po Valley, where pasture is scarce and feeding of the lactating cows –both in ORG and CON– is based on a total mixed ration that includes corn meal or corn silage. The inclusion of corn, which is a C4 plant, in ORG dairy farms does not allow to discriminate ORG from CON milk, because it is identified using the carbon stable isotope ratio milk method which relays on the fact that most CON farms use corn, whereas ORG farms does not (Schwendel et al., 2015;

Inácio and Chalk, 2017). Therefore, the few differences we detected are in line with previous studies on ORG milk (Średnicka-Tober et al., 2016; Manuelian et al., 2022). Nevertheless, Średnicka-Tober et al. (2016) reported greater n-3 and PUFA, and lower n-6 percentage in ORG milk, whereas we observed a lower content (g/100g cheese) of n-3 in Latteria and Cacciota, and of PUFA in Latteria.

CONCLUSIONS

Our study of 4 different cheeses, sampled over many months, showed that ORG and CON cheeses differed slightly in terms of gross composition and mineral and fatty acid contents, depending on the cheese type being analyzed. Asiago PDO fresco showed fewer differences between ORG and CON samples than Latteria, Caciotta, and Mozzarella TSG. Nevertheless, fatty acid content differences between ORG and CON samples of Mozzarella TSG are influenced by the lower fat content in the former than the latter. The huge similarity between ORG and CON of Asiago PDO fresco could be as a result of dealing with a PDO cheese that should follow specific guidelines. This study contributes to filling the gap of information regarding the differences between ORG and CON cheeses, as there are very few studies on the subject.

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