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Effect of milk thermisation and farming system on cheese sensory profile and fatty acid composition

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ABSTRACT

The effect of milk thermisation and farming system on the sensory profile and fatty acid (FA) composition of a traditional cheese under real production conditions was evaluated. Raschera Protected Designation of Origin (PDO) cheese, which is produced in North-West Italy, was chosen as a case study. Cheese samples were collected in summer and winter from dairy plants that processed raw milk (IR) or thermised milk (IT) collected from intensive farms, or raw milk (ER) collected from extensive farms. The sensory profile and FA composition of IR and IT cheese were similar. The ER summer cheeses had a lower cream odour, butter odour and aroma. They had a higher rennet, strong toasted, silage, barn, garlic, boiled vegetables, and smoked odours and aromas, a higher hazelnut odour, and tasted more bitter. The ER summer cheese also expressed a more favourable FA composition for human health, which allowed it to be distinguished among the other Raschera cheese.

1. Introduction

The sensory properties of cheese are closely related to the environmental conditions of milk production, the type of milk that is utilised, and the particular technology that is applied (Urbach, 1990).

Traditional cheeses are typically produced in small factories or on farms, using milk from animals fed a combination of conserved forages, fresh pasture and concentrates (Bovolenta et al., 2014; Carpino et al., 2004). The specifications of these cheeses do not always include restrictions on animal diet composition, which can vary from diets applied in extensive to intensive dairy systems, with significant changes throughout the year due to seasonal variations in the allowance of the various feedstuffs. These variations in cow feeding are known to affect sensory properties of cheese (Abilleira, Schlichtherle-Cerny, Virto, de Renobales, & Barron, 2010; Buchin, Martin, Dupont, Bornard, & Achilleos, 1999; Martin, Verdier-Metz, Buchin, Hurtaud, & Coulon, 2005) and fatty acid (FA) composition (Coppa et al., 2013; Dewhurst, Shingfield, Lee, & Scollan, 2006; Shingfield, Bonnet, & Scollan, 2013).

Pasture feeding is known to lead to an increase in the strong and herbaceous flavours and odours of cheese, but also to give cheese a yellower colour and reduced firmness, compared with cheese made from milk derived from cows fed conserved forages and concentrates (Bonanno et al., 2013; Coppa et al., 2011b; Esposito et al., 2014). Cheese made from fresh-herbage-derived milk is also richer in n-3 FA, conjugated linoleic acid (CLA) and polyunsaturated FA (PUFA), and poorer in saturated FA (SFA) and n-6 FA (Coppa et al., 2015a; Hurtaud, Dutreuil, Coppa, Agabriel, & Martin, 2014; Revello-Chion et al., 2010), with subsequent implications for human health and cheese sensory properties (Farruggia et al., 2014; Givens, 2010). Feeding cows with high proportions of grass silage or hay instead of maize silage may also induce similar changes in the sensory characteristics of cheese, even though they can be less pronounced (Agabriel et al., 2004; Hurtaud, Peyraud, Michel, Berthelot, & Delaby, 2009; Martin et al., 2005).

Furthermore, some traditional cheeses, even when specifications exist, can be made using both raw and heat-treated milk. The heat treatment necessary for pasteurisation of milk can have significant impact on the sensory properties of cheese (Chambers, Esteve, & Retiveau, 2010; Cornu et al., 2009). It can induce a partial loss of the particular sensory features that can be imparted to

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cheese through some feeding systems, such as pasture feeding, especially during summer utilization of upland biodiversified pastures (Coppa et al., 2011b; Farruggia et al., 2014). Consequently, the sensory properties and FA composition of traditional cheeses can be expected to vary extensively. The effect of production conditions on the sensory properties of traditional cheese has rarely been studied in on-farm experiments. Thus, a characterisation of the sensory and FA profiles of traditional cheese could be useful in understanding the role of the production systems and seasons on commercial farms and dairy plants.

The aim of this research was to evaluate the effect of farming system and thermisation of milk on the sensory profile and FA composition of a traditional cheese under real production conditions. Raschera PDO cheese, a traditional cheese that is produced in North-West Italy, was considered as a case study.

2. Materials and methods

2.1. Raschera PDO cheese: a case study

Raschera PDO cheese is a traditional uncooked and pressed cow milk cheese that is produced in the Cuneo Province, in North-West Italy. Currently, almost all Raschera cheese is produced from full-fat bovine milk. The geographical shape of the Cuneo Province is highly heterogeneous and changes significantly over a rather narrow territory. Consequently, the farming systems vary considerably, ranging from intensive maize silage-based farming systems in the Po plain area, to extensive farms on which herds graze on upland pastures in the Alps during summer. The limited number of dairy plants producing Raschera in the Province allowed cheese to be collected from almost all of the producers, and to establish the real variations in production conditions of almost the entire production of Raschera PDO cheese.

2.2. Schedule for cheese sensory evaluation

A representative sample of cheese was collected with the aim of identifying the sensory attributes that are able to describe the sensory profile of Raschera PDO cheese. Five representative factories were selected considering their different farming systems and cheesemaking technology characteristics to obtain the widest possible range of variability of the sensory properties.

A Quantitative Descriptive Analysis (QDA®) (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974) was performed on two cheeses ripened for 60 days, produced in the winter and summer seasons, by each cheese factory. Ten expert panellists selected to form the panel underwent a training period for QDA®, and they were then involved in the development of a list of attributes describing the texture, odour, taste and flavour of cheese. The tests were performed in three sessions (one for winter cheese and two for summer cheese), following the procedure described for the sensory analysis (Nielsen & Zannoni, 1998). Each panellist was asked to identify a list of sensory descriptors of the cheese in individual sensory booths (Hunter & McEwan, 1998; ISO, 1988). These attributes were characterised and agreed upon in a round-table meeting, in which the sampling tastes of the products used as reference odour, flavour and taste were dealt with, to create the final list of attributes that described the sensory profiles of the cheese.

A total of 36 attributes were identified: 14 for odour, 14 for flavour, 4 for taste and 4 for texture (Table 1). Subsequently, a validation test was performed in 14 sessions. During each session, panellists were asked to evaluate the sensory attributes on an intensity scale ranging from 1, at which the attribute was defined as not perceptible, to 9, at which the attribute had the maximum expression.

Statistical analyses of the validation test were performed using Senstools (v 3.3.2, OP&P, Utrecht, The Netherlands), applying a Procrustes Generalised Analysis (PGA; Arnold & Williams, 1986) associated with a GLM of the analysis of variance, to establish agreement among the assessors in the sensory evaluation of each descriptor, and to avoid deviations related to individual panellists. The PGA returns the average score of a sample, corrected for the differences between the individual assessors' judgements (Dijksterhuis, 1996). The minimum and maximum value of each score perceived by the assessors were used to establish the reference range of variation of each attribute, except for those attributes that showed significant differences among samples by analysis of variance. The range of variation for those attributes was established by adding the least square distance achieved by the GLM to the maximum score and subtracting it from the minimum score. The established reference range of variation has been used to conduct the further characterization of the sensory profile of Raschera PDO cheese.

2.3. Characterisation of cheese production systems

To explore the widest possible variation in the production conditions and cheesemaking technologies, ten dairy plants, producing more than 80% of the total Raschera PDO cheese production, were involved in the experiment. One 60-day ripened cheese produced in winter (W, December) and one in early summer (S, June), were collected from each dairy plant, to give a total of 20 cheeses. The production conditions applied on the dairy farms (around 260 farms in total), from which the milk used for the cheesemaking of each collected cheese was derived, were characterised through a questionnaire, in which the main data about the performance of lactating cows and herd characteristics (number of cows and milk yield) and diets of the lactating cows were collected. A questionnaire was also completed in the dairy plants to characterise the main cheesemaking technologies. Overall, the farms from which the dairy plants collected the milk covered a wide variation of production conditions (i.e., cow diet composition and milk production level). However, the characteristics of the farms that supplied milk were quite homogeneous within each dairy plant. Six dairy plants collected milk mainly from intensive dairy farms; three of them produced cheese from raw milk (IR), and three from thermised milk (IT), which was heated at 63–65 °C for 15 s. Four dairy plants collected milk from extensive farms and produced cheese only from raw milk (ER). Thus, these three types of production systems were identified as being representative of the whole Raschera PDO cheese production.

2.4. Cheese sensory analysis

A sensory evaluation was performed, by ten trained panellists, on the 20 sampled cheeses using the sensory attributes defined during the construction of the schedule for cheese sensory evaluation. The samples were presented as described for the construction of the schedule; 3–4 cheese samples were coded with a random 3-digit number and randomly presented to the panellists at 16 °C as 1.5 × 1.5 × 8.0 cm parallelepipeds (Nielsen & Zannoni, 1998). Each session involved three replicates. The sensory evaluation was carried out in individual sensory booths (ISO, 1988), following the same procedure described for the schedule validation test; the panellists scored each descriptor on a scale from 1 (non-perceptible attribute) to 9 (maximal expression of the attribute). In all, six sessions were necessary to analyse all the cheese samples, three for the winter cheeses and three for the summer cheeses. One cheese per system was analysed in each session, except for the last session, in which one more cheese from the ER system was analysed.

2.5. Cheese fatty acid analysis

Each cheese sampled for the sensory analysis was also analysed for FA composition, as described by Revello-Chion et al. (2010). Briefly, 40 g of cheese was accurately ground and transferred to a 50 mL polycarbonate tube (29 × 102 mm, Sorvall cat 03146), then directly centrifuged at 35 °C at 27,000 × g to separate the anhydrous fat. The clear supernatant fraction was separated and immediately stored at −20 °C (Revello-Chion et al., 2010). Lipid extraction and transesterification of the FA were performed according to the methods of Hara and Radin (1978) and to Christie (1982), with the modifications described by Chouinard, Corneau, Sæbø, and Bauman (1999). The gas chromatographic conditions for the FA methyl ester analysis were as described by Revello-Chion et al. (2010).

2.6. Statistics

Statistical analyses were performed with the SPSS for Windows software package (version 16.0; SPSS Inc., Chicago, IL – USA). The average sensory results given by the PGA for each sample and its FA composition data were processed using two general linear models (GLMs) of analysis of variance, one on the IT and IR cheese, to test the difference between cheese for raw or thermised milk, and one on IR and ER cheese, to test the effect of the production system. The effect of season and treatment × season were also tested in both models. Pearson's correlations were also tested between the concentrations of the main FA and the sensory descriptors on all cheese samples that showed significant effects of production system or production system × season by GLM. A Partial Least Square (PLS) regression was performed on each of the main sensory descriptors of cheese using, as predictive variables, the FA that showed significant Pearson's correlations.

3. Results

3.1. Characterisation of the farming systems

The intensive dairy farms investigated reared high-yielding Holstein breeds (average size of 81 lactating cows), with distributed calving over the year, with the aim of standardising the milk production throughout the year as much as possible (Table 2). The main forage in lactating cow diet was maize silage [about 34% of diet dry matter (DM)], with small proportions of hay and grass silage. The concentrate represented almost half of the diet DM; the diet was quite constant throughout the year.

The extensive farms were small and not exclusively specialised in milk production (Table 2), as they reared double-purpose local breeds, with a low milk yield (around 2700 kg cow^{-1} year^{-1}). In the first two months of lactation, part of the milk on these farms was used to wean calves, which were then sold for fattening. Calving was often concentrated in the winter period (November–January). Therefore, only a smaller number of cows calving in spring or summer were milked in summer, and the milk production on the farm decreased in this season. Lactating cows were fed hay, which is the main forage type, in winter (about 63% of diet DM), associated with maize silage (about 23% of diet DM) and small amounts of concentrate (about 12% of diet DM). From April to the end of summer, the conserved forages were substituted with fresh herbage, grazed or cut and fed indoors, with minimal hay and concentrate supplements (about 13 and 14% of diet DM, respectively).

3.2. Characterisation of the dairy plants

The IT dairy plants were larger than the IR and ER; they collected 4 × more milk from a 3 × larger number of farms (Table 3). The IT

Table 1
Descriptive attributes and reference substances corresponding to the maximum attribute value used to construct the sensory evaluation schedule for Raschera PDO cheese.[a]

Attributes	Reference substances and values
Odours/Flavours	
Creamy	Pasteurised fresh cream = 9
Butter	Butter form centrifuged cream = 9
Whey	Acid whey = 9
Rennet	Rennet achieved form lactating calves abomasum = 9
Strong toasted	Thin pieces of cut and peeled onions, fried in butter until beginning to darken on the edges = 9
Silage	Maize silage = 9
Barn	Chopped dirty straw from dairy cow barn = 9
Garlic	Garlic cooked in water for 5 min, then chopped = 9
Soft toasted	Piece of brioche with rind and internal part = 9
Bread rind	Crumbled cereal bread rind = 9
Boiled vegetables	Cauliflower cooked in water for 5–10 min, then milled = 9
Smoked	Smoked Scamorza cut in small cubes = 9
Hazelnut	Dried and 1–3 s chopped hazelnut
Herbage	1 kg of ricotta + 12 g of 1:100 cis-3-exen in ethanol solution = 9
Tastes	
Sweet	1 kg of ricotta + 150 mL of 3:100 fructose solution = 2; 1 kg of Ricotta + 150 mL of 10:100 fructose solution = 6
Salty	1 kg of ricotta + 150 mL of 2:100 NaCl solution = 2; 1 kg of Ricotta + 150 mL of 7:100 NaCl solution = 6
Acid	1 kg of ricotta + 150 mL of 4 g of lactic acid and 0.5 g of NaCl solution = 2; 1 kg of Ricotta + 150 mL of 10 g of lactic acid and 0.5 g of NaCl solution = 6
Bitter	1 kg of ricotta + 150 mL of 0.35:100 caffeine solution = 2; 1 kg of Ricotta + 150 mL of 0.583:100 caffeine solution = 6
Texture	
Hardness	Melted Emmental cheese = 2; skinned wurstel = 4; carrot cooked for 5 min = 7
Springiness	Butter = 1; jelly candies = 4; cooked squid = 7
Adhesiveness	Hard-boiled egg white = 1; hard-boiled egg yolk = 4; melted Emmental cheese = 6
Meltingness	Madeleine cookies = 3; hard-boiled egg yolk = 5; meringue = 7

[a] Evaluation criteria were: odours/flavours: intensity of odour/flavour; tastes, intensity of taste during chewing; hardness, resistance to deformation and breaking at the first chewing; springiness, ability to regain the original form after a soft molar pressure; adhesiveness, resistance to be removed after being 4–8 times chewed, then stuck to the palate; meltingness, rapidity to be dissolved by the saliva after 2–4 chews.

Table 2
Characteristics of intensive and extensive dairy farms in the production systems studied.[a]

Parameter	Intensive		Extensive	
	Average	Range	Average	Range
Lactating cows (number)	81	57–160	38	12–60
Milk yield (T cow^{-1} $year^{-1}$)	9.45	7.53–13.02	2.70	0.60–6.39
Diet composition (% of diet dry matter)[b]				
Maize silage	34	26–41	23; 0	0–36; 0
Grass silage	4	0–21	2; 0	0–12; 0
Hay	19	0–44	63; 13	35–82; 0–37
Fresh herbage	0	0	0; 73	0; 31–100
Concentrate	43	28–64	12; 14	6–39; 0–38

[a] Intensive farm breeds was Holstein, with calving period all year round; extensive farm breeds were Piemontese, Valdostana Red Pied, crossbreeds with calving period of 70% December–March.
[b] Diets are year round for intensive dairy farms; for extensive farms winter and summer values are given, separated by a semi-colon.

and IR dairy plants collected around 80%–85% of the milk from intensive farms. In contrast, the ER dairy plants collected about 75% of the milk from extensive farms.

3.3. Sensory characterisation of cheese from different production systems

When the sensory profile of the IR and ER cheese was compared (Table 4), the ER cheese produced in summer showed a sensory profile that differs for eight odour attributes, seven aroma attributes, and one taste attribute from the other Raschera cheeses. The ER summer cheeses had the lowest cream odour, and butter odour and aroma, and the highest strong toasted, silage, barn, boiled vegetable and smoked odours and aromas, as well as the highest hazelnut odour, and they were the most bitter. Furthermore, on average, the summer cheese had higher hazelnut aroma, herbage odour and aroma, and had poorer melting properties.

When the sensory profiles of the IT and IR cheese were compared (Table 5), it was found that the texture of cheese from raw and thermised milk were deemed to be similar; the IT cheese was less springy and had a numerically higher hardness. The interaction between thermisation and season was not significant. On average, the summer cheese had higher butter odour, cream, rennet, barn, garlic, soft toasted, bread rind, boiled vegetables, smoked, hazelnut, and herbage odours and aromas and were sweeter. The smoked, hazelnut and herbage odours and aromas of all the winter cheese samples (IT, IR and ER) were under the perception threshold.

3.4. Fatty acid composition of cheese from different production systems

When the FA compositions of IR and ER cheese were compared (Table 6), it was found that the ER cheese produced in summer had the highest concentrations of isoC14:0, isoC15:0, anteisoC15:0, C15:0, C15:1cis9, isoC16:0, isoC17:0, anteisoC17:0, C17:0, C17:1cis9, isoC18:0, C18:1trans11, C19:0, C19:1cis10, C18:3n-3, CLAcis9-trans11, C20:0 and total OCFA, BCFA, PUFA, the highest C18:1cis9-to-C16:0 ratio, the lowest concentration of C16:0 and C18:2n-6 and the lowest C18:2n-6-to-C18:3n-3 ratio than the IR cheeses. On average, the summer cheese had lower concentrations of FA from C6:0 to C12:1cis9, C13:0, C14:0 and total SFA and higher concentrations of C4:0, C18:1cis9, MUFA and the C18:1cis9-to-C16:0 ratio.

When the IT and IR cheeses were compared, their FA composition was similar and the interaction between thermisation and season of production was not significant (data not shown). The winter cheese, on average, had higher concentrations of FA from C6:0 to C12:0, of C13:0, C14:0 and total SFA, whereas the summer cheese had higher concentrations of C18:1cis9, CLAcis9trans11 and MUFA and a higher C18:1cis9-to-C16:0 ratio (data not shown).

Table 3
Characteristics of dairy plants manufacturing cheese with thermised milk (IT) or raw milk (IR) collected from intensive farming system or manufacturing cheese with raw milk collected from extensive farming systems (ER).

Average data	IT	IR	ER
Number of dairy plants	3	3	4
Number of farms collected by a dairy plant	40	12	13
Amount of milk collected daily (T)	50.3	13.3	12.6
Contribution to total milk (%) of:			
intensive farms	86	82	27
extensive farms	14	18	73

3.5. Correlations and PLS regressions between fatty acid concentrations and sensory descriptors of cheese

The correlations between the concentration of the main fatty acids and sensory descriptors that showed significant effect of production system or production system × season are shown in Table 7. Butter and garlic odours, and strong toasted, silage, barn and boiled vegetables odours and aromas, showed significant correlation ($P < 0.05$) with C18:1trans11, C18:2n-6, C18:3n-3, CLA-cis9trans11, Branched-chain FA (BCFA), Odd-chain FA (OCFA) and C18:2n-6-to-C18:3n-3 ratio, with coefficients > 0.70. The PLS regression coefficients were significant for all the descriptors tested, except for rennet aroma (Table 8). Strong toasted, silage, barn, garlic, boiled vegetables, smoked and hazelnut odours and barn aroma showed good interrelationship with the main FA ($R^2 > 0.70$).

4. Discussion

4.1. Effect of farming system on cheese fatty acid composition

In winter, the farming system did not significantly affect cheese FA composition. Ferlay et al. (2008) also found only minimal differences between less contrasting winter feeding systems (i.e., mixed diets with maize silage, grass silage and hay) in on-farm conditions when bulk tank milk was analysed. On the other hand, several authors (Coppa et al., 2015a; Ferlay, Martin, Pradel, Coulon, & Chilliard, 2006; Hurtaud et al., 2009) have reported significant differences among winter feeding systems for almost all FA. In particular, in controlled trials, high proportions of maize silage and concentrates have been associated with high concentrations of C18:2n-6, SFA in milk, and with low concentrations of BCFA, C18:3n-3 and CLAcis9trans11, compared with hay- or grass-silage-based diets (Ferlay et al., 2006; Hurtaud et al., 2009; Vlaeminck, Fievez, Cabrita, Fonseca, & Dewhurst, 2006). However, most of these differences were observed in controlled trials with highly contrasting diets. The similarity of FA profiles during winter could be attributable to the use of hays and corn silages in the diets of both extensive and intensive dairy farms. Furthermore, both farming systems commonly supplemented cows with high proportion of concentrates, which probably reduced the differences between the two systems.

A possible effect of low quality hay (late cut, sometimes dried on field during rainy days), could also have reduced the differences in FA composition between the IR and ER winter cheese (Coppa et al., 2015b; Ferlay et al., 2006). Low quality hay is frequently used in extensive systems to feed double-purpose breeds with low feeding

Table 4
Sensory profile of cheese manufactured from raw milk by dairy plants collecting milk from intensive (IR) or extensive (ER) farming systems in winter (W) and summer (S).[a]

Sensory descriptors	IR-W	IR-S	ER-W	ER-S	SEM	System	Season	Interaction
Odours								
Creamy	3.7[ab]	4.3[a]	4.3[a]	3.5[b]	0.16	ns	ns	*
Butter	4.1[ab]	4.7[a]	4.6[a]	3.7[b]	0.13	ns	ns	**
Whey	5.4	5.2	5.0	5.4	0.09	ns	ns	ns
Rennet	4.4	4.8	4.3	5.1	0.10	ns	**	†
Strong toasted	3.3[b]	3.4[b]	3.2[b]	4.1[a]	0.11	†	**	*
Silage	4.2[ab]	4.2[ab]	3.9[b]	5.1[a]	0.16	ns	*	*
Barn	3.4[b]	3.7[b]	3.4[b]	4.8[a]	0.18	*	**	*
Garlic	2.5	2.9	2.4	3.4	0.14	ns	**	†
Soft toasted	3.3	3.8	3.3	3.3	0.13	ns	ns	ns
Bread rind	2.8	3.7	3.1	3.7	0.12	ns	***	ns
Boiled vegetables	2.9[b]	3.3[b]	2.9[b]	4.1[a]	0.16	*	**	*
Smoked	1.0[c]	3.0[b]	1.0[c]	3.8[a]	0.36	*	***	*
Hazelnut	1.0[c]	3.0[b]	1.0[c]	3.3[a]	0.31	**	***	**
Herbage	1.0	3.5	1.0	3.8	0.39	ns	***	ns
Aromas								
Creamy	3.7	4.2	3.9	3.4	0.15	ns	ns	ns
Butter	4.4[ab]	4.7[a]	4.6[a]	4.0[b]	0.10	ns	ns	*
Whey	5.4	5.3	5.3	5.5	0.09	ns	ns	ns
Rennet	4.7	4.8	4.8	5.2	0.11	ns	ns	†
Strong toasted	3.4[b]	3.3[b]	3.0[b]	3.9[a]	0.12	ns	**	**
Silage	4.4[b]	4.1[b]	4.2[b]	4.9[a]	0.14	ns	ns	*
Barn	3.6[b]	3.8[b]	3.6[b]	5.0[a]	0.19	*	**	*
Garlic	3.0[ab]	3.1[ab]	2.7[b]	3.6[a]	0.12	ns	**	*
Soft toasted	2.8	3.4	2.7	3.2	0.10	ns	**	ns
Bread rind	3.1	3.6	3.2	3.9	0.11	ns	**	ns
Boiled vegetables	3.4[b]	3.6[b]	3.2[b]	4.3[a]	0.15	ns	**	*
Smoked	1.0[c]	3.4[b]	1.0[c]	4.1[a]	0.40	*	***	*
Hazelnut	1.0	3.1	1.0	3.2	0.31	ns	***	ns
Herbage	1.0	3.5	1.0	3.4	0.36	ns	**	ns
Tastes								
Sweet	4.4	5.1	4.5	4.5	0.17	ns	ns	ns
Salty	5.4	4.8	5.2	5.4	0.21	ns	ns	ns
Acid	5.2	4.7	4.7	5.3	0.18	ns	ns	ns
Bitter	4.2[b]	4.2[b]	3.6[b]	4.9[a]	0.16	ns	*	**
Texture								
Hardness	3.4	3.5	3.7	4.0	0.17	ns	ns	ns
Springy	3.8	4.3	3.9	3.8	0.09	ns	ns	ns
Adhesive	4.6	4.2	4.6	4.2	0.17	ns	ns	ns
Melting	4.4	4.0	4.4	4.1	0.07	ns	*	ns

[a] Sample numbers were: IR-W and IR-S, 3; ER-W and ER-S, 4; values with different superscript letters differ at $P < 0.05$ within the same row; SEM, standard error of the mean. Significance of system, season and interaction denoted as: ns, not significant; †, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

requirements, whereas it is designed for heifers in intensive systems, as its quality is barely sufficient for high yielding Holstein dairy cows.

In contrast, the feeding system had a significant influence on the FA profile of summer cheese. The cheese from extensive farming systems showed the typical FA composition of milk from fresh-herbage-based diets, with high concentrations of CLAcis9trans11, C18:1trans11, C18:3n-3, PUFA, OCFA and BCFA, and low concentrations of SFA and C18:2n-6, as also reported by Coppa et al. (2012), Dewhurst et al. (2006) and Shingfield et al. (2013). Summer variations of these FA concentrations have been observed in milk from pasture-based farming systems by several authors (Ellis et al., 2006; Heck, van Valenberg, Dijkstra & van Hooijdomk, 2009; Hurtaud et al., 2014), due to the presence of fresh herbage in the cow diet. In the intensive farming system, the lack of fresh herbage in the cow's diet made the FA profile of the summer cheese similar to that of the winter season (Borreani et al., 2013).

4.2. Effect of farming system on sensory profile

Several studies (Hunter & McEwan, 1998; Martin, Pomiès, Pradel, Verdier-Metz, & Rémond, 2009) have shown that sensory protocols for quantitative descriptive analysis of cheese could be successfully applied to characterize cheese. Therefore, this study utilised sensory analysis to evaluate the effect of farming systems and seasons on the sensory profile of a semi-hard cheese (Raschera PDO) from real production conditions. This approach has rarely been found in literature (Bittante et al., 2011; Esposito et al., 2014), because of the difficulty of collecting a group of samples representative of the variations that occur in real production systems. Studies on the sensory properties of cheese as reported by production conditions, are more often conducted in simplified controlled trials in which contrasting feeding regimes are compared (Buchin et al., 1999; Coppa et al., 2011b; Hurtaud et al., 2009). Even when milk from commercial farms (often a small number of farms) was used, a standardisation of cheesemaking or ripening processes was usually applied (Agabriel et al., 2004; Bonanno et al., 2013; Bugaud et al., 2001). Thanks to the heterogeneity of the production conditions, condensed over a small territory and on a restricted number of dairy plants, Raschera PDO cheese offered the opportunity to study the variations in the sensory profile of almost the entire production under real production conditions.

The sensory profiles of the IR and ER cheeses produced in the winter did not differ. This could be attributable to the utilisation of corn silage and concentrates also in extensive winter diets. On the other hand, the summer cheese from extensive farms was characterised by higher intensities of the sensory descriptors of strong flavours and odours, such as toasted, barn, garlic and silage descriptors. This could be due to the effect of fresh herbage in cow

Table 5
Sensory profile of cheese manufactured from thermised milk (IT) or raw milk (IR) by dairy plants collecting milk from intensive farming system in winter (W) and summer (S).[a]

Sensory descriptors	IT	IR	W	S	SEM	Thermisations	Season	Interaction
Odours								
Creamy	4.0	4.0	3.7	4.2	0.12	ns	*	ns
Butter	4.4	4.4	4.2	4.6	0.09	ns	†	ns
Whey	5.3	5.3	5.3	5.2	0.09	ns	ns	ns
Rennet	4.9	4.6	4.5	5.0	0.09	ns	**	ns
Strong toasted	3.4	3.3	3.3	3.5	0.05	ns	ns	ns
Silage	4.3	4.2	4.2	4.3	0.08	ns	ns	ns
Barn	3.8	3.5	3.5	3.8	0.09	ns	†	ns
Garlic	3.0	2.7	2.6	3.1	0.10	ns	**	ns
Soft toasted	3.1	3.6	3.1	3.5	0.14	ns	†	ns
Bread rind	3.1	3.2	2.8	3.5	0.12	ns	***	ns
Boiled vegetables	3.5	3.1	3.0	3.5	0.12	ns	*	ns
Smoked	2.3	2.0	1.0	3.1	0.31	ns	***	ns
Hazelnut	2.2	2.0	1.0	3.1	0.30	ns	***	ns
Herbage	2.5	2.3	1.0	3.6	0.37	ns	***	ns
Aromas								
Creamy	3.7	4.0	3.6	4.0	0.14	ns	†	ns
Butter	4.3	4.6	4.3	4.5	0.10	ns	ns	ns
Whey	5.5	5.4	5.5	5.4	0.10	ns	ns	ns
Rennet	5.0	4.8	4.7	5.0	0.11	ns	†	ns
Strong toasted	3.6	3.3	3.4	3.5	0.07	ns	ns	ns
Silage	4.6	4.3	4.5	4.4	0.10	ns	ns	ns
Barn	4.0	3.7	3.6	4.0	0.11	ns	†	ns
Garlic	3.2	3.0	2.9	3.3	0.12	ns	*	ns
Soft toasted	2.8	3.1	2.7	3.2	0.14	ns	†	ns
Bread rind	3.2	3.3	3.0	3.4	0.08	ns	*	ns
Boiled vegetables	3.8	3.5	3.5	3.8	0.11	ns	†	ns
Smoked	2.4	2.2	1.0	3.4	0.35	ns	***	ns
Hazelnut	2.2	2.0	1.0	3.1	0.30	ns	***	ns
Herbage	2.4	2.3	1.0	3.5	0.36	ns	***	ns
Tastes								
Sweet	4.2	4.8	4.1	4.8	0.29	ns	*	ns
Salty	5.5	5.1	5.4	5.2	0.19	ns	ns	ns
Acid	5.3	5.0	5.1	5.1	0.17	ns	ns	ns
Bitter	4.4	4.2	4.3	4.3	0.14	ns	ns	ns
Texture								
Hardness	4.2	3.5	3.9	3.8	0.19	†	ns	ns
Springy	3.5	4.1	3.6	3.9	0.14	*	ns	ns
Adhesive	4.3	4.4	4.4	4.2	0.14	ns	ns	ns
Melting	4.1	4.2	4.3	4.1	0.06	ns	ns	ns

[a] There were 6 samples for IR, ER, W and S; SEM, standard error of the mean. Significance of thermisations, season and interaction denoted as: ns, not significant; †, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

diet, which is known to increase scores for floral and vegetal notes, and to decrease butter and creamy notes (Carpino et al., 2004). Furthermore, several other studies (Agabriel et al., 2004; Coppa et al., 2011b; Esposito et al., 2014) have shown that summer cheese derived from pasture-fed cows had stronger notes than those produced in winter or from cows fed hay or silage.

The typical sensory profile of summer dairy products from extensive farming system, based on pasture utilisation, has also been correlated, by several authors, with the abundance of other odour active compounds, such as indoles (responsible for animal and barn notes), sulphur compounds and toluene (burnt, smoked and toasted notes) or terpenoids (green and herbaceous notes) (Bendall, 2001; Moio, Dekimpe, Etievant & Addeo, 1993; Mounchili et al., 2005). These compounds could have contributed to the high barn, silage, toasted and smoked odours and flavours and to the low butter and cream notes of the ER cheese produced in summer.

The microbial origin of odour-active compounds has also been suggested by Verdier-Metz et al. (2002), who noted that the differences in sensory properties observed for Cantal cheese produced with raw-milk from cow fed different diets were lower in pasteurised-milk cheese from the same diets. Recent studies by Verdier-Metz et al. (2012a) and Verdier-Metz, Monsallier, and Montel (2012b) have illustrated how the microbial flora of cow teat skin is a potential source of diverse microbial populations that vary in composition according to the environment in which the cows are reared and according to the diet composition. Thus, a possible different microflora of raw milk may have contributed to the development of the sensory characteristics of the ER summer cheese during ripening.

The practice on extensive farms of concentrating calving in winter periods may result in late summer cheeses mainly made from by late-lactation milk. Milk from late lactations is known to have a high somatic cell count and native enzyme activities, e.g., plasmin, which plays an important role on proteolysis (with implications on texture), and on the odour-active compounds derived from proteolysis during cheese ripening (Coulon, Delacroix-Buchet, Martin, & Pirisi, 2004). However, in the present experiment, the ER cheese was produced in early summer with animals in mid lactation; therefore, no differences were observed in cheese texture. Furthermore, other factors related to the cow diet composition, cheesemaking technology or cheese ripening might have been confounding in determining the typical ER cheese sensory profile.

4.3. Effect of thermisation on cheese characteristics

Thermisation of milk did not affect the FA composition of the milk. The negligible effect of a milk heat treatment, due to pasteurisation or cheesemaking technology, on cheese FA composition is well known (Esposito et al., 2014; Lucas et al., 2006; Revello-Chion et al., 2010). However, the similarity of the IT and IR cheese

Table 6
Fatty acid composition of cheese manufactured form raw milk by dairy plants collecting milk from intensive (IR) or extensive (ER) farming system in winter (W) and summer (S).[a]

Fatty acid (g 100 g^{-1} FA)	IR-W	IR-S	ER-W	ER-S	SEM	System	Season	Interaction
C4:0	3.17	3.44	2.66	3.67	0.159	ns	*	ns
C6:0	2.46	2.19	2.50	2.25	0.045	ns	**	ns
C7:0	0.05	0.03	0.03	0.02	0.004	*	**	ns
C8:0	1.48	1.24	1.52	1.24	0.042	ns	***	ns
C9:0	0.06	0.04	0.05	0.02	0.004	*	**	ns
C10:0	3.35	2.72	3.36	2.59	0.115	ns	***	ns
C10:1cis9	0.30	0.26	0.34	0.28	0.010	ns	**	ns
C11:0	0.09	0.07	0.07	0.03	0.007	*	**	ns
C12:0	3.70	3.05	3.70	2.92	0.124	ns	**	ns
C12:1cis9	0.08	0.07	0.09	0.07	0.003	ns	*	ns
isoC13:0	0.12	0.10	0.13	0.13	0.004	*	ns	ns
C13:0	0.14	0.12	0.12	0.10	0.005	*	*	ns
isoC14:0	0.10^{b}	0.09^{b}	0.12^{b}	0.22^{a}	0.015	**	**	**
C14:0	11.00	10.16	11.13	9.99	0.222	ns	*	ns
C14:1cis9	0.97^{b}	0.98	1.05	0.88	0.030	ns	ns	ns
isoC15:0	0.25^{b}	0.25^{b}	0.28^{b}	0.44^{a}	0.024	**	*	*
anteisoC15:0	0.48^{b}	0.47^{b}	0.50^{b}	0.80^{a}	0.044	**	*	*
C15:0	1.18^{b}	1.08^{b}	1.10^{b}	1.51^{a}	0.059	*	†	**
C15:1cis9	0.03^{b}	0.03^{b}	0.04^{b}	0.09^{a}	0.007	***	***	***
isoC16:0	0.23^{b}	0.21^{b}	0.27^{b}	0.37^{a}	0.020	**	†	*
C16:0	28.81^{a}	27.98^{a}	29.03^{a}	25.60^{b}	0.627	ns	†	*
C16:1cis9	1.80	1.78	1.78	1.74	0.037	ns	ns	ns
isoC17:0	0.43^{b}	0.41^{b}	0.44^{b}	0.58^{a}	0.023	*	†	*
anteisoC17:0	0.48^{b}	0.44^{b}	0.45^{b}	0.60^{a}	0.022	†	ns	*
C17:0	0.58^{b}	0.56^{b}	0.56^{b}	0.91^{a}	0.054	†	†	*
C17:1cis9	0.29^{b}	0.27^{b}	0.27^{b}	0.45^{a}	0.028	†	†	*
isoC18:0	0.05^{b}	0.04^{b}	0.05^{b}	0.07^{a}	0.005	†	ns	*
C18:0	9.74	10.97	9.53	9.80	0.284	ns	ns	ns
C18:1cis9	21.46	23.07	21.47	22.51	0.389	ns	*	ns
C18:1trans11	1.79^{b}	1.80^{b}	1.71^{b}	3.48^{a}	0.271	†	*	*
C18:2n-6	2.66^{a}	2.64^{a}	2.86^{a}	1.92^{b}	0.131	ns	*	*
C19:0	0.05	0.04	0.05	0.09	0.008	†	ns	†
C19:1cis10	0.06^{b}	0.05^{b}	0.06^{b}	0.11^{a}	0.008	*	†	*
C18:3n-3	0.35^{b}	0.39^{b}	0.46^{b}	0.95^{a}	0.079	**	*	*
CLAcis9trans11	0.47^{b}	0.61^{b}	0.50^{b}	1.56^{a}	0.152	*	*	*
C20:0	0.13^{b}	0.12^{b}	0.14^{b}	0.20^{a}	0.010	**	†	*
SFA	68.13	65.33	67.72	64.16	0.724	ns	*	ns
MUFA	28.26	30.84	28.35	30.87	0.568	ns	*	ns
PUFA	3.60^{b}	3.83^{b}	3.94^{b}	4.98^{a}	0.217	†	ns	*
OCFA	2.53^{b}	2.28^{b}	2.34^{b}	3.34^{a}	0.146	†	†	*
BCFA	2.14^{b}	2.02^{b}	2.22^{b}	3.20^{a}	0.152	**	*	*
C18:1cis9/C16:0	0.75	0.82	0.74	0.90	0.030	ns	*	†
C18:2n-6/C18:3n-3	7.81^{a}	7.06^{a}	6.33^{a}	2.27^{b}	0.721	**	*	*

[a] Sample numbers were: IR-W and IR-S, 3; ER-W and ER-S, 4; values with different superscript letters differ at $P < 0.05$ within the same row; SEM, standard error of the mean. Significance of system, season and interaction denoted as: ns, not significant; †, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

sensory profiles was unexpected. Only texture was marginally affected by the heat treatment. However, the hardness and less springy texture of cheese made from thermised milk was in contrast with the findings of Beuvier et al. (1997), who reported that pasteurisation decreased the firmness and the granular characteristics of Swiss-type cheese. This would seem to suggest that other upstream factors, such as cheesemaking practices and the gross composition of cheese, may have interacted to determine these differences.

In terms of odour and aroma, Cornu et al. (2009) found less intense, rancid, musty, pungent and more creamy and hazelnut odours in pasteurised milk than in raw milk Cantal cheese. Similarly, Chambers et al. (2010) found stronger, more butyric and mouldy flavours and lower musty and hearty notes in several French raw milk cheeses than in pasteurised milk cheeses. Most of these pasteurized milk cheeses also showed more pronounced dairy attributes (such as butter, dairy fat, and dairy sweet), but the extent of the sensory differences between raw and pasteurised milk cheese depended on the cheese type. On the other hand, Chouliara, Georgogianni, Kanellopoulou, and Kontominas (2010) did not find any significant differences in odour or taste between raw and thermised milk at two temperatures (55 °C and 75 °C per 15 s), even up to two days after the heat treatment. This may suggest that the thermisation process, compared with pasteurisation, might not have a sufficient impact on milk to alter the endogenous characteristics of raw milk, and that many organisms responsible for the development of odour-active compounds in cheese may survive thermisation, i.e., those responsible for amino acid degradation or proteolysis. However, this aspect has not been investigated in the present trial. Furthermore, some of the previous findings on the effect of pasteurisation on the sensory properties of cheese were observed in controlled trials with a standardised cheesemaking technology.

In commercial dairy plants, cheesemakers who adopt a specific cheesemaking technology empirically adapt the details of the cheesemaking methods to the daily changes in the chemical and technological characteristics of the milk (Martin & Coulon, 1995). This continuous adaptation may interact with milk heat treatment and may together explain the lack of sensory differences between the raw milk and thermised milk cheese examined in the present study. The differences in sensory properties between the summer and winter cheese were similar to those observed when the IR and ER cheese was compared. This may suggest a non-negligible effect of the small proportion of milk from extensive farms in the milk

Table 7
Pearson correlation coefficients of the main fatty acids and sensorial descriptors of odours and aromas.[a]

Sensory descriptors	C16:0	C18:1c9	C18:1t11	C18:2n-6	C18:3n-3	CLAcis9trans11	ECSFA	SFA	UFA	MUFA	PUFA	C18:1c9/C16:0	BCFA	OCFA	C18:2n-6/C18:3n-3
Odours															
Creamy	-	-	-	0.61**	-	-	-	-	-	-	-	-	−0.51*	−0.56*	0.48*
Butter	-	-	−0.45*	0.73***	−0.57**	−0.51*	-	-	-	-	-	-	−0.69**	−0.71***	0.71***
Rennet	-	0.46*	-	−0.62**	-	-	-	-	-	0.46*	-	-	-	-	−0.44*
Strong toasted	−0.55*	-	0.75***	−0.79***	0.77***	0.80***	−0.62**	−0.50*	0.50*	-	0.58**	0.50*	0.79***	0.65**	−0.74***
Silage	-	-	0.53*	−0.86***	0.59**	0.62**	−0.50*	-	-	-	-	-	0.70**	0.72***	−0.72***
Barn	−0.55*	-	0.75***	−0.79***	0.78***	0.82***	−0.67**	−0.55*	0.55*	0.47*	0.59*	0.53*	0.82**	0.69**	−0.77***
Garlic	-	-	0.54*	−0.73***	0.50*	0.62**	−0.52*	−0.45*	0.45*	0.44*	-	0.45*	0.61***	0.48*	−0.55*
Boiled vegetable	-	-	0.57**	−0.77***	0.57**	0.68**	−0.57**	−0.47*	0.47*	0.46*	-	0.46*	0.69**	0.57**	−0.62**
Smoked	−0.52*	0.58**	0.59**	−0.59**	0.49*	0.65**	−0.67**	−0.64**	0.64**	0.65**	-	0.65**	0.51*	0.44*	−0.45*
Hazelnut	-	0.61**	0.45*	−0.53*	-	0.52*	−0.57**	−0.57**	0.57**	0.61**	-	0.58**	-	-	-
Aromas															
Butter	-	-	−0.44*	0.51*	−0.47*	−0.48*	-	-	-	-	-	-	−0.55*	-	-
Rennet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strong toasted	-	-	0.51*	−0.76***	0.45**	0.59**	-	-	-	-	-	-	0.62**	0.53*	-
Silage	-	-	0.47*	−0.72***	0.48*	0.53*	-	-	-	-	-	-	0.63**	0.64**	−0.52*
Barn	−0.54*	-	0.75***	−0.82***	0.74***	0.81***	−0.65**	−0.53*	0.53*	0.46*	0.54*	0.53*	0.83***	0.70**	−0.71***
Garlic	-	-	0.47*	−0.65**	0.40*	0.53*	−0.49*	-	-	-	-	-	0.53*	0.46*	-
Boiled vegetable	-	-	0.59**	−0.75***	0.56**	0.68**	−0.58**	−0.49*	0.49*	0.47*	-	0.49*	0.68**	0.58**	−0.56*
Smoked	−0.50*	0.63**	0.55*	−0.57**	0.46**	0.62**	−0.67**	−0.65**	0.65**	0.67**	-	0.66**	0.48*	-	-
Bitter taste	-	-	0.49*	−0.69**	0.47**	0.57**	−0.48*	-	-	-	-	-	0.58**	0.55*	−0.47*

[a] Statistical significance (n = 20) denoted by:*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; -, $P > 0.05$.

Table 8
Partial least square regression for the main sensory descriptors of odours and aromas developed using the fatty acids that showed significant correlations with each descriptor.[a]

Sensory descriptors	R^2	SEC	Significance
Odours			
Creamy	0.34	0.24	**
Butter	0.64	0.20	***
Rennet	0.46	0.19	**
Strong toasted	0.86	0.13	***
Silage	0.71	0.22	***
Barn	0.89	0.18	***
Garlic	0.74	0.21	***
Boiled vegetable	0.88	0.18	***
Smoked	0.81	0.49	***
Hazelnut	0.85	0.41	**
Aromas			
Butter	0.28	0.17	*
Rennet	-	-	-
Strong toasted	0.67	0.18	***
Silage	0.41	0.44	**
Barn	0.95	0.14	***
Garlic	0.32	0.23	**
Boiled vegetable	0.56	0.25	**
Smoked	0.49	0.71	**
Bitter taste	0.37	0.29	**

[a] SEC: standard error of calibration; significance denoted by:*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; -, $P > 0.05$.

collected by the dairy plants that collected milk almost form intensive dairy farms. Another possible explanation could be related to seasonal differences in the microbial composition of milk, as previously discussed by Verdier-Metz et al. (2012).

4.4. Relationship between FA composition and sensory profile of cheese

A new finding of this study was the significant correlations found between the concentration of several FA in cheese and the intensity of sensory descriptors. Some authors (Coppa et al., 2011a; Cornu et al., 2009) hypothesised that the odour-active compounds may derive from the oxidation of FA, especially from PUFA. The PUFA are present in higher concentrations in pasture-derived dairy products than in those from conserved forages and concentrates (Coppa et al., 2015b; Shingfield et al., 2013), and have a putative lower stability towards oxidation than SFA (Kirstensen, Hedgegaard, Nielsen, & Skibsted, 2004). The PUFA oxidation results in alcohols, esters, aldehydes and ketones, which can give dairy products silage, green, herbaceous, intense, pungent, acid, burnt, bitter, smoked and toasted notes (Bendall, 2001; Moio et al., 1993; Mounchili et al., 2005).

The significant correlations and regressions that were found in the present study among the main FA and sensory descriptors of cheese could contribute to strengthen the hypothesis of the origin of part of the odour-active compounds from oxidation of FA, and in particular PUFA, as these FA showed the highest correlation coefficients with the sensory descriptors of strong notes. Even if the present study does not allow the identification of a direct origin of odour-active compounds from FA oxidation, the significant correlations and regressions that were found in the present study among the main FA and sensory descriptors of cheese may strengthen the hypothesis of a possible contribution of part of the odour-active compounds from FA to the sensory profile of cheese, as previously reported for milk (Bendall, 2001; Moio, et al., 1993).

This seemed to be more evident for PUFA, which showed the highest correlation coefficients with the sensory descriptors of strong notes of Raschera Cheese. On-farm, the concentration of FA was shown to be directly related to cow diet composition and able to authenticate the farming system (Coppa et al., 2013, 2015a). Coppa et al. (2013) developed predictive equations for cow diet composition based on milk FA concentrations. As an example, according to these authors, the concentration in milk of C18:2n-6 have been positively correlated with proportions of maize silage and concentrate in the cows' diet, and the n-6/n-3 ratio has been negatively correlated with the proportion of fresh herbage in their diet. Consequently, assuming FA as indicators of cow diet composition, the significant correlation found between FA composition and sensory descriptors in the present study, suggest an indirect relationship between the proportions of various feedstuffs in cow diet and the sensory profile of cheese. Several studies have shown the capability of sensory analysis to distinguish between cheese derived from cows fed different diets in controlled experiments (Bovolenta et al., 2014; Coppa et al., 2011b; Hurtaud et al., 2009) or with standardised cheesemaking (Agabriel et al., 2004; Bonanno et al., 2013). The correlations found in the present experiment between FA and sensory descriptors confirm and reinforce the capability of sensory analysis to distinguish cheese according to the cows' diet composition in real production conditions.

5. Conclusions

Raschera PDO cheese was used as a case study to evaluate the effects of production system on the sensory properties and FA composition of cheese under real production conditions. The sensory profile and FA composition of IR and IT cheese were similar, which suggests a smaller impact of thermisation on the cheese sensory properties than that of pasteurisation, which is probably reduced even more by cheesemakers through fine adaptation of their cheesemaking technologies to the daily changes in the chemical and technological characteristics of the milk. Sensory analysis showed an excellent capability to distinguish cheese according to the farming system applied on the scale of almost the entire production of the cheese type studied. Summer cheeses produced from extensive farming systems showed a higher intensity of sensory attributes and a better FA composition for human nutrition. These results help to highlight the typicality of traditional cheeses, and should be taken into account when reviewing their specifications and targeting the commercial strategies for their valorisation.

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