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CICLO XXIII

Sources of variation in the Trentingrana cheese production chain

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“A mind is like a parachute. It doesn't work if it's not open”

“It is not the fruits of scientific research that elevate a man and enrich his nature,

but the urge to understand and the intellectual work”

Albert Einstein (1879 – 1955)

Dedicato alla mia Famiglia e a Riccardo

CONTENTS

ABSTRACT

Protected Designation of Origin (PDO) is a suitable tool to protect the reputation of regional foods and to eliminate the unfair competition and misleading of consumers by non-genuine products. Moreover, the achievement of the PDO label represents an opportunity to reach a premium price for the product, particularly in disadvantageous areas such as the Alps where the relationship between local economy and environment preservation is strong. More than 50% of the milk produced in Italy is processed into PDO cheeses and the most popular are Grana Padano and Parmigiano Reggiano. Trentingrana is a Grana-type PDO cheese manufactured in the mountain area of the Trento province. Although this label belongs to the most popular Grana Padano, cheese making protocol rules are more strict and similar to those of Parmigiano Reggiano. This thesis is based on the results of a wide research project aimed at monitoring the whole Trentingrana cheese production chain.

Specific objectives of this work were a) to investigate sources of variation of herd bulk milk destined to Trentingrana cheese production and monthly farm quality score used in the milk payment system (Chapter 2), b) to study factors affecting the quality classification of Trentingrana wheels (Chapter 3), and c) to investigate sources of variation of sensory traits of ripened Trentingrana cheese and the quality index used for payment of the wheels (Chapter 4).

The thesis starts with a general introduction on international and national dairy sector (Chapter 1), followed by three contributions (Chapters 2, 3 and 4), and general conclusions (Chapter 5).

Chapter 2 assessed the impact of dairy factory, year of production, and month of production on milk yield and quality traits of milk used to produce Trentingrana cheese and the monthly farm quality score adopted to calculate the farm milk price. Relevant differences among dairy factories were found, particularly for milk yield. The year of production had a strong influence on milk yield and much less on quality aspects. Finally, the month of production exerted a significant influence on milk yield and exhibited a circannual variation, whereas the influence on quality traits was less pronounced. The milk farm quality score showed high variability and was significantly affected by all the effects included in the model. levant differences among dairy factories were detected.

Chapter 3 focused on factors affecting the quality classification of Trentingrana cheese wheels. Traits considered were the percentage of first quality wheels on total wheels examined at 9 months of ripening, the percentage of first quality wheels on total wheels examined at 18 months of ripening and the percentage of first quality wheels at 18 months of ripening on the number of wheels evaluated at 9 months. The experimental unit was the batch of 2-months of production of each of 10 cooperative dairies from 2002 to 2008. An analysis of variance was carried out to investigate the influence of dairy factory, and year and season of production on the above traits. All factors significantly influenced cheese quality classification, with the dairy factory being the most important source of variation, followed by season and year of production. The first 4 years of production had a relevant and negative impact on the percentage of wheels chosen as first quality. Regarding the season effect, the best results were obtained in spring and summer, and the worst in autumn and winter.

Chapter 4 dealt with the analysis of sources of variation of sensory traits and quality index of Trentingrana cheese. Fixed effects included in the model were dairy factory, and year and season of production All factors significantly affected the studied traits, with the exception of interactions between dairy and season of production for texture and external aspect, and between year and season of production for odor. Dairy was the most important source of variation for visually assessed traits and quality index, whereas the year of production was the most important for flavor attributes. The latter traits were always highly correlated among them and with the quality index. Correlations among visually assessed attributes, between them and flavor attributes, and between them and the quality index were more erratic.

Key words: *cheese quality, milk trait, PDO, ripening, sensory attribute*

RIASSUNTO

Le Denominazioni di Origine Protetta (DOP) sono strumenti atti a proteggere la reputazione dei prodotti locali e preservare i consumatori dalla concorrenza sleale di prodotti non originali. Il conseguimento del marchio DOP rappresenta un'opportunità per aumentare la remuneratività di prodotti originari da zone di produzione svantaggiate come ad esempio le Alpi, dove la sussistenza di un'economia sana è basilare ai fini della preservazione del territorio.

Più del 50% del latte prodotto in Italia, è trasformato in formaggi DOP e i due più importanti consorzi di produzione Italiani (Grana Padano e Parmigiano Reggiano) coprono quasi il 70% della produzione di formaggi DOP italiani.

Il trentingrana è un esempio di formaggio DOP a pasta dura e lunga maturazione prodotto in provincia di Trento. Nonostante commercialmente Trentingrana sia la produzione alpina del ben più famoso grana Padano, il protocollo di produzione presenta regole più ferree rispetto al Grana Padano, risultando, di fatto, molto più simile al disciplinare di produzione adottato per l'altro grande formaggio a pasta dura italiano: il Parmigiano Reggiano.

La tesi qui presentata si basa sui risultati ottenuti da un progetto di ricerca che avuto come oggetto il monitoraggio dinamico dell'intera filiera di produzione Trentingrana.

Obiettivi della tesi sono dunque a) analizzare le fonti di variazione del latte di massa utilizzato quotidianamente per la produzione di Trentingrana e del punteggio mensile, utilizzato quest'ultimo ai fini della definizione del compenso mensile del latte alle aziende produttrici (Capitolo 2), b) valutare l'influenza del periodo di stagionatura in magazzino sulla qualità, e quindi classificazione, delle forme di Trentingrana (Capitolo 3) e c) analizzare le fonti di variazione degli aspetti sensoriali normalmente deputati a definire la qualità organolettica del formaggio a fine

stagionatura e studiarne l'indice di qualità organolettico, parametro di fondamentale importanza ai fini della definizione del prezzo di mercato del Trentingrana.

La tesi inizia con un'introduzione generale (Capitolo 1), in cui si riporta una breve visione d'insieme del settore lattiero caseario, seguita dai tre contributi scientifici e il capitolo di conclusioni generali (Capitolo 5).

Nel capitolo 2 è stato affrontato lo studio delle fonti di variazione del latte di massa utilizzato per la produzione di Trentingrana. È stato utilizzato un modello lineare che ha tenuto conto degli effetti fissi del caseificio di produzione, dell'anno di produzione, del mese di produzione e delle interazioni di primo ordine. Si sono considerati come variabili parametri composizionali e sanitari del latte utilizzati per il pagamento latte qualità e il punteggio mensile attribuito a ciascuna azienda conferente, calcolato in base agli esiti delle analisi di laboratorio dei parametri sopracitati. L'effetto del caseificio ha riportato una grossa variabilità tra le strutture considerate, soprattutto per quanto riguarda il peso di latte conferito a munta da ciascuna azienda. L'anno di produzione ha visto un generale miglioramento di tutte le variabili considerate eccetto che per SCS, mentre l'effetto del mese di produzione ha evidenziato come vi sia un chiaro andamento circannuale, con i valori migliori in inverno e i peggiori in estate. Lo stesso punteggio mensile del latte ha riportato un' alta variabilità ed un aumento, tra il primo e l'ultimo anno preso in considerazione, pari all'8,5%.

Nel capitolo 3 si analizzato come il periodo di stagionatura incida sulla qualità del formaggio e quindi sulla classificazione delle forme di Trentingrana. Le principali variabili considerate sono state la percentuale di forme risultanti di prima qualità all'esame ispettivo a 9 mesi di stagionatura sulle totali prodotte nel bimestre di produzione di riferimento (QW_{9mo}); la percentuale di forme risultanti di prima qualità all'esame ispettivo a 18 mesi di stagionatura sulle forme risultanti di prima qualità all'esame ispettivo a 9 mesi (QW_{18mo}) e la percentuale di forme risultanti di prima qualità all'esame ispettivo a 18 mesi di stagionatura sulle totali prodotte nel bimestre di produzione di riferimento (QW_{TOT}). L'unità sperimentale si identifica nei 6 bimestri di produzione di ciascuno dei 10 caseifici considerati, in un intervallo temporale di 7 anni (dal 2002 al 2008). Le variabili sono state valutate utilizzando un modello lineare che includeva gli effetti fissi del caseificio di produzione, dell'anno di produzione, del bimestre di produzione e delle interazioni tra caseificio e anno e tra caseificio e bimestre. Tutti gli effetti influenzano significativamente ($P<0,05$) I parametri considerati. Il caseificio è stato la maggiore fonte di variazione, seguito dall'effetto del bimestre e dall'anno di produzione. Si è riscontrato come vi sia stato un significativo peggioramento della qualità durante I primi 4 anni di osservazione. Il bimestre di produzione ha riportato valori migliori per forme prodotte in primavera – estate e peggiori durante il periodo autunno – invernale.

Nel capitolo 4 si è andati a valutare le fonti di variazione dei parametri organolettici e dell'indice di qualità di 652 forme, scelte a campione in 11 caseifici nel corso di 10 anni di produzione. Gli effetti fissi considerati nel modello lineare sono stati il caseificio di produzione, l'anno e il bimestre di produzione e le interazioni di primo ordine. Tutti i fattori hanno significativamente influenzato i parametri trattati ($P<0,05$) con l'eccezione dell'interazione tra caseificio e bimestre per i parametri "aspetto esterno" e "texture" e dell'interazione tra anno e stagione per il parametro "odore" ($P>0,05$). Il caseificio è stato la maggiore fonte di variazione per i parametri visivi e l'indice di qualità, mentre l'anno influisce fortemente sui parametri olfatto – gustativi.

Parole chiave: *DOP, qualità formaggi, stagionatura*

Chapter 1: General Introduction

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The world dairy sector

During the last decade, the world scenery of the dairy sector has changed. In industrialized countries, dairy products intakes seem to have reached the saturation point and the same trend is also characterizing the Middle East, Africa and Latin America that since 1970s have shown a constant increase of the demand. On the contrary, in the Far East the trend for dairy products consumption is positive: table 2 shows that from 2006 to 2007 the milk production reported an increase of 1,6% worldwide, mainly attributable to the consistent increase of the Chinese production (+9,6%). A great economic progress has been registered in this country, leading to an increase of dairy products intake. FAO hypothesizes that this phenomenon will not last for a long period, because selling prices are stable and associated with a continuous increase of production costs. The containment politics on production imposed by the European Union and North America, aiming to regulate demand and offer, have brought to a decline of production quotas in developed countries, that represent more than 60% of the total production. The stable production in EU is also caused by the progressive reduction of the economic support to the market; moreover, the retail prices increase is causing a decrease in the demand (Ismea, 2008). Contemporarily, countries that do not undergo to a productive bond, such as Australia and New Zeland, are expanding their productive capacity, resulting more competitive on the global market.

Table 2. Milk world production, thousand of t (Ismea, 2008)

	2003	*2004*	*2005*	*2006*	**2007**
UE-27	130,970	131,414	133,260	133,071	133,278
USA	77,289	77,534	80,254	82,462	84,095
India	36,500	37,500	37,520	41,000	42,140
China	17,463	22,606	27,534	31,934	35,000
Russia	33,000	32,000	32,000	31,100	32,000
Brasil	22,860	23,317	24,250	25,230	26,750
N. Zealand	14,346	15,000	14,500	15,200	15,595
World	541,446	546,305	690,978	558,248	567,232

The world dairy sector is destined to further changes, caused by the continuous increase of production and consumption in developing countries. The UE, although showing a constant level of production and still representing the first milk producer in the world market, shows a low incidence in the total production (Table 2)

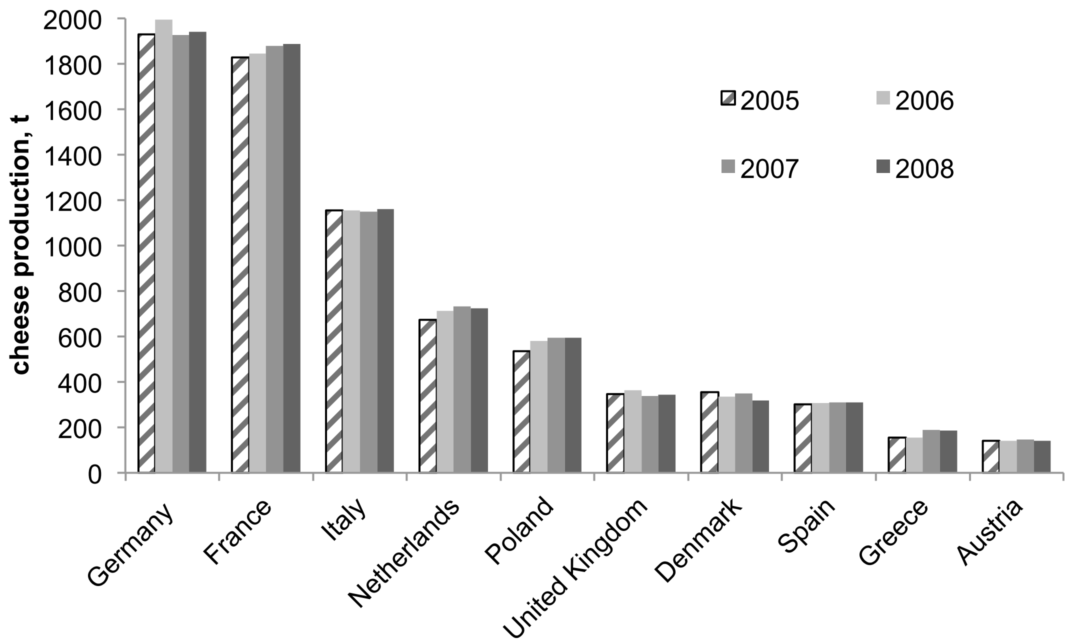
From 2003 to 2007, cheese world production (Table 3) has registered a production increase of 11% (Ismea, 2008). At the same time, UE and USA, that together hold the 62% of the world cheese production, have registered an increase of 5 and 13 % respectively. Brasil, even though representing the third cheese producer in the world, reported an increase of about 26 %.

Table 3. Cheese world production, thousand of t (Ismea, 2008)

	2003	*2004*	*2005*	*2006*	**2007**
UE-27	8,393	8,517	8,667	8,766	8,887
USA	3,882	4,025	4,150	4,325	4,389
Brasil	460	470	495	528	580
Argentina	325	370	400	480	475
Egypt	450	455	480	408	475
Russia	335	350	375	405	420
Australia	368	389	375	362	360
World	19,219	20,019	20,582	20,977	21,344

Italy represents the third cheese producer in the UE27, and with Germany (first producer) and France (second producer) covers more than 50% of the production (Figure 2).

Figure 2, main PDO producer in UE27, yearly trend (EUROSTAT, 2010)



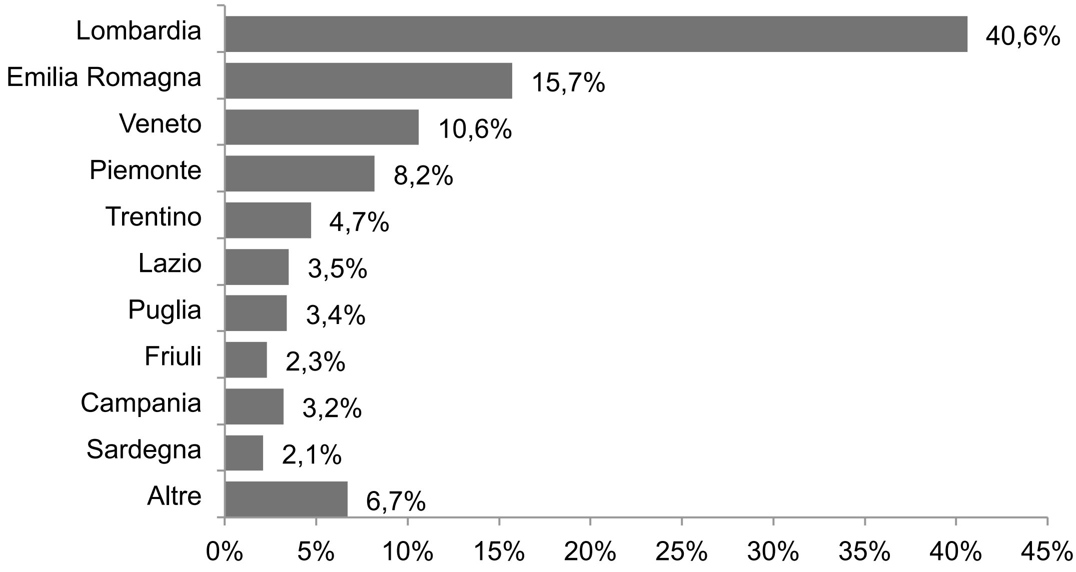
The Italian dairy sector

The dairy sector in Italy represents the first sector in the food industry, with a turnover estimated at 14.500 millions of € in 2008, and an increase of 1.04% in comparison with the previous year (Assolatte, 2009). In Italy the majority of the milk produced (93.4%) is cow milk, followed by the ovine milk (4.5%), river-buffalo milk (1.9%) and goat milk (0.2%). Milk production in Italy is principally located in the northern part of the country (Table 3), where almost the totality of the animals reared for milk purpose are cows, while in the Center and South of Italy also sheep and goats are reared; last but not least, the river buffalo is traditionally reared in southern regions.

Table 3. t of milk collected from Italian herds in 2007; species and geographic repartition (ISTAT, 2010)

	Cow	*Sheep*	*Goat*	*River Buffalo*	**Total**
North	8,472286	3,854	8,222	10,400	8,494763
Centre	7,28716	127,785	4,526	30,264	891,292
South	1,064223	358,968	13,627	168,086	1,604905
Total	10,265226	490,607	26,375	208,752	10,990961

Figure 1. Regional cow milk delivery (CLAL, 2009)



Cheese production in Italy

The national dairy sector is not homogeneous in the country: milk processing industries are located in the North of Italy, where several dairy factories and stocking centers can be found, to which herds confer their milk (istat 2010). The region where the dairy sector is more productive is Lombardy, followed by Emilia Romagna, Veneto and Piemonte (istat 2010). In the South of Italy the regions where the most dairy factories are present are Campania and Puglia. In the last five years dairy cooperatives and small dairy factories have notably decreased in all regions, except for Sardinia and some areas in the South of the country.

In Italy the productive realities vary depending on the species from which the milk is obtained, the dairy traditions, the region of production and the type of products obtained (Table 8).

The cheese production has shown a little increase in the last seven years (8.3%), even if in 2007 a negative trend has been observed (-0,40%) in comparison with the previous year. However, the most produced types of cheese are the fresh ones, followed by the hard types, and all together cover about the 75% of the total Italian cheeses production (Table 8).

Table 8. Cheese National production (t) divided for type of texture (Istat 2010)

	2002	***2003***	***2004***	***2005***	***2006***	***2007***	**2008**
Hard	407,807	394,853	418,615	414,177	412,467	416,422	424,608
Semi hard	93,662	90,303	95,499	102,827	97,324	90,405	90,863
Soft	171,201	176,781	184,995	189,094	192,575	188,825	190,479
Fresh	400,084	435,433	439,619	449,483	451,669	453,758	455,535
Total	1,072,756	1,097,371	1,138,730	1,155,582	1,154,036	1,149,412	1,161,487

Cheeses with protected designation of origin (PDO) in Italy

The Regulation 510/ 2006 of the European Community Protected designation of origin is defined as "origin designation" the name of a region, of a determined place or, in exceptional cases, of a village that is used to design an agricultural product:

- That takes origin in that region, determined place or village
- Whose qualities are essentially due to a particular geographic area, including natural and human factors
- Whose production, processing and elaboration take place in that delimited geographic region

In Italy cheeses represent 19,2% of the products branded as PDO (Ismea, 2010), occupying the first position in terms of turnover (3,900 million of Euros in 2009, with an increase of 24% in comparison with 2008, Table 10). More than 50% of the milk produced in Italy is processed into PDO cheeses. It can be observed in Figure 2 that the majority of the PDO cheese in Italy is obtained with cow milk.

Figure 2. Use of milk of different species in PDO cheese production in 2008 (Clal, 2010)

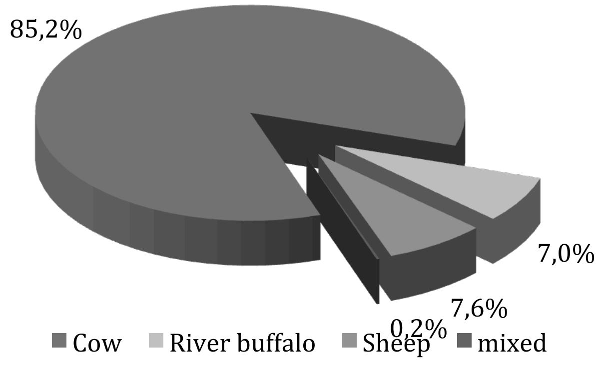


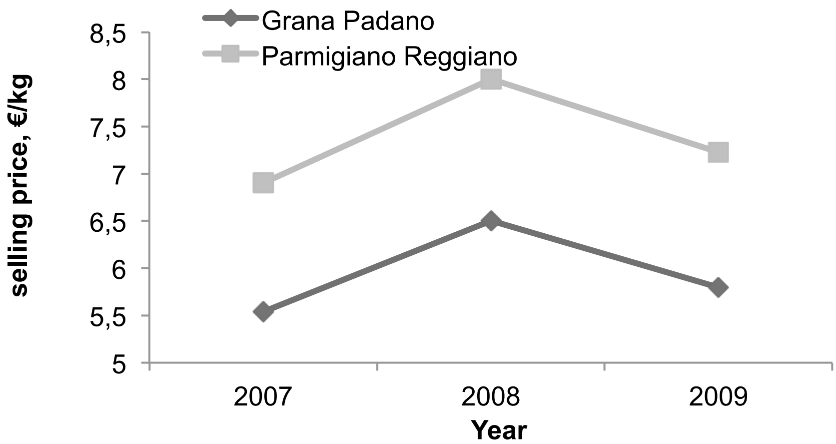
Table 9. Italian PDO cheeses ordered by registration date and region of production (MIPAF 2010; DOOR, 2010)

	Designation	Region
21/06/96	Canestrato Pugliese	Puglia
21/06/96	Fontina	Valle d'Aosta
21/06/96	Formai de Mut dell'Alta Valle Brembana	Lombardia
21/06/96	Gorgonzola	Lombardia
21/06/96	Grana Padano	Emilia Romagna, Lombardia, Piemonte, Veneto, Prov. Aut. Trento
21/06/96	Montasio	Friulii Venezia Giulia, Veneto
21/06/96	Murazzano	Piemonte
21/06/96	Pecorino Siciliano	Sicilia
21/06/96	Provolone Valpadana	Emilia Romagna, Lombardia, Veneto, Prov. Aut. Trento
21/06/96	Quartirolo Lombardo	Lombardia
21/06/96	Taleggio	Lombardia, Piemonte, Veneto
21/06/96	Valle d'Aosta Fromadzo	Valle d'Aosta
02/07/96	Bitto	Lombardia
02/07/96	Bra	Piemonte
02/07/96	Castelmagno	Piemonte
02/07/96	Fiore Sardo	Sardegna
02/07/96	Monte Veronese	Veneto
02/07/96	Pecorino Sardo	Sardegna
02/07/96	Pecorino Toscano	Lazio, Toscana, Umbria
02/07/96	Ragusano	Sicilia
02/07/96	Raschera	Piemonte
02/07/96	Robiola di Roccaverano	Piemonte
02/07/96	Toma Piemontese	Piemonte
02/07/96	Valtellina Casera	Lombardia
13/11/96	Casciotta d'Urbino	Marche
05/07/03	Caciocavallo Silano	Basilicata, Calabria, Campania, Molise, Puglia
06/09/03	Parmigiano Reggiano	Emilia Romagna, Lombardia
23/12/03	Spressa delle Giudicarie	Prov. Aut. Trento
16/02/07	Stelvio ; Stilfser	Prov. Aut. Bolzano
16/10/07	Asiago	Veneto, Prov. Aut. Trento
15/12/07	Pecorino di Filiano	Basilicata
05/02/08	Mozzarella di Bufala Campana	Campania, Lazio
03/06/08	Casatella Trevigiana	Veneto
30/10/09	Pecorino Romano	Lazio, Sardegna, Toscana
03/12/09	Formaggio di Fossa di Sogliano	Emilia Romagna, Marche
11/02/10	Provolone del Monaco	Campania
22/05/10	Piave	Veneto
29/10/10	Vastedda della valle del Belìce	Sicilia

The dairy sector positively influences the Italian food production economy, as 5 dairy products are included in the first 20 Italian PDO products for level of production and turnover (ismea, 2010). The main actors are Grana Padano and Parmigiano Reggiano, that together cover about the 70% of the Italian PDO production (Table 10).

Although in 2009 the Grana Padano production registered a slight inflection (-3.07%), its turnover increased by 4% (Figure 3, Table 10). The other famous Italian cheese, Parmigiano Reggiano, reported a slightly decrease from 2007 to 2009, while its turnover did not showed peculiar variation (Figure 5). Nevertheless, both Grana Padano and Parmigiano reggiano showed the same selling price trend, with the highest values caught by Parmigiano Reggiano (Figure 3).

Figure 3, Grana Padano and Parmigiano Reggiano selling prices, €/kg (CLAL. 2010)



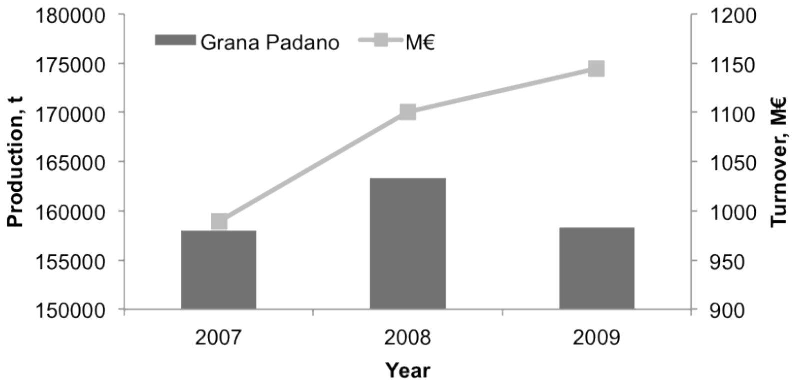
National PDO dairy production decreased in 2009 of about 7.3% compared to 2008 and the same was for turnover that decreased of a 0.6% (Table 10).

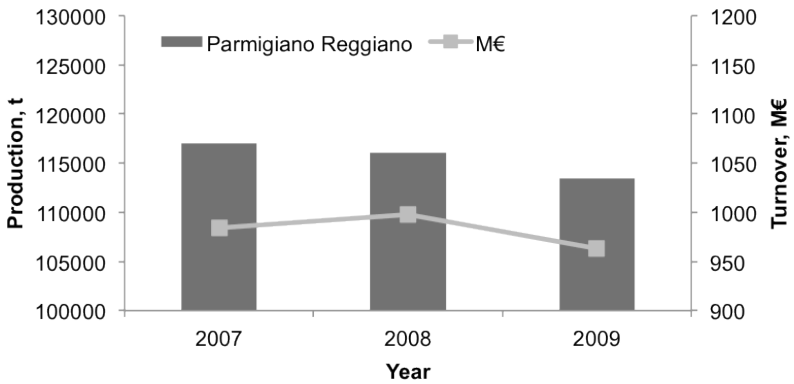
	Italian cheeses production (t)				Italian cheeses turnover (millions of €)			
	2007	***2008***	***2009***	***∆% 2008***	***2007***	***2008***	***2009***	***∆% 2008***
Grana Padano	158.017	163.341	158.326	*-3,07*	989	1,101	1,145	*3.99*
Parmigiano Reggiano	117.044	116.064	113.436	*-2,26*	984	998	963	*-3.50*
Gorgonzola	48.860	48.721	47.644	*-2,21*	347	235	262	*11.48*
Mozzarella di Bufala Campana	35.640	31.960	33.900	*6,07*	186	223	206	*-7.62*
Pecorino Romano	33.425	29.461	25.581	*-13,17*	182	172	163	*-5.23*
Total PDO production*	460.568	459.978	448.672	***-7,28***	2,963	3,107	3,088	***-0.6***

Table 10, main PDO Italian cheeses production (t) and production turnover (millions of €) from 2007 to 2009 (CLAL, 2010; ismea, 2010)

*included meat products, vegetables and fruits, olive oils, vinegars

Figure 4, yearly production and turnover of the main PDO Italian cheeses





The Italian PDO dairy sector is well appreciated also abroad. Almost the 64% of PDO export is represented by dairy products (Table 11) and in the last 3 years (2007 – 2009) dairy sector occupies the first place in the exported PDO both for exported amount and turnover (CLAL, 2010; ismea, 2010). Total export turnover for 2009 was of 832.43 millions of euros and registered an 11% of increase in comparison to the previous year (Table 11).

Table 11. Italian PDO export turnover (ismea, 2010)

Products	**2008**	**2009**	∆ % 09/08
Cheeses	745.6	832.4	11.6
Meat products	290.2	352.7	21.6
Vegetables and Fruits	48.7	57.6	18.3
Olive Oils	26.3	51.6	96.1
Vinagres	6.0	3.0	-
Total	**1,116.9**	**1,297.5**	**16.2**

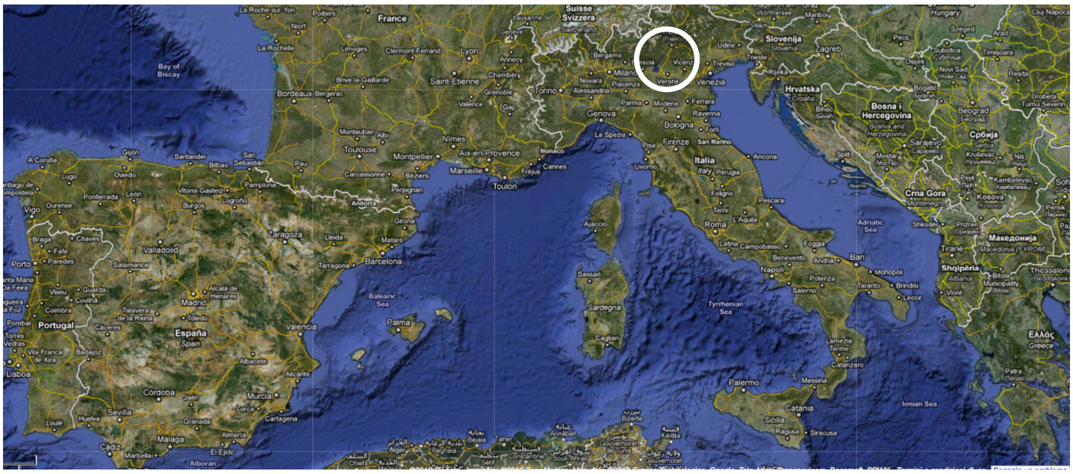
The most exported Italian PDO cheese is Grana Padano, that showed a turnover of 379 millions of Euros, followed by Parmigiano Reggiano (202 millions of Euros) for the year 2009. In comparison to 2008, exported turnover of Grana Padano increased by 26%, while much lower was the increment registered for Parmigiano Reggiano (3%).

The Trento Province

Geographic localization

The Province of Trento, also called “Trentino ” is an autonomous province of Italy and is one of the two provinces which constitute Italy’s region of Trentino-Alto Adige/Südtirol, located in the North of Italy. (Figure 5) The region borders with Austria to the north, Switzerland to the Northwest and with the Italian regions of Lombardia and Veneto to the West and South, respectively.

Figure 5, Trento Province in Europe map (Google Maps, 2010)



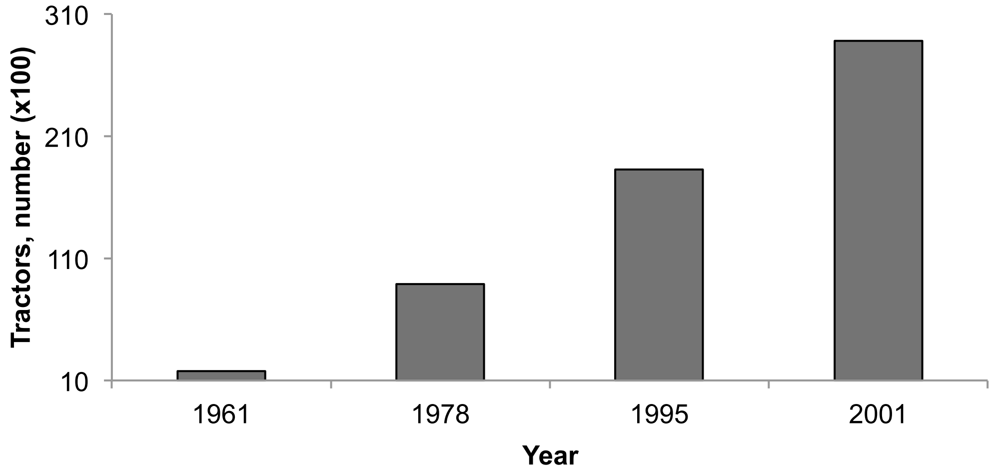
It covers 13,607 km² and is extremely mountainous, covering a large part of the Dolomites and the Southern Alps.

The province has an area of 6,207 km², most of it mountainous land (20% is over 2,000 m and 70% over 1,000 m) and covered by vast forests (50% of the territory)(statweb, 2010).

From family to business economy

In the last 40 years, Trento Province Agricolture and Dairy sector underwent deep changes: Since the 70’s, these sectors were hit by mechanization, thanks to which agricoltural products yield have notably improved.

Figure 6, number of tractors from 1961 to 2002 (Rauzi et al. 2004).



The typical Alpine management, where the whole family livelihood was based on its own agricultural products, has been substituted with a market economy, where mechanization brought to an increase in productivity and an orientation towards the specialization of the farms. The diffusion of machinery (Figure 6), brought to a strong decrease in the number of both farms and people employed in the agricultural sector: from 1951 to 2001 the number of farms decreased from 57,000 to 34,600 units, while the people employed passed from 63,464 to 8,276 units. Regarding the number of cows, in the same period they decreased from 96,700 to just 46,250 units, while average cow milk yield increased from 1,600kg/year to 6,800kg/year (Rauzi et al., 2004).

So far, the current population of 22,967 dairy cattle produce yearly about 160,000 tons of milk and about 83% of it is processed by the local dairy industry (FPA. 2009).

An Alpine Italian PDO cheese: the Trentingrana

Trentingrana is a hard long ripened cheese manufactured in the mountain area of the Province of Trento. Although this label belongs to the most popular PDO Grana Padano cheese (Salvadori Del Prato, 1994) cheese making rules of Trentingrana are more strictly. Indeed, as the Trentingrana cheese making protocol does not allow the use of silages for cows feeding and does not admit the addition of lysozyme during the milk coagulation (D.L. 20 luglio. 2006), the cheese making protocol is more similar to that used for the most famous Italian hard long ripened cheese Parmigiano Reggiano. Production technology includes milk skimming by cream surfacing of the evening milk. The day after, 500 liters of skimmed evening milk are moved into a typical conic shape vat of 1000 litres of volume and 500 liters of morning whole milk are added. The cheese making process starts with a gentle stirring, and a heating at 30°C. The milk mix is also added of the previous ‘day fermented whey (Giraffa et al., 1997; Franciosi et al., 2010) and rennet. After milk coagulation and the cutting phase, the temperature is increased at 52 – 54°C, in order to improve the curd draining. From each vat two cheese wheels of about 40 kg each are obtained and, , after 20 days of brine, they are ripened for at least 9 month in the origin dairy factory.

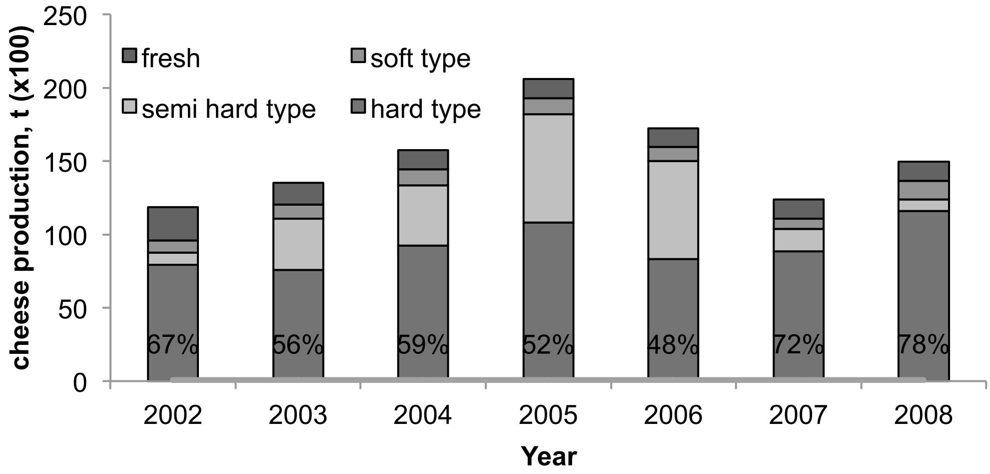
The CONCAST – Trentingrana Consortium

The presence of a wide variety of cooperative structures have always characterized the territory of the Province of Trento: due to the difficult alpine environment, farms have always been of small size and with low productions; for these reasons people tended to create cooperatives in order to obtain a better management from the scarce resources of the territory. Since XX century the "mechanization evolution" described in the previous paragraph, has been increasing the importance of these structures. Today, many cooperative structures represent the main subject moving the whole agricultural Province economy forward (Rauzi et al. 2004).

Consortium CONCAST – Trentingrana is the most important dairy cooperative structure in the province of Trento. Its history begins in 1973, when the 161 dairy factories spread among the whole territory of the Province, joined in the "Trentingrana consortium" in order to increase the selling market of Trentingrana cheese. Twenty years later Trentingrana consortium improved its competence by founding the CONCAST – TRENTINGRANA Consortium, that deals with the milk and cheese quality control.

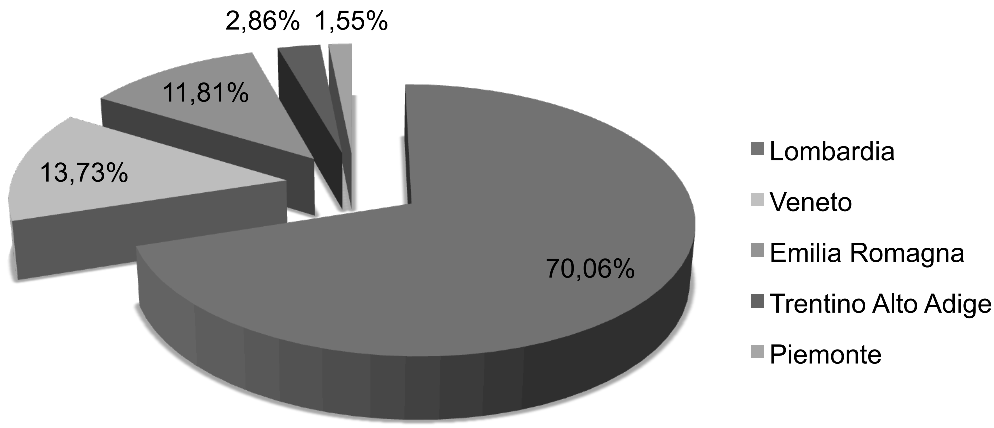
Today 90% of total bovine milk production is processed by the 18 CONCAST – TRENTINGRANA dairy factories and from 2002 to 2008, an average of 60% of cheese production in Trento province has been represented by Trentingrana cheese production (figure 7)

Figure 7. Trento Province cheese production for type of cheeses and % of Trentingrana cheese on total production; Hard type = Trentingrana cheese (istat. 2010; Concast – Trentigrana consortium data. 2010); %value = Trentingrana production on total cheeses production.



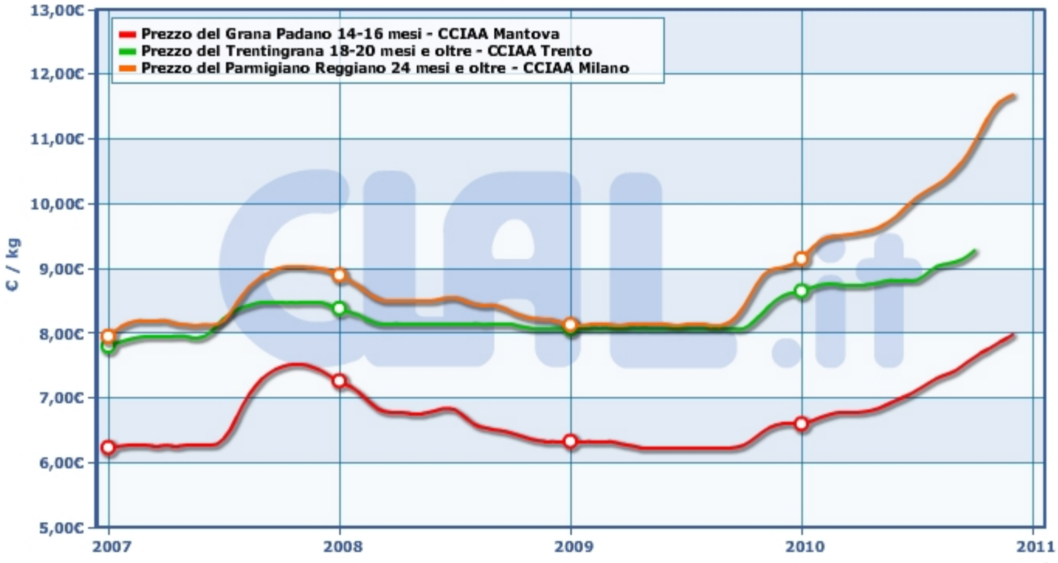
Yearly Trentingrana production, with about hundred thousand wheels, is representing only the 2.8% of the total Grana Padano cheese yearly production (Figure 8). Despite the low influence on the whole consortium production, Trentingrana cheese reported an higher selling price in comparison to that of Grana Padano one.

Figure 8. Grana Padano cheese yearly production: areas of production and % on the total production



As represented on Figure 9, Trentingrana and Parmigiano Reggiano prices are very similar and in 2010 Trentingrana price was of about 2€ higher, than Grana Padano

Figure 9. Grana Padano, Trentingrana and Parmigiano Reggiano cheeses: yearly selling prices comparison (clal, 2010)



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Chapter 2:

Sources of variation of quality traits of herd bulk milk used for Trentingrana cheese production

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ABSTRACT

The objective of this study was to investigate sources of variation of herd bulk milk destined to Trentingrana cheese production. Trentingrana cheese is an Alpine PDO production label of the most popular Grana Padano cheese, manufactured only with milk produced in the northeastern Italian Province of Trento.

A total of 93,725 herd bulk milks from 799 herds and 15 dairies were available for statistical analysis. Samples were analyzed at the central laboratory of the Consortium of Dairy Factories for the following quality traits: fat and protein contents, somatic cell count, total bacterial and clostridial counts, urea content. Based on the results of analysis carried out by the central laboratory of the Consortium, each farm receives every month a farm quality score (MFQS) that is used to calculate the monthly farm milk price. Milk quality scores and milk quality traits were analyzed using a model that included fixed effects of dairy, year and season of production, and all first-order interactions. Dairy factory effect significantly influenced all considered traits. Effect of year reported a general increase in all traits considered, with exception of SCS, which has slightly worsened from 2002 to 2008, while season effect reported the best quality of milk expressed in winter and the worst in summer. Variability of milk farm quality score was high and year effect evidenced a milk farm quality score increase of about 8.5% from first to last year considered. Indeed, further investigations are needed to account also for coagulations properties, in order to achieve a whole herd bulk milk quality traits evaluation.

Key words: *bulk milk, dairy factory, quality, payment system, Trentingrana*

INTRODUCTION

European regulations for labeled products (e.g., Protected Designation of Origin, **PDO**) are suitable tools to protect the reputation of the regional foods and eliminate the unfair competition and misleading of consumers by non-genuine products (Bertoni et al., 2001; European Commission PDO database, 2010). The label often includes the region of origin of the product to communicate environmental characteristics to the consumers; by using a geographical indication, marketers are able to exploit existing positive ideas that consumers have about the specific area of production (Van Ittersum et al., 2007). This type of recognition is a consequence of an EU agricultural policy that encourages the diversification and characterization of products to achieve better market equilibrium, reducing surplus, and sometimes stimulating an extensive agricultural production system. The purpose is to link the environmental protection and the reduction of sociological problems with the heritage and cultural diversity of traditional agricultural products (Bertoni et al., 2001). Moreover, the achievement of the PDO label represents an opportunity to reach a premium price for the product (Bouamra-Mechemache et al., 2010), particularly in disadvantageous areas such as the Alps where the relationship between local economy and environment preservation is strong.

An example of Alpine PDO product is Trentingrana (TG), a hard type cheese manufactured in Trento province (northeastern Italian Alps). Trentingrana is a cooked, long time ripened cheese produced with unheated and partially skimmed raw milk from cows milked twice a day. Even if TG belongs to the most popular Grana Padano Consortium (Salvadori Del Prato, 1994), production rules are more restrictive and the cheese making protocol is more similar to Parmigiano Reggiano cheese. In particular, the use of silages to feed cows is forbidden because of late blowing of wheels (Cocolin et al., 2004). The use of lisozyme is also forbidden.

Traditionally, milk destined to TG is manufactured in several dairy factories located in the province of Trento, and is produced by small farms mainly rearing dairy and dual-purpose cattle breeds. These farms are spread across several valleys, each having specific environmental features, and characterized by medium to low levels of production and appreciable technological properties of milk (De Marchi et al., 2007). However, the farming system within the province is gradually changing towards larger and more intensive herds; this process is closely related to the increased number of high-producing Holstein-Friesian cows, along with the improvement of managerial conditions and the introduction of technological innovations within the dairy herd.

As a consequence of all these peculiarities, several factors may have an influence on the quality of milk destined to TG cheese. In the last years, an increasing incidence of discarded wheels and worsening of sensory aspects of TG production have been observed (Bittante et al., unpublished data). Possible factors affecting the quality may be found at farm, dairy factory, and ripening store level. The objective of this study was to investigate sources of variation of herd bulk milk destined to TG production. This is the first step of a wider research (Trentingrana project) aiming at monitoring the whole TG chain production.

MATERIALS AND METHODS

Data and editing procedure

A total of 130,286 herd bulk milk samples were collected twice per month by 18 dairies from 2002 to 2008 and analyzed at the central laboratory of the Consortium of Dairy Factories (Spini di Gardolo, Trento) for several quality aspects: fat and protein contents, somatic cell count (**SCC**), total bacterial and clostridial counts, and urea. All traits, except for urea, are included in the milk quality payment system adopted by dairy factories to pay farmers. Each farm receives every month a quality score (MFQS), based on the results of analysis carried out by the central laboratory of the Consortium. MFQS is then used to calculate the monthly farm milk price, on the basis of fixed monetary coefficients that vary among dairy factories.

Milk yield per milking (**MY**) was also available for each herd. Approximately 90% of milk delivered to dairy factories is used to produce TG. During the summer, short ripened products are profitable because the demand achieves the highest peak, because in some valleys there is a high presence of tourists. Also, some farms use alpine pastures in summer and the Consortium regulation does not allow the use of this milk for manufacturing TG. Therefore, dairy factories with interruptions of TG production during the year were discarded from the dataset. After editing, a total of 93,725 herd bulk milks from 799 herds and 15 dairies were available for statistical analysis. To achieve normality and homogeneity of variances, values of SCC were log-transformed to somatic cell score (**SCS**) as [$SCS = \log_2(SCC/100{,}000) + 3$] following Ali and Shook (1980), and total bacterial and clostridial counts were transformed to log bacterial count (**LBC**) and log clostridial count (**LCC**), respectively, by means of base-10 logarithm.

Statistical analysis

$$y_{ijklm} = \mu + D_i + Y_j + M_k + H_l(D_i) + (D \times Y)_{ij} + (D \times M)_{ik} + (Y \times M)_{jk} + \varepsilon_{ijklm},$$

where y_{ijklm} is observation *ijklm* for MY, fat content, protein content, SCS, LBC, LCC, urea or MFQS; μ is the overall intercept of the model; D_i is the fixed effect of the *i*th dairy factory (i = 1 to 15); Y_j is the fixed effect of the *j*th year of production (j = 2002 to 2008); M_k is the fixed effect of the *k*th month of production (k = January to December); $H_l(D)_i$ is the fixed effect of the *l*th herd nested within the *i*th dairy factory; $(D \times Y)_{ij}$, $(D \times M)_{ik}$, and $(Y \times M)_{jk}$ are first order interactions between the main effects; ε_{ijklm} is the random residual associated with observation *ijklm*.

RESULTS AND DISCUSSION

Descriptive statistics of production traits are shown in Table 1. The average values of milk quality traits are comparable to those previously reported by De Marchi et al. (2007, 2008). Milk yield delivered to dairy factories by each herd averaged 161 kg per milking and showed a large variation (CV = 119%).

Both bacterial and somatic cell content of milk processed to TG do not exceed the legal limit of 100,000 UFC/mL and 400,000 somatic cells/mL (Council Directive 92/46/EEC, 1992), while MFQS reported the lowest CV value among the studied variables.

Table 1. Descriptive statistics of milk yield and quality traits

Trait[1]	n	Mean	CV, %	Minimum	Maximum
MY, kg/herd/milking	93,725	161	119	20	2,087
Fat, %	93,047	3.88	8.4	2.87	4.91
Protein, %	93,349	3.39	6.0	2.77	4.01
SCS, units	93,318	3.96	27.7	0.60	7.30
LBC, units	93,322	4.86	11.8	4.00	6.62
LCC, units	90,785	2.03	5.4	2.00	2.89
Urea, mg/100 mL	93,069	27.4	23.8	8.0	47.0
MFQS	93,725	4.5	5.08	-44	35

[1]MY, milk yield; LBC, $\log_{10}$ of total bacterial count; LCC, $\log_{10}$ of clostridial count; MFQS, monthly farm quality score

Results from the ANOVA are summarized in Table 2. The coefficients of determination ranged from 0.04 (LCC) to 0.91 (MY), and all the effects included in the model significantly explained the variability of the 8 traits (*P* < *0.001*).

Table 2. Results from ANOVA (*F*-values)[1] for milk yield and quality traits.

		Trait[2]							
Effect[3]	df	MY	Fat	Protein	Urea	SCS	LBC	LCC	MFQS
Dairy factory	14	13.6	19.9	6.71	7.45	7.47	5.33	3.78	11.4
Year of production	6	195	76.3	150	842	24.2	186	85.7	168
Month of production	11	513	392	311	150	100	241	5.38	425
Herd(dairy factory)	784	855	55.3	78.4	50.4	66.4	109	1.83	65.2
D x Y	84	48.0	5.56	11.3	8.08	5.75	21	2.40	8.28
D x M	154	28.6	17.8	24.7	5.05	4.32	5.52	1.92	15.4
Y x M	66	3.01	18.0	15.4	164	2.67	10.1	7.48	14.3
R^2		0.91	0.45	0.47	0.43	0.42	0.54	0.04	0.45
RMSE		58.4	0.24	0.15	4.96	0.84	0.39	0.11	7.41

[1]Effects were highly significant for all traits (*P* < 0.001).
[2]MY, milk yield; LBC, $\log_{10}$ of total bacterial count; LCC, $\log_{10}$ of clostridial count.
MFQS, Monthly farm quality score.
[3]D x P, is the interaction effect between dairy factory and year of production; D x M, is the interaction effect between dairy factory and month of production; Y x M, is the interaction effect between year and month of production.
RMSE, root mean square error.

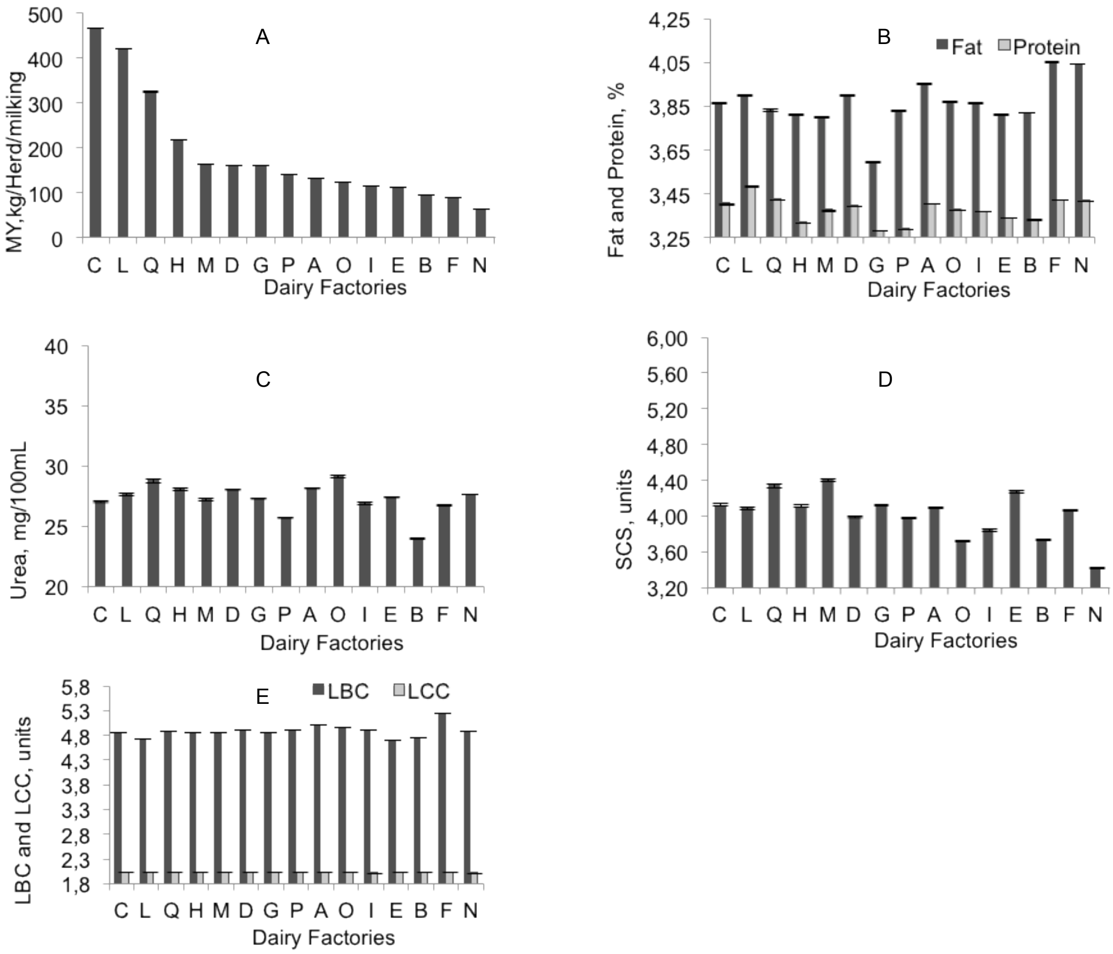
Pearson's correlations of MFQS with other traits were estimated using the CORR procedure of SAS (2008). The MFQS was positively and significantly (*P* < *0.001*) correlated with MY (0.06), fat content (0.58), and protein content (0.74), whereas it was negatively and significantly ($P < 0.001$) correlated with SCS (-0.29), LCC (-0.12), and LBC (-0.32).

Effect of dairy factory

Cooperative dairies are located in different valleys of Trento province, and differ largely in terms of number of associated herds, cattle breeds, level of production, and amount of milk processed daily. Also, farmers deliver milk in 50-L cans (not refrigerated) or tanks (refrigerated or not), and this has an impact on the microbial growth in milk destined to TG (Franciosi et al., 2009).

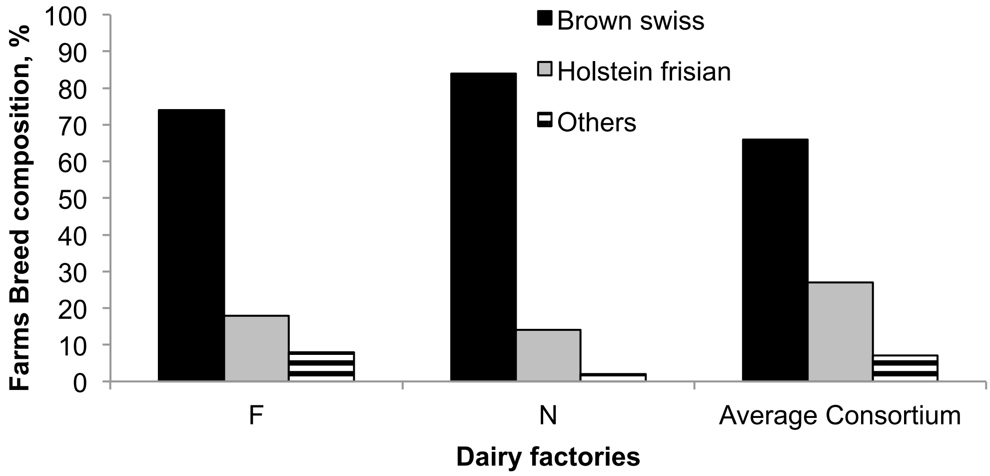
Least squares means of dairy factory effect for MY and quality traits are reported in Figure 1. The first 3 dairies (C, L, and Q) are characterized by associated herds which produce much higher MY than others. Certain variability among dairy factories was found also for fat and protein contents. For example dairies F and N showed the highest fat content among all considered dairies (Figure 2).This could be explained by the fact that farms supplying for dairies F and N, are characterized to rear more Brown Swiss in comparison to the average consortium values (Figure 2)

Figure 1. Least squares means (with SE) of dairy factory effect for milk yield and quality traits. Dairy factories are ordered according to milk yield per milking delivered by farms.



It is well know that local breeds produce milk with higher fat content (Schutz M. M., 1990; De Marchi, 2007; De Marchi, 2008). Regarding the sanitary traits (SCS and bacterial counts) variability among dairies was not observed (Figure 1).

Figure 2. Dairy F and N farms breed composition (%) compare to the average Consortium farm breed composition (%). Average Consortium= General LSM values of Trentingrana consortium reared breeds.



Effect of year of production

Year of production significantly explained the variability of the investigated traits (*P < 0.001*). The average amount of milk delivered by associated farms increased by 12.4% from 2002 to 2008 (Table 4). In the last years, the number of Holstein-Friesian cows is increasing in the province of Trento; this can be acknowledged as the main contributor to the increase of MY. For quality traits, changes over years were not so appreciable as for MY.

SCS was the only milk payment trait subjected to a slight worsening during the studied period. It is commonly recognized that SCS milk content is correlated with the presence of mastitis infection in the cow's udders (Kitchen, 1981; Munro et al., 1984). The main enzyme associated with high milk SCS is plasmin, a proteolytic and heat – stable enzyme (Barbano, 2006). Therefore, high level of plasmin concentration in milk has a negative influence on cheese making, as it affects both final curd firmness and consistency (Bastian and Brown, 1996; Fantuz et al., 2001; Albenzio et al., 2004;). Nevertheless, plasmin represents the dominant and most common indigenous milk proteinase, and its contribute is essential for the primary proteolysis during the ripening period of several cheeses such as Emmental (Gagnaire et al., 2001), Cheddar, Blue cheese, Parmigiano Reggiano and Feta (Sousa et al., 2001).

Except for lbc trait, Pearson's correlations between year effect and milk quality traits were not significant; however, MFQS trend (Figure 3) reflects the same evolution reported for fat and protein (Table 4). As for those traits, MFQS have achieved the highest value in 2007 and then slightly decreased in 2008.

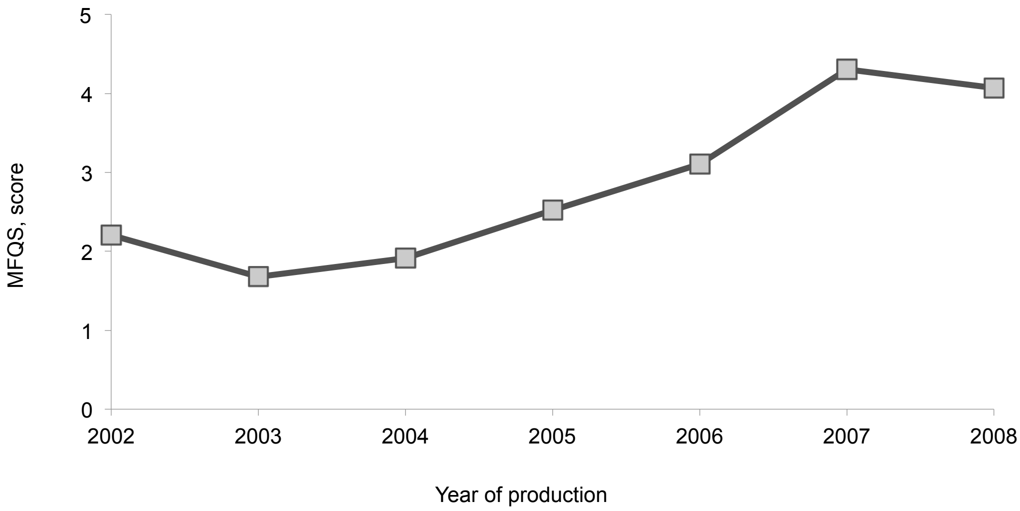
Table 4. Least squares means[1] of year of production effect for milk yield and quality traits.

	Year of production						
Trait[2]	2002	2003	2004	2005	2006	2007	2008
MY, kg/herd/milking	170	177	189	186	191	193	191
Fat, %	3.82	3.84	3.87	3.88	3.87	3.89	3.87
Protein, %	3.37	3.35	3.36	3.36	3.38	3.40	3.40
Urea, mg/100mL	27.1	29.8	26.1	26.2	27.2	26.2	28.7
SCS, units	3.95	4.05	4.04	4.06	4.05	3.98	4.01
LBC, units	4.94	4.93	4.94	4.91	4.86	4.80	4.82
LCC, units	2.05	2.03	2.03	2.02	2.03	2.02	2.02

[1]Standard errors for MY ranged from 0.58 to 0.65, for fat ranged from 0.0024 to 0.0027, for protein ranged from 0.0015 to 0.0017, for urea ranged from 0.0498 to 0.0560, for SCS ranged from 0.0084 to 0.0094, for LBC ranged from 0.0039 to 0.0044, for LCC ranged from 0.0011 to 0.0012.

[2]MY, milk yield; LBC, $\log_{10}$ of total bacterial count; LCC, $\log_{10}$ of clostridial count.

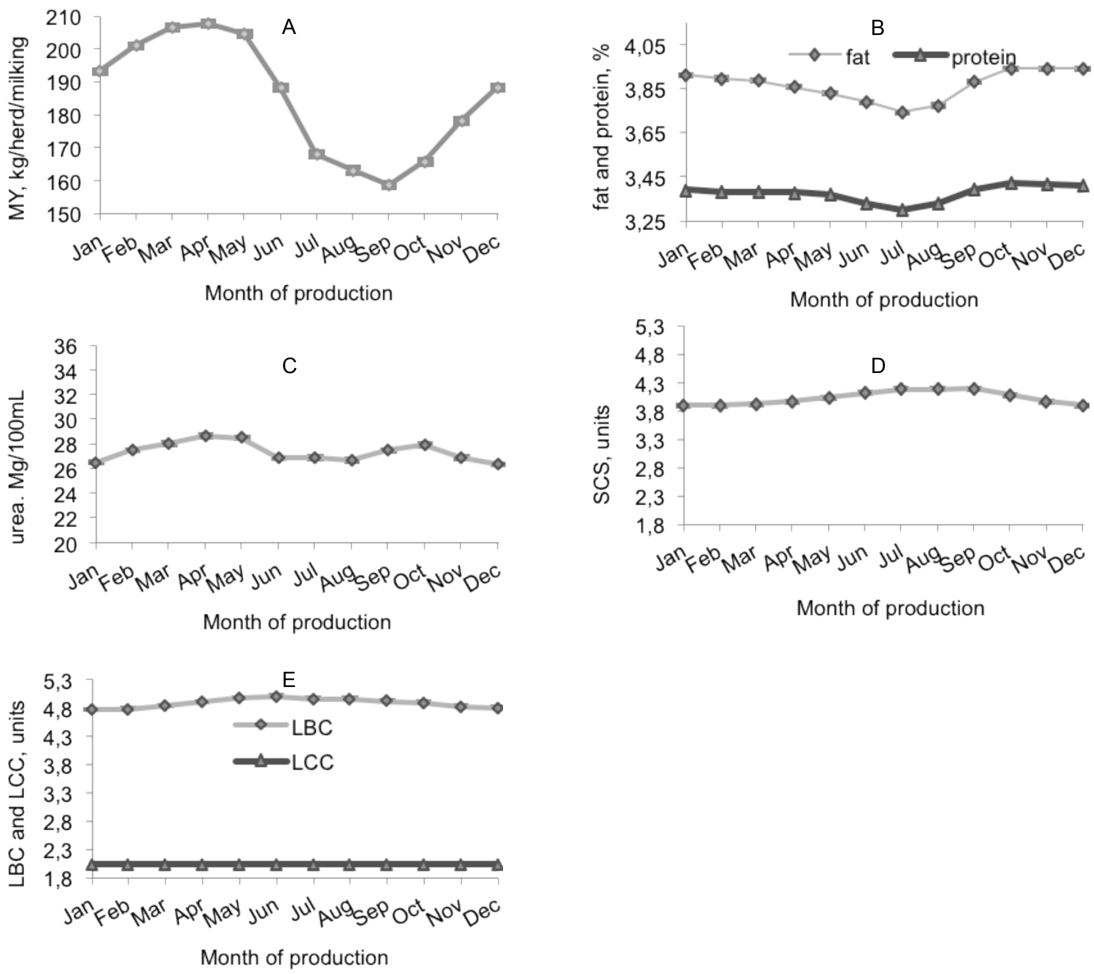
Figure 3. Least squares means of MFQS for milk quality payment.



Effect of month of production

Month of production was significant for all milk attributes considered (P<0.001). Figure 4 reports least squares means of month of production for the studied traits.

Figure 4. Least squares means (with SE) of month of production effect for milk yield and milk quality traits.



Milk yield shows a clear circannual trend, with the highest amount delivered to dairies in winter and spring, and the worst in summer and autumn (Figure 4A). Fat, protein, SCS, and urea showed similar trends, even if much less pronounced (Figure 4B, C, D); these results are consistent with those by Malacarne et al. (2005) on milk used for Parmigiano Reggiano cheese production.

Changes of the diet, climatic factors, and relatively high concentrations of calvings in the last months of the year could explain the seasonal trend for MY. Urea content shows a decrease during the summer period (Figure 4C). Even if the majority of studies in literature suggested different assumptions for the seasonal variation of this trait (Wattiaux, 2005; Oudah, 2009) our results are consistent with those reported by Arunvipas et al. (2004). The decreasing content during summer period could be explain by the fact that TG production guidelines do not allow the practice of summer pasture for lactating cows. So far, urea content is not used in milk payment systems of milk. Nevertheless, Martin et al. (1997) discovered that this trait directly influences acidification kinetics, chemical composition and texture characteristics of matured cheeses. Therefore urea content could be suggested to be included as an additional milk quality payment trait.

CONCLUSIONS

Milk yield and quality aspects of herd bulk milk used to produce TG cheese were significantly influenced by all the effects included in the analysis. Notable differences among dairy factories were detected, particularly for MY. The year of production has a strong influence on MY and much less on quality traits. The month of production exerted a significant influence on MY and a clear circannual variation was found, whereas the influence on quality traits was less marked. The MFQS showed high variability and was significantly affected by all the explanatory variables. Future studies will focus account on milk coagulation properties to achieve a whole herd bulk milk quality traits evaluation.

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Chapter 3:

Factors affecting the incidence of first quality wheels of Trentingrana cheese

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ABSTRACT

Trentingrana (or Grana Trentino) is a Protected Designation of Origin hard cheese produced in the eastern Italian Alps by small cooperative dairies. To obtain the certification of quality, wheels are evaluated at 9 months of ripening and those classified as first quality are revaluated at 18 months, i.e., the end of ripening. Traditionally, the classification is based on some sensory features: the external aspect of the wheel, the internal texture through the sound produced by beating the wheel with a special hammer, and the flavor evaluated sniffing a needle previously inserted in the wheel. Traits considered were the percentage of first quality wheels on total wheels examined at 9 (QW_{9mo}) and 18 (QW_{18mo}) months of ripening, and their combination, i.e., the percentage of first quality wheels at 18 months of ripening on the number of wheels evaluated at 9 months (QW_{TOT}). A total of 557,088 cheese wheels were examined. The experimental unit was the batch of 2 months of production of each of 10 cooperative dairies from 2002 to 2008. Data were analyzed with a model that included fixed effects of dairy, year and season of production, and interactions between dairy and year and dairy and season. The coefficients of determination of the model were 0.57, 0.68, and 0.67 for QW_{9mo}, QW_{18mo}, and QW_{TOT}, respectively. All factors significantly ($P < 0.05$) influenced the traits, with dairy being the most important source of variation, followed by season and year of production. Notable differences were found between the best and the worst dairy for QW_{9mo} (11.5%), QW_{18mo} (21.1%), and QW_{TOT} (25.6%). The first 4 years of production had a relevant and negative impact on the percentage of wheels chosen as first quality; in particular, QW_{TOT} significantly decreased from 2002 to 2005 (-9.4%). Nevertheless, the situation changed after 2005 when a complete recovery was detected. Interaction between dairy and years were highly significant. The season of production influenced the studied traits with the best results in spring and

summer, and the worst in autumn and winter. Finally, the interaction between dairy and season, even though significant, was less relevant. Compared to average values, the 3 best dairies were smaller, with smaller associated farms, and showed less variation due to year and season of production. Reasons for these important effects should be further investigated to achieve better qualification of Trentingrana cheese.

INTRODUCTION

Since 1992, European Union (European Union Council Regulation No 2081/92. 1992) defined the Protected Geographical Status (**PDO**: Protected Designation of Origin; **PGI**: Protected Geographical Indication; **TSG**: Traditional Speciality Guaranteed) as the framework, defined by the law, to protect the reputation of regional foods, eliminating unfair competition and misleading of consumers by non genuine products which may be inferior in quality or with different sensory characteristics (Moio and Addeo, 1998). Typical cheeses represent a large proportion of PDO products, particularly in countries such as Italy, France and Spain. To obtain the PDO status, a product must be entirely manufactured within the specific region, according to traditional specified techniques, and thus acquire unique properties, that should be evaluated and monitored (Bertoni et al., 2001; Boscaini et al., 2003). As the processing techniques of PDO products are strictly regulated by the European Union Council Regulation No 2081/92 (1992), there is a limited possibility to adapt them to the characteristics of the unprocessed food and to correct its possible abnormalities. The final evaluation and approval of processed food is therefore crucial and strictly regulated (Elortondo et al., 1999, 2007), especially in the case of hard cheeses (Galgano et al., 2001; Masotti et al., 2010). Protected Designation of Origin regulations lead to an increase of production costs, but they are an opportunity to achieve relevant economic rewards from the market (Bouamra-Mechemache and Chaaban, 2010).

The Trentingrana hard cheese (known also as Grana Trentino) is a geographic specification of the most popular PDO Grana Padano (Salvadori Del Prato, 1994). It is manufactured in the mountain area of the Province of Trento (Italy), eastern Italian Alps. Typically, milk to produce Trentingrana is obtained from small farms (less than 30 cows) rearing dairy or dual purpose breeds (Brown Swiss, Simmental, Rendena, Alpine Grey) characterized, in comparison to Holstein Frisian, by lower milk production, higher fat and protein contents and better coagulation properties, as reported by De Marchi et al., 2007. In the last years, an increasing number of larger and more intensive farms, mainly rearing Holstein Friesian cows, supply milk to produce Trentingrana. Milk from Holstein Friesian is characterized also by a lower cheese yield than Brown Swiss, even after taking into account the fat and protein contents (De Marchi et al., 2008).

Trentingrana is produced by small cooperative dairy factories, which generally collect milk from associated farms twice a day. The cheese is manufactured using partly raw milk according to an approved procedure (D.L. 20 luglio. 2006; similar to Parmigiano Reggiano cheese: in particular, silages are not allowed to feed cows and additives, beyond rennet, are forbidden in cheese making. Moreover only a natural starter culture obtained from the spontaneous fermentation of part of the previous day's whey, can be added (Franciosi et al., 2010). A limited number of studies investigated the effect of dairy factory on the quality of hard cheeses; nevertheless, Bellesia et al. (2003) evidenced large variability among dairies for volatile components of Parmigiano Reggiano cheese, and Careri et al. (1996) reported a much lower variability on the same type of cheese in relation to chemical parameters and non-volatile fractions.

The Trentingrana cheese wheels are classified according to some sensory features and their evaluation is used in the dairy payment system.

Information on the quality classification of hard PDO cheeses wheels is unavailable in scientific literature. Therefore, the objective of this study was to investigate the sources of variation of quality classification of the Trentingrana cheese.

MATERIALS AND METHODS

Field Data

Data of Trentingrana wheels were obtained by the ripening store of the Consortium of Dairy Factories operating in the province of Trento. Dairy factories involved in the study processed almost all the amount of milk collected from the associated farms (88%) to obtain Trentingrana cheese, while only a small part of milk was destined to other products.

The procedure of quality evaluation had two crucial steps of selection: the first was carried out in the dairy factories at 9±a months of ripening and the second in the ripening store of the Consortium at 18±1 months of age. During these 2 steps, all wheels were individually checked and classified by official inspectors who evaluated the external aspect of the wheel (color, integrity, presence of moulds, swellings), the internal texture through the sound produced by beating the wheel with a special hammer to recognize inner holes or imperfections, and the flavor evaluated sniffing the inner mass flavor after the insertion of a specific long needle in the wheel. Each wheel was classified as “first quality”, “second quality” or “discarded”. Only wheels classified as “first quality” at 9±1 months of ripening received the Trentingrana denomination and were admitted to the final evaluation at 18±1 months of age.

Because the quality evaluation took place every 2 months, the experimental unit of this study was the batch of 2 months of production of each of 10 cooperative dairies from 2002 to 2008. Hence, the number of expected experimental units was 420 (10 dairies x 7 years x 6 two-months periods), with a total of 557,088 cheese wheels evaluated. However, because some dairies did not consistently produced Trentingrana over all years or decided to sell the product before the end of the ripening period, the number of final experimental units available for statistical analysis was less (n = 386).

Traits considered were the percentage of first quality wheels on total wheels examined at 9±1 months (**QW_{9mo}**) and 18±1 months (**QW_{18mo}**) of ripening, and their combination, i.e., the percentage of first quality wheels at 18±1 months of ripening on the number of wheels evaluated at 9±1 months (**QW_{TOT}**). The last trait reflects the technological and economical efficiency of Trentingrana cheese production chain. Moreover, information on the number of associated farms, the amount of milk processed daily to obtain cheese, and the number of wheels produced in a 2 months period were available, as well as the amount of milk per milking supplied by each farm to the dairy.

Statistical analysis

An ANOVA was performed on studied traits with the GLM procedure (SAS Inst. Inc., Cary, NC) using the following linear model:

$$y_{ijkl} = m + DF_i + YP_j + SP_k + (DF \times YP)_{ij} + (DF \times SP)_{ik} + e_{ijkl},$$

where y_{ijkl} is the dependent variable; m is the overall intercept; DF_i is the fixed effect of the *i*th dairy factory (*i* = 1 to 10); YP_j is the fixed effect of the *j*th year of production (*j* = 2002 to 2008); SP_k is the fixed effect of the *k*th season of production (*k* = 1 to 6); $(DF \times YP)_{ij}$ is the fixed interaction effect between dairy factory and year of production; $(DF \times SP)_{ik}$ is the fixed interaction effect between dairy factory and season of production; and e_{ijkl} is the random residual $N \sim (0, \sigma^2_e)$. The season effect was classified into six bi-monthly classes (January and February, March and April, May and June, July and August, September and October, November and December). The level of significance was set to $P < 0.05$.

RESULTS AND DISCUSSION

Production traits

Descriptive statistics of production traits are reported in Table 1. Dairy factories were of moderate to small size; the amount of milk processed daily to obtain cheese, the number of wheels produced in a 2 months period, and the number of associated herds averaged 12.6 ton, 1,374 and 38, respectively. Associated herds were generally small and supplied only 225 kg of milk per milking, reflecting the typical dairy production of the Alps. All traits showed a medium to high variability and the coefficient of variation ranged from 39% for the amount of milk processed daily to obtain cheese to 67% for the amount of milk per milking supplied to the dairy. Medians suggest that traits are normally distributed, except for the amount of milk per milking supplied by each farm to the dairy and the number of wheels produced in a 2 months period which are slightly right-skewed. However, skewness and kurtosis for these 2 traits were relatively low (1.15 and 0.10, and 0.92 and 0.53, respectively; data not shown).

Table 1. Descriptive statistics of production traits and first quality wheels of Trentingrana cheese

	Mean	**Median**	**SD**	**Minimum**	**Maximum**
Production traits					
Herds, n/dairy	38	39	22	8	81
Milk, kg/herd/milking	225	166	150	55	639
Milk, ton/dairy/d	12.6	12.3	4.9	1.8	28.8
Wheels, n/dairy/2-mo	1,374	1,219	610	165	3,472
First quality wheels, %[2]					
QW_{9mo}	84.8	86.4	9.8	31.1	100
QW_{18mo}	80.1	82.4	13.4	22.9	100
QW_{TOT}	68.9	70.7	16.4	7.1	96.7

[1]The experimental unit is the batch of 2-mo of production of each of 10 cooperative dairies from 2002 to 2008.

2QW9mo is the percentage of first quality wheels on total wheels examined at 9±1 mo of ripening, QW18mo is the percentage of first quality wheels on total wheels examined at 18±1 mo of ripening, and QWTOT is the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening.

Production traits were significantly influenced by all factors included in the model ($P < 0.001$; Table 2). In particular, dairy factory was the most important source of variation, followed by season and year of production. Coefficients of determination were higher than 0.97, indicating that effects included in the model were capable of accounting for almost the entire variation of the traits; also, root mean square errors were lower than 10% of the mean.

Table 2. Results from ANOVA (F-value and significance) for production traits and first quality wheels of Trentingrana cheese[1]

	Dairy	**Year**	**Season**	**DF x YP**	**DF x SP**	**RMSE**	**R^2**
df	9	6	5	54	45	266	
Production traits							
Herds, n/dairy	6,348***	101***	528***	9.5***	129***	1.6	0.996
Milk, kg/herd/milking	3,956***	161***	31.3***	24.9***	5.4***	14.8	0.993
Milk, ton/dairy/d	1,308***	23.2***	365***	12.0***	52.8***	0.7	0.985
Wheels, n/dairy/2-mo	935***	11.1***	153***	6.6***	24.8***	114	0.976
First quality wheels, %[2]							
QW_{9mo}	6.9***	5.7***	5.8***	2.4***	1.5*	7.7	0.567
QW_{18mo}	21.0***	4.3***	9.1***	3.3***	1.8**	9.2	0.679
QW_{TOT}	18.5***	5.3***	8.3***	3.1***	1.6*	11.4	0.666

[1]The experimental unit is the batch of 2-mo of production of each of 10 cooperative dairies from 2002 to 2008.

[2]QW_{9mo} is the percentage of first quality wheels on total wheels examined at 9±1 mo of ripening, QW_{18mo} is the percentage of first quality wheels on total wheels examined at 18±1 mo of ripening, and QW_{TOT} is the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening.

DF x YP, is the interaction effect between dairy factory and year of production; DF x SP, is the interaction effect between dairy factory and season of production; RMSE, is the root mean square error.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

The number of farms conferring milk to dairies decreased during the studied period (data not shown) and was affected by a strong seasonal effect (Table 2); several herds use alpine pastures during the summer season (June to September) and milk obtained during this period is destined to products other than Trentingrana cheese. The amount of milk per milking collected from the associated herds was strongly affected by year of production (Table 2); in particular, an increase was observed over the years (data not shown, P<0.0001) confirming the process of production intensification. The amount of milk processed daily as well as the number of wheels produced in 2 months, were strongly affected by season of production (Table 2). As mentioned above, the main reason for this effect is the practice of using alpine pasture during the summer.

Least squares means of production traits across dairy factories are reported in Table 3. The number of associated herds largely differed among dairies as well as the amount of milk per milking supplied by each farm, the amount of milk processed daily to obtain cheese, and the number of wheels produced in a 2 months period.

Table 3. Least squares means (±SE) of production traits across dairy factories

Dairy	Herds, n/dairy	Milk, kg/herd/milking	Milk, ton/dairy/d	Wheels, n/dairy/2-mo
a	40 ± 0.28	133 ± 2.5	10.5 ± 0.12	590 ± 19
b	24 ± 0.26	176 ± 2.4	8.1 ± 0.12	925 ± 18
c	33 ± 0.50	201 ± 4.6	13.1 ± 0.23	897 ± 35
d	49 ± 0.26	99 ± 2.3	9.7 ± 0.11	1,071 ± 18
e	18 ± 0.26	448 ± 2.3	15.8 ± 0.11	2,169 ± 18
f	14 ± 0.26	516 ± 2.4	14.8 ± 0.12	1,394 ± 18
g	50 ± 0.26	146 ± 2.3	14.6 ± 0.11	1,785 ± 18
h	63 ± 0.26	172 ± 2.3	21.3 ± 0.11	2,283 ± 18
i	72 ± 0.26	68 ± 2.3	9.8 ± 0.11	1,163 ± 18
l	15 ± 0.26	265 ± 2.3	8.0 ± 0.11	987 ± 18

The dairy factory with the smallest number of associated herds accounted for only 14 farms, but each herd supplied 516 kg of milk per milking. On the other hand, the dairy factory with the highest number of associated herds accounted for 72 farms, but each herd supplied only 68 kg of milk per milking. The amount of milk processed daily ranged from 8.0 to 21.3 ton, and the number of wheels produced in 2 months varied from 590 to 2,283.

First quality wheels

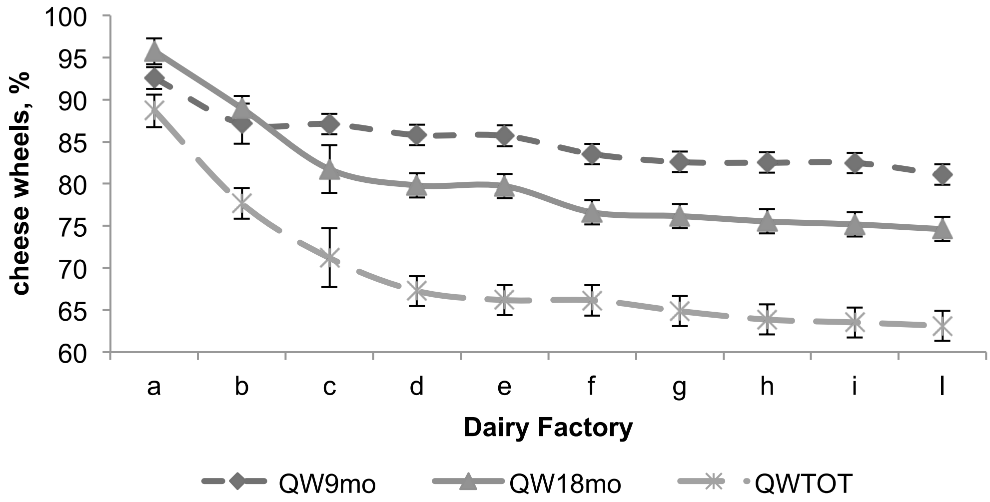
Descriptive statistics of wheels of Trentingrana cheese selected as first quality are shown in Table 1; QW_{9mo}, QW_{18mo}, and QW_{TOT} averaged 84.8, 80.1, and 68.9%, respectively. The variability of these traits was huge, particularly for QW_{TOT} which ranged from 7.1 to 96.7% and showed a higher coefficient of variation (24%) compared to QW_{18mo} (17%) and QW_{9mo} (12%).

Quality classification traits also were significantly influenced by factors included in the model ($P < 0.05$; Table 2). In particular, dairy was the most relevant source of variation, followed by season and year of production, and the interactions between dairy and year and dairy and season. Coefficients of determination showed that these effects explained a larger variation for QW_{18mo} (0.68) and QW_{TOT} (0.67) than QW_{9mo} (0.57).

Least squares means of studied traits across dairy factories are shown in Figure 1. Dairies were ordered according to decreasing estimates of QW_{TOT} and similar trends were found for the other two traits. The correlation between LSM of QW_{9mo} and QW_{18mo} was positive and high (81%), as well as between QW_{TOT} and QW_{9mo} (90%), and QW_{TOT} and QW_{18mo} (98%; data not shown). These last two correlations were expected as QW_{9mo} and QW_{18mo} are components of QW_{TOT}. The difference between the best and the worst dairy was 11.5, 21.1, and 25.6% for QW_{9mo}, QW_{18mo}, and QW_{TOT}, respectively, i.e., it has increased during the ripening period. As reported in Table 1, about one third of the wheels was not selected as first quality. Nevertheless, 3 dairy factories (a, b and c) performed much better than the others, particularly for QW_{TOT} (Figure 1), and among them the best one showed a very high percentage of QW_{TOT}. The 3 dairies had some common characteristics:

they produced a lower number of wheels of Trentingrana cheese than the mean and their associated farms produced less milk than the overall mean (Table 3), i.e., they are small cooperative dairies with small associated farms.

Figure 1. Least squares means of first quality wheels of Trentingrana cheese across years of production (QW_{9mo} is the percentage of first quality wheels on total wheels examined at 9±1 mo of ripening, QW_{18mo} is the percentage of first quality wheels on total wheels examined at 18±1 mo of ripening, and $QW_{TOT}$is the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening).(Standard errors of estimates ranged from 1.2 to 3.5.

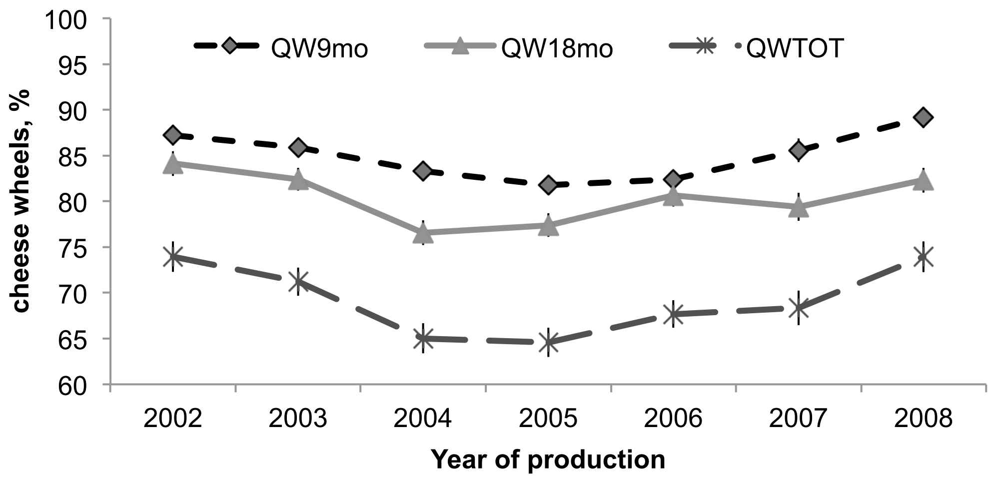


On the other hand, they are located in different valleys of the Province of Trento, characterized by heterogeneous environmental conditions and proportions of breeds. The dairy with the best QW_{TOT} (a) is located 638 m above sea level and collects milk from 40 associated farms mainly rearing Brown Swiss cows. The second is located 831 and the third 204 m above sea level and collect milk from a low number of associated herds rearing 50% Brown Swiss cows and 50% other breeds (mainly Holstein Friesian).

Rennet coagulation time and curd firmness of milk are important for cheese making and the quality of the final product (Martin et al., 1997; Ng-Kwai-Hang et al., 1989; Johnson et al., 2001). They are influenced by casein genotypes (Davoli et al., 1990; Comin et al., 2007; Penasa et al., 2010) and breed of cows, which can explain part of the variability among dairies in the current study. During the same period, a tendency for worsening of average coagulation properties of milk destined to Trentingrana cheese has been discovered (N. Cologna, personal communication). However, several studies reported that a genetic basis for coagulation ability of milk exists (Ikonen et al., 1999; Comin et al., 2005; Cassandro et al., 2008; Vallas et al., 2010) and the genetic improvement is possible (Dal Zotto et al., 2008; De Marchi et al., 2009; Cecchinato et al., 2009).

Least squares means of first quality wheels of Trentingrana cheese across years of production depicted a peculiar trend (Figure 2). In particular, QW_{9mo} decreased from 2002 to 2005 and then completely recovered, with a higher percentage in 2008 than 2002; QW_{18mo} decreased significantly from 2002 to 2004 and then recovered in 2008, but not completely; and Qw_{TOT} decreased by approximately 10% from 2002 to 2005. In general, the first 4 years led to relevant losses of productivity for the dairy factories, while the following years showed a progressive recover of wheels selected as first quality.

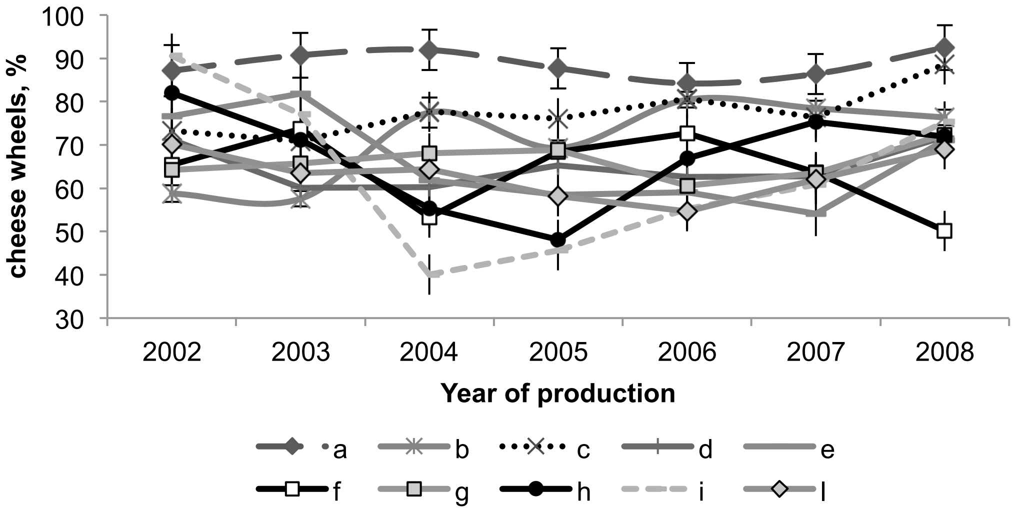
Figure 2. Least squares means of first quality wheels of Trentingrana cheese across years of production (QW_{9mo} is the percentage of first quality wheels on total wheels examined at 9±1 mo of ripening, QW_{18mo} is the percentage of first quality wheels on total wheels examined at 18±1 mo of ripening, and $QW_{TOT}$is the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening). Standard errors of estimates ranged from 1.0 to 1.9.



Reasons for the negative trend during the first years are not clear. The technology of production of Trentingrana cheese is established by the Consortium of Dairy Factories and determined by PDO specifications, i.e, they are strictly regulated. The 2003 was an abnormal year (Trento Province weather forecast website. 2010) a very hot and dry summer reduced the quantity and the quality of forages on the whole alpine region (Nardone et al. 2010). This situation influenced the feeding strategies of cows until summer 2004. However, the abnormality of summer 2003 cannot explain the slow recovery after 2004. Quality traits (Cologna et al., 2010) and microbiological aspects (Franciosi et al., 2009) of milk were satisfactory and remained almost stable across the studied period. The number of Holstein Friesian cows has been increasing, while an opposite trend is evidenced by traditional alpine dairy and dual purpose breeds. Moreover, the management of dairy farms is changing with a reduction of the number of small and an increase of the number of large herds. However, the relationship between these aspects and quality of Trentingrana cheese should be better investigated.

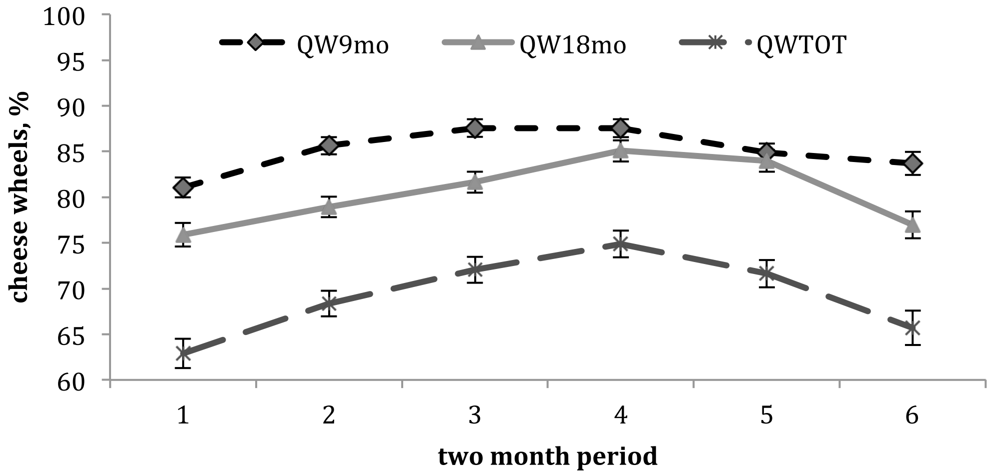
Results of the interaction effect between dairy and year of production for QW_{9+18mo} are displayed in Figure 3. Dairies largely differed across years and within the same year important differences were found. The best 3 dairies showed much less pronounced changes from one year to another, confirming their stability across the studied period.

Figure 3. Least squares means of the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening (QW_{TOT}) of Trentingrana cheese across dairy factories and years of production. Standard errors of estimates ranged from 4.7 to 12.6.



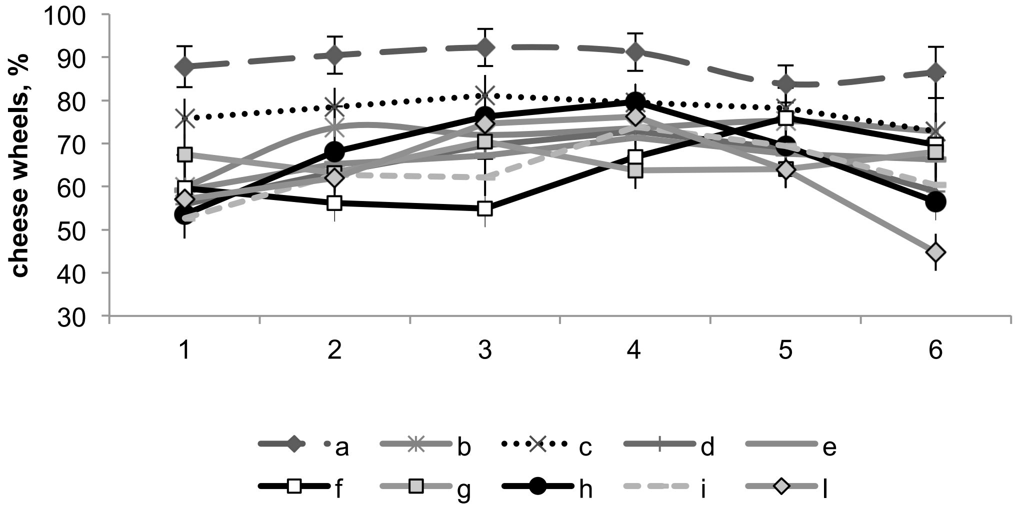
Least squares means of first quality wheels of Trentingrana cheese across seasons (2 months periods) of production are shown in Figure 4. All traits achieved the highest percentages for cheese produced in spring and summer, and the worst in autumn and winter. Also, the quality of milk processed into cheese highlighted a circannual variation, but with the best results in winter and the worst in summer (Cologna et al., 2010). Changes of the diet, climatic factors, and relatively high concentrations of calvings in the last months of the year could explain the seasonal trend. The season of production strongly influenced yield and quality of several cheeses: Parmigiano-Reggiano (Careri et al., 1996; Summer et al., 2007a,b), Cheddar (Kefford et al., 1995), Idiazabal (Mendia et al., 2000), Montasio (Polentarutti et al., 2001), Castellano (Gaya et al., 2003; Fernandez-Garcia et al., 2004), Cantal (Agabriel et al., 2004), Crottin (Tamagnini et al., 2006), and Asiago (Segato et al., 2007).

Figure 4. Least squares means of first quality wheels of Trentingrana cheese across seasons (2-mo periods) of production (QW_{9mo} is the percentage of first quality wheels on total wheels examined at 9±1 mo of ripening, QW_{18mo} is the percentage of first quality wheels on total wheels examined at 18±1 mo of ripening, and $QW_{TOT}$is the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening). Standard errors of estimates ranged from 0.9 to 1.9.



Results of the interaction effect between dairy and season (2 months periods) of production for QW_{9+18mo} are displayed in Figure 5. The significance found for this effect was probably due to the different number of herds using alpine pastures, the different proportion between small traditional and more intensive farms, and the different environmental and climatic conditions of the valleys of the province. All dairies had the highest quality values in spring and the worst in autumn; half of them (l, h, f, I and d) presented a much lower variation across months than others.

Figure 5. Least squares means of the percentage of first quality wheels at 18±1 mo of ripening on the number of wheels evaluated at 9±1 mo of ripening (QW_{TOT}) of Trentingrana cheese across dairy factories and seasons (2-mo periods) of production. Standard errors of estimates ranged from 4.3 to 12.8



CONCLUSIONS

The study revealed the importance of the evaluation of Trentingrana PDO hard cheese and the need of a continuous monitoring of the quality. Also, it was possible to quantify and clarify the sources of variation of the percentage of wheels selected as first quality at 9±1 (mid-evaluation) and 18±1 (final evaluation) months of ripening. Results evidenced a reduction of the percentage of first quality wheels for a large number of dairies between 2002 and 2005, followed by a complete recovery. The reason of this trend is not well known; climatic factors and the evolution of the management and characteristics of associated dairy herds may only partially explain these changes; hence, further researches are needed. Dairy factory was the most important source of variation for the studied traits and the 3 best dairies were characterized by small traditional associated farms and they produced a lower amount of Trentingrana cheese compared to other dairies. Moreover, they were less influenced by variations of quality due to season and year of production. Future studies will focus on the relationship between wheels selected as first quality and milk aspects.

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Chapter 4:

Monitoring of sensory attributes used in the quality payment system for Trentingrana cheese

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ABSTRACT

Trentingrana is a Protected Designation of Origin (PDO) hard cheese manufactured in the valleys of the Trento province (eastern Italian Alps) by several small cooperative dairies linked in a consortium. 9 months from production, wheels are delivered to a shared facility, ripened up to 18 months, and assessed by a panel of experts for 7 attributes, namely external aspect, rind thickness, paste color, texture, odor, taste, and aroma. The evaluation takes place every 2 months and wheels are sampled within each dairy. Based on the results of the assessment, dairies receive a price premium or penalty depending on a quality index which is a weighed sum of the scores received by each sampled wheel for sensory traits. Sensory scores and quality index of 652 wheels representing 11 dairies and 10 years of production were analyzed using a model that included fixed effects of dairy, year and season of production, and first-order interactions between them. The coefficients of determination ranged from 0.50 (texture) to 0.66 (aroma). All factors significantly ($P < 0.05$) affected the studied traits, with the exception of interactions between dairy and season of production for texture and external aspect, and between year and season of production for odor ($P > 0.05$). Dairy was the most important source of variation for visually assessed traits (external aspect, rind thickness, paste color, and texture) and for quality index, while year of production was the most important for flavor attributes (odor, taste, and aroma). The latter traits were always highly correlated among them and with the quality index, while correlations among visually assessed attributes, between them and flavor attributes, and between them and the quality index were more erratic. The sensory evaluation of quality performed by an expert panel has proven to be a useful tool to define the quality index and address the payment system for Trentingrana cheese, while it has

some limitations to correctly describe the sensory profile of the cheese and to identify specific defects and possible remedies.

Key words*: dairy factory, payment system, sensory attribute, panel, Trentingrana cheese*

INTRODUCTION

Because of strict regulations imposed on milk origin and production techniques, Protected Designation of Origin (**PDO**) cheeses are often variable, and the quality may depend on the farming system, the cow breed, the individual dairy factory, the geographical area, the season, and the year (Bertoni et al., 2001). Protected Designation of Origin constraints increase production costs but represent an opportunity to achieve a premium price for the product (Bouamra-Mechemache et al., 2010). In PDO cheeses, systematic control of their quality is essential to monitor the production chain, so that satisfactory prices can be established and maintained (Delahunty and Piggott, 1995; Noel et al., 1998; Elortondo et al., 1999, 2007; Galgano et al., 2001).

A representative example of PDO product is the Trentingrana (also known as “Grana Trentino”), an Italian hard cooked cheese that has a typical granular texture and a distinctive flavor profile developed during a ripening period of at leasts 18 months (Salvadori Del Prato, 1994; Boscaini et al., 2003). Trentingrana production thecnology includes a milk skimming by cream surfacing and the addition of previous day fermented whey, in order to improve the milk bacterial quality and enrich it with a microflora both important for milk acidification and the development of the cheese flavour (Giraffa et al., 1997; Franciosi et al., 2010). Trentingrana is a secondary label of Grana Padano and can be produced only in a restricted area, the Trento province (eastern Italian Alps), where the cheese is the most important dairy product (4,000 ton/yr). The environment in which the product is obtained (mountain area), restrictions in cow feeding (silages are forbidden), and traditional manufacturing protocols (lysozime is not permitted) are the main features contributing to the uniqueness of the cheese. On average, herds supplying milk to dairies for Trentingrana production are small; 87% of them has less than 30 cows and the major breeds are Italian Brown Swiss, dual purpose Italian Simmental, and local breeds (Rendena and Alpine Grey). In recent years, the proportion of milk sourced from larger and more specialized dairy farms, often rearing Italian Holstein Friesian cows, has been growing.

Trentingrana is produced by several small dairy cooperatives linked in a consortium whose official inspectors, after about 9 and 18 months from production, evaluate all wheels individually, and classify them as “first-quality”, “second-quality”, and “discarded” (Bittante et al., unpublished data). Sampled “first-quality” wheels from each dairy are then assessed by a panel of experts for some traditional sensory attributes and the consortium sells the first-quality cheese of participating dairies and reward or penalize them using price premiums or penalties according to results of the sensory evaluation.

The panel of experts check if the product complies with stated requirements. Experts evaluate the presence of defects as well as of certain positive sensory characteristics; based on the evaluation, the product is graded in different levels of sensory quality, from a standard to an excellent one. The assignation of a quality level to a product is made with reference to a mental standard individually developed by the experts. The members of the panel are people with a consolidated experience in tasting cheese, especially Grana-type cheese, so they have developed skills to evaluate sensory characteristics of this product but they have not been given systematic training and they do not use standardized methods. This is a common approach of many ‘‘Sensory Committees’’ of PDO product (Elortondo et al., 2007) and it is one of the most controversial strategies used in sensory quality control (Costell, 2002). The disadvantages of this approach are well known: the perceptiveness can vary day to day and the judgement may vary under the influence of external factors (Feria-Morales, 2002). The practical value of the information obtained from a quality control system based on sensory evaluation depends on the correct fulfillment of some important requirements: i) the selection of the sensory quality standard; ii) the establishment of the sensory specification; iii) the set up of sample preparation and evaluation procedure; iv) the selection, training and maintenance of the panel; and v) an experimental design to control product, judges and replicates effects.

This paper is part of a wider research project that seeks to analyze production chain of Trentingrana cheese. Specifically, the objective of the study is to investigate sources of variation of the sensory traits used to monitor the quality level and the quality index used for payment of Trentingrana cheese. Moreover, the adequacy of the current evaluation system to give a sensory description of the product and to be used as a management tool by dairies is critically discussed.

MATERIALS AND METHODS

Field Data

The small dairy cooperatives, which produce PDO Trentingrana cheese, are linked in the Consortium of Dairy Factories of the Trento province (Italy). At about 9 months from production, official inspectors by the Consortium visit each dairy and evaluate all wheels individually according to external aspects (color, integrity, presence of mould, swelling) and the sound obtained by beating the wheel with a special hammer to recognize inner holes or imperfections (Bittante et al., unpublished data). Based on results of this evaluation, wheels are classified as “first-quality”, “second-quality”, and “discarded”. The cheese is then delivered to a shared facility and ripened up to at least 18 months when another evaluation resembling the one just described takes place. Then, a second type of quality assessment is carried out, namely the evaluation of some basic sensory attributes, which is performed by a panel of experts on first-quality wheels sampled from each dairy. Since 1999, the Consortium sells the first-quality wheels of participating dairies and reward or penalize them using price premiums or penalties according to results of the sensory evaluation.

The Consortium provided us with data on monitoring of sensory attributes of Trentingrana performed during the period 2000-2010 on cheeses produced by 11 dairy factories from 1999 to 2008. The quality monitoring was based on the traditional sensory evaluation, approved by the Consortium that is performed six times each year for each dairy, so that the quality of cheese manufactured could be monitored every two months. We used data editing to extract the evaluation of one Trentingrana wheel for each 2 months period, year and dairy factory, leading to a total of 660 wheels. Eight wheels were discarded because of missing or incomplete data, so that the final dataset accounted for 652 wheels.

Traditional sensory monitoring was conducted by a panel of experts jury members composed of individuals involved in several aspects of cheese production and marketing. These experts evaluated wheels using a protocol featuring seven parameters: external aspects of the wheel, rind thickness, paste color, texture (visually assessed), odor, taste, and aroma. The list of attributes assessed by the panel and their description are summarized in Table 1. The seven traits were evaluated using score charts based on a ten-point scale (1 = very bad/unacceptable and 10 = very good/excellent; from 1 to 5 points the judgment is negative, from 6 to 10 positive), but, in practice, only scores from 3 to 10 were awarded by the panel, because only wheels classified as first-quality (G. Bittante, unpublished data), were assessed (n = 652). For each wheel, the scores given to each trait by panel experts were averaged and a quality index was calculated as the weighed sum of the average scores received by each sampled wheel. Weights considered for each sensory trait to calculate the index, with respect to their relative importance, are reported in Table 1. The quality index has traditionally been used by the Consortium to establish price premiums or penalties for Trentingrana cheese produced by associated dairies.

Table 1. List of traditional sensory attributes of Trentingrana cheese judged by the expert panel. For each parameter, the evaluation instructions are given and the weight used in the definition of cheese price is reported. The anchors on the 10-point scale are 1= very bad/unacceptable and 10=very good/excellent; from 1 to 5 points the judgment is negative from 6 to 10 positive.

Attribute	Instruction	Weight
Visual evaluation	The judge looks at the external and internal surface of the wheel and evaluates the following characteristics:	
External aspects	*The regularity of wheel shape, its surface integrity, the uniformity and type of crust color, the degree of definition of trademark*	1.0
Rind thickness	*The crust thickness*	1.0
Paste Color	*The color of paste and its degree of uniformity between the various parts of the section*	1.3
Texture	*The degree of grain fineness of paste microstructure*	1.0
Evaluation by smelling	The judge smells the wheel in different zones and evaluates the following characteristics:	
Odor	*The quality of odor sensation based on the intensity and equilibrium of sensation perceived by smelling (caused by the presence of typical aromas related to ripened grana cheese and by the absence of anomalous aromas related to defects of fermentation)*	1.7
Evaluation by tasting	The judge samples some cheese pieces from different zones (in correspondence to the central and the external sides of the wheel), tastes and evaluates the following characteristics:	
Taste	*The quality of taste sensation, based on the intensity and equilibrium of basic tastes (salty, acid, sweet, bitter) and the pungent sensation*	1.8
Aroma	*The quality of flavor sensation, based on the intensity and equilibrium of sensation perceived during the chewiness and after the swallowing relating to odor retro nasal perception (caused by the presence of typical aromas related to ripened grana cheese and by the absence of anomalous aromas related to defects of fermentation)*	1.7

Statistical Analysis

An ANOVA was carried out on sensory attributes and quality index using the GLM procedure (SAS Inst. Inc., Cary, NC) according to the following linear model:

$y_{ijkl} = m + D_i + Y_j + S_k + (D \times Y)_{ij} + (D \times S_{ik}) + (Y \times S)_{jk} + e_{ijkl}$,

where y_{ijkl} is the observed trait; m is the intercept of the model; D_i is the fixed effect of the *i*th dairy factory (*i* = 1 to 11); Y_j is the fixed effect of the *j*th year of production (*j* = 1999 to 2008); S_k is the fixed effect of the *k*th season of production (*k* = 1 to 6); $(D \times Y)_{ij}$ is the fixed interaction effect between dairy factory and year of production; $(D \times S)_{ik}$ is the fixed interaction effect between dairy factory and season of production; $(Y \times S)_{jk}$ is the fixed interaction effect between year and season of production; and e_{ijkl} is the random residual N ~ $(0, \sigma^2_e)$. The season effect was classified into six bi-monthly classes (January and February, March and April, May and June, July and August, September and October, November and December). The level of significance was set to $P < 0.05$.

Pearson's correlations between the traits were estimated using raw data, among LSM of the fixed effects of dairy factory, of year of production, season of production, and residuals through the CORR procedure (SAS Inst. Inc., Cary, NC). The level of significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

The descriptive statistics shown in Table 2 indicate that the average scores for all traditional sensory attributes of Trentingrana cheese were positive in all instances, ranging from 7.04 for aroma to 7.70 for visually assessed texture. The SD approached 0.50 points for most traits, although much lower variability was detected for texture (SD = 0.37; CV = 4.8%), whereas external aspects showed higher variability (SD = 0.74; CV = 9.7%).

Table 2. Descriptive statistics of traditional sensory attributes of Trentingrana cheese and of quality index used for cheese payment

Attribute	n	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
External aspect	652	7.65	0.74	4.40	9.86	-0.47	0.62
Rind thickness	652	7.44	0.54	4.50	9.00	-1.00	3.08
Paste color	652	7.54	0.55	3.17	8.83	-1.34	7.37
Texture	652	7.70	0.37	5.50	8.67	-1.10	3.37
Odor	652	7.34	0.41	5.33	8.20	-0.20	0.45
Taste	652	7.20	0.54	4.67	9.00	-0.18	0.80
Aroma	652	7.04	0.55	4.83	8.67	-0.09	0.15
Quality index	652	70.0	3.50	47.8	79.3	-0.57	2.15

All traditional sensory attributes were characterized by left-skewed and leptokurtic distributions, with relevant differences among traits: paste color, texture, and rind thickness exhibit values < -1.0 for skewness and > 1.0 for kurtosis, whereas aroma showed a more normal distribution. The quality index averaged 70.0 points, wich is slightly above the value (68.0) assumed as reference by the Consortium to define the base price of first-quality Trentingrana cheese. The SD was 3.50 (CV = 5.0%), and skewness and kurtosis were intermediate to those calculated for sensory attributes (Table 2). Taking into account the price premiums/penalties payment scheme adopted by the Consortium (Figure 1), it appears that a SD unit of the quality index causes a premium/penalty of 0.181 €/kg; considering that the average selling price of first-quality cheese during the period of the study was 6.523 €/kg, it means that a variation of 10% of the quality index (2 SD units) leads to a variation of 5.5% of the selling price.

Table 3. Conversion table quality index - premiums/penalties price (€cent/kg) of first-quality Trentingrana cheese.

Quality index	**€cent/kg**
78	49,1
77	43,9
76	38,7
75	33,6
74	28,4
73	23,2
72	18,1
71	12,9
70	7,7
69	2,6
68	**0**
67	-2,6
66	-7,7
65	-12,9
64	-18,1
63	-23,2
62	-28,4
61	-33,6
60	-38,7

Analysis of variance (Table 4) showed that effects included in the model explained between 50% (texture) and 66% (aroma) of total variability. Significance was found for all factors (*P* < 0.05), except for interactions between dairy factory and season of production for external aspect and texture, and between year and season of production for odor (*P* >0.05).

Table 4. Results from ANOVA for traditional sensory attributes of Trentingrana cheese and for quality index used for cheese payment

	Effect[1]							
Trait	**Dairy**	**Year**	**Season**	**D x Y**	**D x S**	**Y x S**	R^2	**RMSE**
df	*10*	*9*	*5*	*90*	*50*	*45*		
External aspect	14.9***	9.72***	2.40*	2.28***	1.32†	1.48*	0.58	0.58
Rind thickness	20.3***	9.01***	16.4***	2.08***	2.43***	3.30***	0.65	0.39
Paste color	7.63***	2.38*	7.41***	1.53**	2.24***	1.91***	0.51	0.47
Texture	9.14***	3.87***	5.45***	1.46**	1.36†	1.98***	0.50	0.32
Odor	12.3***	15.4***	4.26***	2.04***	1.68**	1.38†	0.58	0.32
Taste	9.65***	24.2***	5.70***	1.98***	1.40*	1.85**	0.60	0.41
Aroma	9.10***	44.8***	6.56***	2.00***	1.46*	1.52*	0.66	0.39
Quality index	17.5***	10.5***	8.14***	2.25***	1.55*	1.88***	0.60	2.68

†*P* < 0.10, **P* < 0.05, ***P* < 0.01, ****P* < 0.001.

[1]DF x YP, is the interaction effect between dairy factory and year of production; DF x SP, is the interaction effect between dairy factory and season of production; YP x SP, is the interaction effect between year and season of production.

RMSE, root mean square error.

The residual SD of traditional sensory attributes ranged from 0.32 points for texture and odor to 0.58 points for external aspect, and was 2.68 points for the quality index.

As expected, Pearson's correlations among raw data showed that the quality index was positively correlated (*P* < 0.001) with all its component traits (Table 5), particularly with odor, taste and aroma attributes.

Table 5. Pearson's correlations[1] between the quality index used for cheese payment and traditional sensory attributes of Trentingrana cheese

	Raw	Dairy	Year	Season	Residual
Quality index with					
External aspect	0.37***	0.69*	-0.40	0.18	0.37***
Rind thickness	0.43***	0.88***	-0.53	0.68	0.38***
Paste color	0.72***	0.90***	0.45	0.96**	0.71***
Texture	0.67***	0.91***	0.17	0.82*	0.66***
Odor	0.86***	0.94***	0.96***	0.85*	0.83***
Taste	0.87***	0.91***	0.90***	0.96**	0.87***
Aroma	0.84***	0.94***	0.93***	0.91*	0.87***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

[1]*Raw* are the correlations between raw data of each wheel evaluated; *Dairy* are the correlations between least squares means of the dairy effect; *Year* are the correlations between least squares means of the year of production effect; *Season* are the correlations between least squares means of the season of production effect; *Residual* are the correlations between the residuals of each wheel evaluated.

This was not only because these attributes carried the highest weights (Table 1), but also because they were highly correlated among them (Table 6).

Table 6. Pearson's correlations[1] between traditional sensory attributes of Trentingrana cheese

	Raw	Dairy	Year	Season	Residual
External aspect with					
Rind thickness	0.25^{***}	0.71^{*}	0.80^{**}	0.09	-0.02
Paste color	0.15^{***}	0.47	0.44	-0.02	0.11^{**}
Texture	0.30^{***}	0.66^{*}	$0.57^{\dagger}$	0.43	0.12^{**}
Odor	0.13^{***}	0.49	$-0.58^{\dagger}$	-0.10	0.15^{***}
Taste	$0.07^{\dagger}$	0.43	-0.75^{*}	0.07	0.15^{***}
Aroma	0.05	0.48	-0.67^{*}	0.02	0.18^{***}
Rind thickness with					
Paste color	0.32^{***}	0.90^{***}	0.20	0.70	0.28^{***}
Texture	0.42^{***}	0.79^{**}	0.41	0.83^{*}	0.30^{***}
Odor	0.20^{***}	0.71^{*}	-0.68^{*}	0.31	0.22^{***}
Taste	0.17^{***}	0.66^{*}	-0.77^{**}	0.46	0.19^{***}
Aroma	0.11^{**}	0.72^{*}	-0.76^{*}	0.33	0.16^{***}
Paste color with					
Texture	0.57^{***}	0.82^{**}	$0.58^{\dagger}$	$0.81^{\dagger}$	0.57^{***}
Odor	0.55^{***}	0.82^{**}	0.33	$0.80^{\dagger}$	0.49^{***}
Taste	0.51^{***}	0.77^{**}	0.08	0.91^{*}	0.49^{***}
Aroma	0.46^{***}	0.82^{**}	0.13	0.87^{*}	0.47^{***}
Texture with					
Odor	0.46^{***}	0.86^{***}	-0.02	0.40	0.46^{***}
Taste	0.44^{***}	0.79^{**}	-0.17	0.62	0.50^{***}
Aroma	0.39^{***}	0.81^{**}	-0.13	0.53	0.47^{***}
Odor with					
Taste	0.82^{***}	0.96^{***}	0.95^{***}	0.96^{**}	0.75^{***}
Aroma	0.81^{***}	0.98^{***}	0.96^{***}	0.97^{**}	0.75^{***}
Taste with					
Aroma	0.90^{***}	0.98^{***}	0.98^{***}	0.99^{***}	0.87^{***}

$^{\dagger}P < 0.10$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

[1]*Raw* are the correlations between raw data of each wheel evaluated; *Dairy* are the correlations between least squares means of the dairy effect; *Year* are the correlations between least squares means of the year of production effect; *Season* are the correlations between least squares means of the season of production effect; *Residual* are the correlations between the residuals of each wheel evaluated.

Thus, odor, taste, and aroma of Trentingrana cheese are the main key drivers of price premiums/penalties paid to dairies, while visually assessed parameters have a lower impact on the economic value of cheese. Tables 5 and 6 show that correlations among the residuals were very close to those obtained using raw data.

Effect of the dairy factory

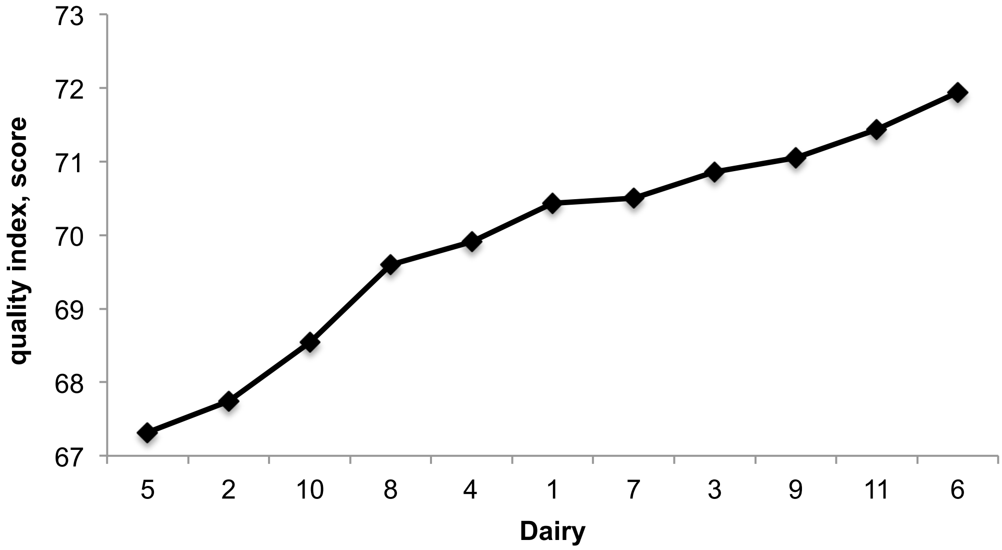
The dairy factory was the most important source of variation in visually assessed traits (external aspect, rind thickness, paste color, and texture) and quality index, and the second most influential component on flavor attributes (odor, taste, and aroma) of Trentingrana cheese (Table 4). Figure 1 ranks the participating dairies in comparison to the quality index, from the worst to the best; it is worth noting that the ranking for most attributes was very similar to that of the quality index.

This is also confirmed by Pearson's correlations between quality index and sensory attributes computed on LSM of the dairy effect (Table 5), which were positive and high ($P < 0.05$). Correlations among traditional sensory attributes computed using the LSM of the dairy effect were positive and moderate to high, ranging from 0.43 (external aspect with taste) to 0.98 (odor with aroma and taste with aroma; Table 6); significance was found in all cases except for correlations between external aspect with paste color, odor, taste, and aroma.

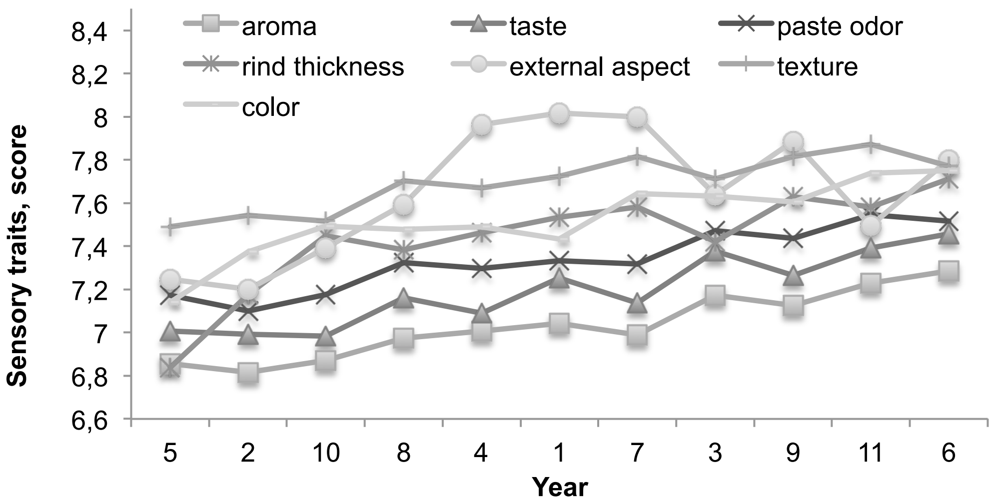
The dairy factory was also found to be the most important source of variation when experts of the Consortium identified first–quality Trentingrana wheels (Bittante et al., unpublished data), and when quality characteristics of other cheeses were evaluated (Bellesia et al., 2003; Drake et al., 2008). The processing of milk and cheese are very similar among dairies because all of them adhere to the PDO rules.

Figure 1. Least squares means of (a) quality index used for cheese payment and (b) traditional sensory attributes of Trentingrana cheese across dairy factories. Dairies are ordered according to LSM of the quality index.

(a)



(b)



9 months from production, wheels are delivered to a single shared facility managed by the Consortium where they stay for the ripening period of 18 months. However, possible explanations of the strong influence of dairies on studied traits could be related to several aspects. Cooperative dairies largely differed in terms of number of associated herds, level of production of these herds, amount of milk processed daily, number of wheels manufactured (Bittante et al., unpublished data),

and the procedure of transportation of milk. Small farmers usually deliver milk using 30 or 50-L cans, while larger farms use refrigerated tanks.

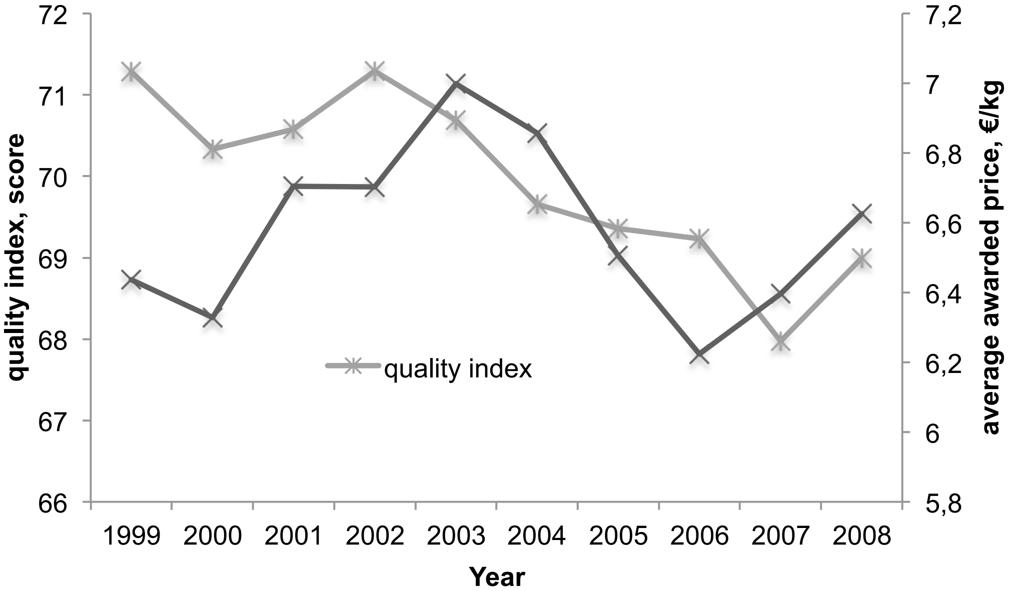
Variation in characteristics of processed milk is another important aspect that may explain differences among dairies, because farming systems differ across valleys and highlands of the Trento province in terms of altitude, breeds, and use of summer Alpine pastures. Analysis performed on bulk milk used for manufacturing Trentingrana cheese identified highly significant differences in fat, protein, and urea contents, somatic cell score (SCS), and total bacterial and clostridial counts (Cologna et al., 2010), and good hygienic conditions of raw milk (Franciosi et al., 2009). Both farming systems and feeding regimes significantly influenced milk composition, and physical and sensory attributes of PDO and traditional cheeses (Agabriel et al., 2004; Tornambè et al., 2005).

Effects of year of production

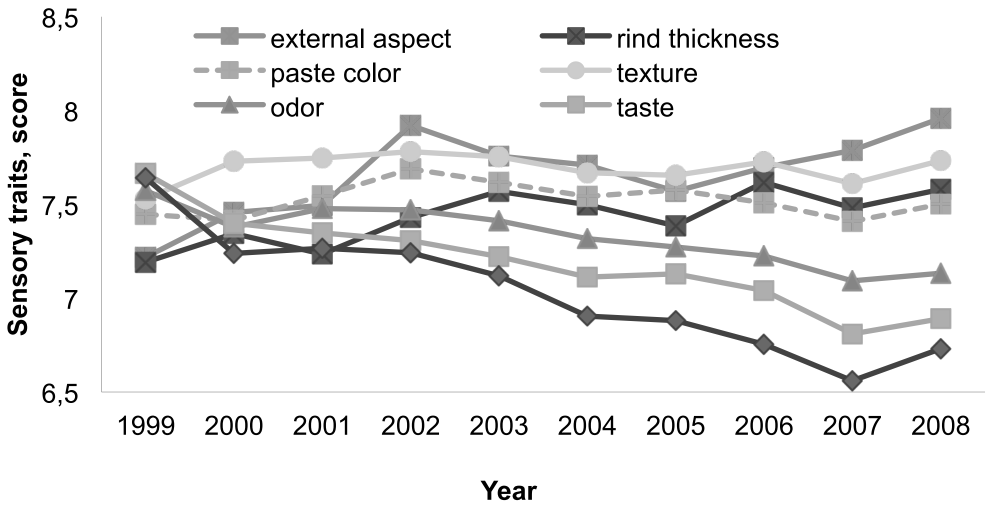
Statistical analysis revealed that year of production was important ($P < 0.05$) in explaining the variation of traditional sensory attributes and quality index of first-quality wheels of Trentingrana cheese. The quality index was stable during the first years (Figure 2a), followed by a sharp decline from 2002 to 2007, and a partial recovery in 2008. A similar trend was detected for flavor traits, whereas visual attributes showed fewer changes across years (Figure 2b). During the same period, the average selling price of first-quality cheese has shown variations in the range of 10% between the maximum and the minimum value (Figure 2a). Pearson's correlations computed on LSM of the year effect clearly confirmed that the quality index was strictly, positively, and significantly ($P < 0.001$) correlated with flavor attributes, but not with visual traits (Table 5). Also, correlations among flavor parameters computed on LSM of the year effect were positive, very strong, and highly significant ($P < 0.001$), whereas correlations among visual attributes, and between these and flavor attributes were more erratic, and significance was reached only in few cases (Table 6).

Figure 2. Least squares means of (a) quality index used for cheese payment and average selling price (€/kg), and (b) traditional sensory attributes of Trentingrana cheese across years of production.

(a)



(b)



Year of production was also found to be highly significant in explaining the variability of the percentage of first-quality wheels of Trentingrana cheese, but the pattern differed from that described above. Indeed, the percentage of wheels classified as first quality decreased from 2002 to 2005, and recovered thereafter (Bittante et al., unpublished data). Further research is needed to explore reasons that led to worsened flavor attributes and quality index of cheese over the years. As the evaluation of the attributes is not based on objective references, it cannot be excluded that the decrease of the average scores over years depends, in part, on a change in the mental standard of experts rather than on the quality of cheese. Hence, such a research is difficult because the evaluation system of the Consortium seeks to assess product desirability in the absence of any precise description of major features of the sensory profile (Drake, 2004, 2007; Foegeding and Drake, 2007). Also, although it appears that the odor desirability of Trentingrana cheese is deteriorating, we cannot identify the particular odor attribute causing the adverse effect (Bodyfelt et al., 2008). If traditional sensory evaluation is indeed still regarded as useful in the commercial evaluation of cheese, the procedure is of reduced value when viewed as a method of monitoring and improving the Trentingrana production chain (Nielsen et al., 1998, Costell, 2002; Feria-Morales, 2002; Elortondo et al., 2007)).

During the studied period, dairy techniques remained substantially unchanged, mainly because of a perceived need to rigidly follow the PDO production rules. However, the number of farms delivering milk to cooperative dairies decreased, and both the quantity of milk processed daily and the number of wheels produced, gradually increased (Bittante et al., unpublished data). The average amount of milk delivered by associated farms to dairies gradually increased, mainly because of the progressive substitution of traditional Alpine breeds such as Brown Swiss with

Holstein-Friesian. Also, changes in the genetics of animals within breed, feeding strategies, and rearing systems influence sensory features of PDO cheeses (Agabriel et al., 2004). These developments raise relevant questions of the future of Trentingrana industry because milk from Holstein-Friesian cows is characterized by lower fat and protein contents. However, bulk milk delivered to dairies during the study period has trended higher in both fat and protein contents, and lower in overall bacterial and clostridial count; only SCS trend was unfavorable (Cologna et al., 2010). Likely, any negative effect of the increased number of Holstein-Friesian cows on milk contents is balanced by a long-term positive genetic trend in all breeds reared in the province, and by the beneficial environmental effects induced by intensification. Use of Holstein-Friesian milk reduces cheese yield in comparison with Brown Swiss milk (Malacarne et al., 2006), even after adjustment for fat and protein content (De Marchi et al., 2008).

Holstein-Friesian milk is also characterized by poorer milk coagulation properties (MCP) than milk from Alpine breeds (De Marchi et al., 2007). The clotting characteristics of milk influence both cheese yield and sensory attributes (Ng-Kwai-Hang et al., 1989; Martin et al., 1997). None of the dairy breeds reared in the Trento province was directly selected for enhanced MCP characteristics (rennet coagulation time and curd firmness), although such traits are heritable in Holsteins Friesians (Oloffs et al., 1992; Comin et al., 2005; Cecchi et al., 2007; Cassandro et al., 2008; Vallas et al., 2010), and in Brown Swiss breeds (Cecchinato et al., 2009) and they are used for quality milk payment schemes in the province, and despite the fact that infrared spectrometry has been suggested to be useful for genetic improvement of MCP (Dal Zotto et al., 2008; Cecchinato et al., 2009; De Marchi et al., 2009). In Italian Brown Swiss cows, indirect improvement of MCP traits may be expected because of the inclusion of k-casein genetic variants in the selection index; it is accepted that the B k-casein allele elevates desirable MCP parameters (Aleandri et al., 1990; Comin et al., 2008; Penasa et al., 2010), mainly by increasing the proportion of k-casein in milk (Bonfatti et al., 2010). Thus, trends in MCP traits must be monitored and any possible relationships with cheese yield, composition, and/or sensory quality should be further investigated.

Effects of season of production

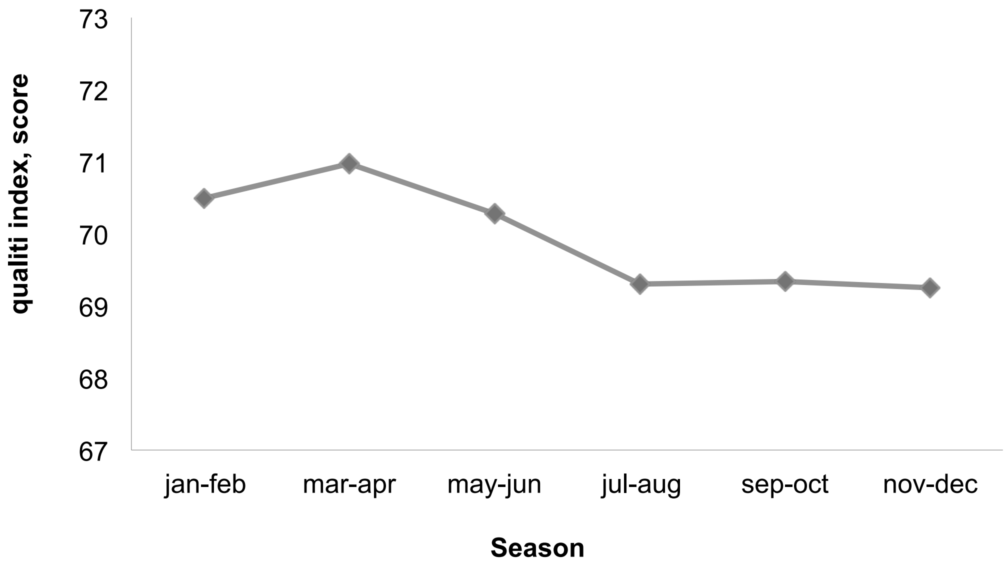
Season of production was significant for all sensory attributes and quality index of Trentingrana cheese (*P* < 0.05; Table 3). With the exception of external aspect, the highest average scores for sensory parameters were found for wheels produced from January to June (Figure 4b). This trend is not consistent with that evidenced by Cologna et al. (2010) for quality traits of milk used for Trentingrana cheese production. Indeed, fat and protein contents, SCS, and total bacterial and clostridial counts, showed more desirable values in summer season than in winter. Similar results were obtained by Summer et al. (2007), who studied milk destined to Parmigiano-Reggiano cheese industry. The trend observed for the percentage of Trentingrana wheels classified as first quality (Bittante et al, unpublished data) was very close to that reported here for sensory evaluation. Thus, cooperative dairies achieve their best and most profitable results during late spring and beginning of summer for both the evaluations.

As a result of seasonal variations in component traits, the quality index showed a circannual trend, with the highest scores from January to June and the lowest from July to December (Figure 3a), thus resembling what found for individual sensory attributes. Similar results were obtained for Castellano cheese by Gaya et al. (2003). Large seasonal variations in sensory properties are often found in PDO cheeses, especially if produced in mountain or extensive farming systems (Mendia et al., 2000; Polentarutti et al., 2001; Agabriel et al., 2004; Segato et al., 2007).

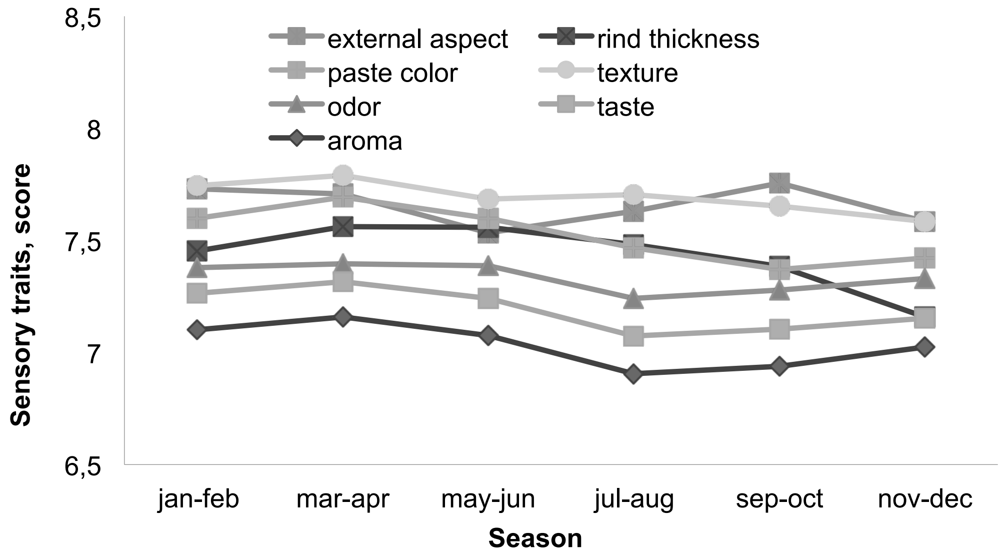
To understand seasonal variation, it should be recalled that Trentingrana cheese is a typical PDO product obtained in mountain areas according to traditional techniques, and mainly using milk from small farms. This means that the cow-feeding regimen is not constant during the year, although it basically relies on hay and concentrates. As previously mentioned, silages are not permitted because of the risk of contamination of milk with clostridia that can lead to off-flavors and excessive gas formation, a defect known as late-blowing of cheese.

Figure 3. Least squares means of (a) quality index used for cheese payment and (b) traditional sensory attributes of Trentingrana cheese across seasons of production.

(a)



(b)



Milk produced during summer on high pastures of the Alps cannot be used for Trentingrana production. This is because milk from grazing cows is very variable in quality (Buchin et al., 1999). Moreover, according to tradition several farmers rearing Alpine breeds transfer the entire herd to the high pastures during summer, therefore, seasonality of production is evident; inseminations are predominantly performed in winter, followed by late lactation and dry period in summer, and calving in autumn when the herd come back to the permanent farm. The obvious consequence of this management strategy is that seasonal variation of sensory attributes and milk quality traits reflects not only climatic aspects such as temperature and humidity, but also changes in lactation stage, feeding regime, housing systems, and breed proportion in lactating cows (Agabriel et al., 2004; Coulon et al., 2005; Martin et al., 2005, 2009). The last-enumerated group of factors probably also explains the significant interactions between year and season of production (Table 3), whereas interactions between dairy and year, and dairy and season are probably attributable to variations in the level of farming intensification in the valleys of the Trento Province.

Pearson's correlations between the quality index and sensory traits of Trentingrana cheese computed on LSM of season effect were positive, high, and significant ($P < 0.05$), with the exception of external aspect and rind thickness (Table 4). When relationships among sensory attributes based on LSM of the season effect were considered, only few parameters were significantly correlated, particularly those involving odor, taste, and aroma ($P < 0.01$; Table 5).

CONCLUSIONS

The scores for the seven sensory attributes and the quality index used to determine price premiums or penalties of Trentingrana cheese varied according to dairy factory, year and season of production, and interactions between these main sources of variation. Apart from seasonal variations, which must be regarded as inevitable when the quality of cheese produced in a mountainous environment from milk obtained from small traditional farms is examined, our study shows a decrease of traditionally evaluated flavor parameters over years. This negative trend appears not to be attributable to any change in dairy production technology, but rather to intensification of dairy farming, even though a slow change in evaluation criteria by experts cannot be excluded; thus, further investigations are required to better ascertain this topic. Finally, the dairy factory is the key source of variation when traditional sensory attributes of Trentingrana cheese are evaluated.

The major limitation of the sensory evaluation system adopted by the Consortium is the lack of a precise analytical quantitative description of sensory attributes according to sensory profiling methods. The traits evaluated by the experts reflect subjective judgments on a not so clearly defined spectrum between desirability and undesirability, and do not employ analytical sensory descriptors. Even if sensory evaluation by experts is shown to be useful in monitoring the overall quality of Trentingrana cheese and a useful tool to define the quality index and address price premiums or penalties for the cheese, the process fails to identify the specific problems causing changes in cheese attributes, and thus does not assist in the development of an understanding of why quality is falling or how the problem can be solved. Another limitation is the lack of a reference chart that anchors individual scores to objective values. An analytical rigorous descriptive sensory analysis system based on a trained panel for the evaluation of Trentingrana cheese has to be developed, and such a tool should be implemented to systematically monitor cheese production in cooperative dairies.

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Chapter 5:

General conclusions

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The main steps of the whole Trentingrana cheese chain were discussed in this PhD thesis.

In Chapter 2 the characteristics of herd bulk milk used to produce Trentingrana cheese were studied. Milk yield and quality aspects were significantly influenced by all the effects included in the analysis. Both year and season of production had a strong influence on milk yield but much less on quality aspects. Milk farm quality score evidenced, for the year of production effect, an increase of 8.5% from the first to the last year. Month of production showed a clear circannual variation with the best milk quality expressed in winter and the worst in summer. The milk farm quality score reported an high variability and was significantly affected by all the explanatory variables.

Statistical analysis carried out in Chapter 3 were useful to evaluate the sources of variation of quality classification of Trentingrana cheese. Results evidenced a reduction of the percentage of first quality wheels for a large number of dairies between 2002 and 2005, followed by a complete recovery. Dairy factory was the most important source of variation for the studied traits. The three best dairies were characterized by small traditional associated farms and lower cheese production in comparison to the others.

Chapter 4 considered factors affecting sensory attributes of Trentingrana cheese. The study showed a decrease score for flavor parameters over years. This negative trend appeared not to be attributable to any change in dairy production technology, but rather to intensification of dairy farming. Dairy factory represented the key source of variation when traditional sensory attributes of Trentingrana cheese were evaluated.

The three chapters evidenced the importance of a continuous monitoring of the quality of the Trentingrana production chain. Futures studies will focus on milk coagulation properties, the relationship between wheels selected as first quality and milk aspects and the improvement of the sensory evaluation system adopted by the Consortium to evaluate the final ripened cheese.

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