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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 dairy factories. To obtain the certification of quality, wheels are evaluated at 9 ± 1 mo of ripening and those classified as first quality are revaluated at 18 ± 1 mo. Traditionally, the assessment is based on 2 sensory features: namely, the external aspect of the wheel and the internal texture; the latter is evaluated through the sound produced by beating the wheel with a special hammer. Traits considered in the study were the percentage of first-quality wheels of total wheels examined at 9 ± 1 (QW_{9mo}) and 18 ± 1 (QW_{18mo}) mo of ripening, and their combination [i.e., the percentage of first-quality wheels at 18 ± 1 mo of ripening of the number of wheels evaluated at 9 ± 1 mo (QW_{tot})]. The experimental unit was the batch of 2 mo of production of each of 10 cooperative dairy factories from 2002 to 2008. Data were analyzed with a model that included fixed effects of dairy factory, year and season of production, and interactions between dairy factory and year, and dairy factory and season. The coefficients of determination of the models were 0.57, 0.68, and 0.67 for QW_{9mo}, QW_{18mo}, and QW_{tot}, respectively. All factors significantly influenced the traits, with dairy factory being the most important source of variation, followed by season and year of production. Remarkable differences were found between the best and the worst dairy factory for QW_{9mo} (11.5%), QW_{18mo} (21.1%), and QW_{tot} (25.6%). The first 4 yr of production had a negative effect on the percentage of wheels labeled as first quality and QW_{tot} decreased from 74 to 64%; nevertheless, a complete recovery was detected in the following years. The season of production strongly influenced the studied traits with the best results in spring and summer, and the worst in autumn and winter. Compared with average, the 3 best dairy factories were smaller, with smaller associated farms, and showed lower variation across years and seasons of production. Results support the relevance of routinely assessing and monitoring the quality of Trentingrana cheese.
Key words: dairy factory, quality, ripening, Trentingrana cheese

INTRODUCTION

Since 1992, European Union legislation has defined the Protected Geographical Status [Protected Designation of Origin (**PDO**); Protected Geographical Indication (PGI); and Traditional Specialty Guaranteed (TSG)] as the framework 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). To obtain the PDO status, a product must be entirely manufactured within a delimited geographic area and follow specific processing techniques (Bertoni et al., 2001; Boscaini et al., 2003). The number of labeled products is rapidly increasing in Europe and cheese is largely benefiting from PDO regulation, especially in France, Italy, and Greece, with 45, 34, and 20 cheeses manufactured under this quality label, respectively (Bouamra-Mechemache and Chaaban, 2010). Generally, PDO regulations increase production costs, but they represent an opportunity to achieve economic rewards from the market.

The Trentingrana hard cheese (known also as Grana Trentino) is a geographic specification of the most popular PDO Grana Padano (Salvadori Del Prato, 1994) manufactured in the mountain area of Trento Province, 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); these animals are characterized by lower milk production, higher fat and protein contents, and better milk coagulation properties than Holstein-Friesians (De Marchi et al., 2007). Despite this, the number of Holstein-Friesian cows has increased in the alpine regions, and this may be a disadvantage for Trentingrana production, as cheese yield from this breed is lower than Brown Swiss (De Marchi et al., 2008).

Trentingrana is produced by small cooperative dairy factories, which generally collect milk from associated

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farms twice per day. The cheese is manufactured using partially skimmed raw milk according to a procedure regulated by the Italian law (Legislative Decree July 20, 2006) and similar to that adopted by Parmigiano Reggiano: silages are not allowed to feed cows and only rennet can be used as additive during milk processing. Moreover, only a natural starter culture obtained from the spontaneous fermentation of part of the previous day's whey (Franciosi et al., 2010) can be added to raw milk during cheese making.

A limited number of studies investigated the quality of Grana-type hard cheeses. Bellesia et al. (2003) found 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 nonvolatile fractions. Nevertheless, no information on the quality classification of PDO hard cheeses is currently available. Therefore, the objective of this study was to investigate the sources of variation of quality evaluation of the Trentingrana cheese.

MATERIALS AND METHODS

Field Data

Data of Trentingrana wheels were obtained from the ripening store of the Consortium of Dairy Factories operating in Trento province, Italy. Dairy factories (n = 10) destined 88% of milk collected from the associated farms to obtain Trentingrana cheese, whereas the remaining 12% was processed into other products.

The procedure of quality evaluation provided for 2 crucial steps of selection: the first was carried out in the dairy factories on 9 ± 1 mo ripened cheese and the second in the central store of the Consortium on 18 ± 1 mo ripened cheese. During the first step, all wheels produced by a given dairy factory in a 2 mo period (approximately 1,300 wheels) were individually checked by an official inspector for external aspect (color, integrity, presence of molds, swellings) and internal texture through the sound produced by beating the wheel with a special hammer to recognize inner holes or imperfections. Based on the results of the evaluation, wheels were classified as first quality, second quality, or discarded, and only those labeled as first quality received the Trentingrana denomination and were admitted to the second step (i.e., the evaluation at 18 ± 1 mo of age, which resembled exactly the procedure described previously).

The experimental unit of the study was the batch of 2 mo of production of each of 10 cooperative dairy factories from 2002 to 2008, and thus, the number of expected experimental units was 420 (10 dairy factories × 7 years × six 2-mo periods). However, because some dairy factories did not consistently produce Trentingrana over all years or seasons, or decided to sell the product before the end of ripening, the final experimental units available for statistical analysis were less (n = 386). Traits considered were the percentage of first-quality wheels of total wheels examined at 9 ± 1 (**QW_{9mo}**) and 18 ± 1 (**QW_{18mo}**) mo of ripening, and their combination [i.e., the percentage of first-quality wheels at 18 ± 1 mo of ripening of the number of wheels evaluated at 9 ± 1 mo (**QW_{tot}**)]. The QW_{tot} is very important for the Consortium because it reflects the technological and economic efficiency of Trentingrana cheese production chain. Besides the above traits, the number of associated farms, the amount of milk processed daily to obtain cheese, the number of wheels produced in a 2-mo period, and the amount of milk per milking supplied by each farm to the dairy factory were available.

Statistical Analysis

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

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

where y_{ijkl} is the dependent variable; μ is the overall intercept; DF_i is the fixed effect of the ith dairy factory (i = 1 to 10); YP_j is the fixed effect of the jth year of production (j = 2002 to 2008); SP_k is the fixed effect of the kth 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 ε_{ijkl} is the random residual $N \sim \left(0, \sigma_e^2\right)$. The season effect was classified into 6 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-mo pe-

Table 1. Descriptive statistics of production traits and first-quality wheels of Trentingrana cheese (n = 386)[1]

Item	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
Production trait						
Herds, n/dairy	38	22	8	81	0.39	−1.14
Milk, kg/herd per milking	225	150	55	639	1.15	0.10
Milk, ton/dairy per day	12.6	4.9	1.8	28.8	0.79	0.86
Wheels, n/dairy per 2 mo	1,374	610	165	3,472	0.92	0.53
First-quality wheels,[2] %						
QW_{9mo}	84.8	9.8	31.1	100	−1.56	4.00
QW_{18mo}	80.1	13.4	22.9	100	−1.10	1.35
QW_{tot}	68.9	16.4	7.1	96.7	−0.77	0.64

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

riod, 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 in 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 factory. Values of skewness and excess kurtosis were close to zero, suggesting that traits were normally distributed.

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 always higher than 0.97 and root mean square errors were lower than 10% of the mean. The number of farms conferring milk to dairy factories decreased during the studied period (data not shown) and was affected by a strong season effect (Table 2); several herds use alpine pastures in summer (June to September) and milk produced during this period is not used to obtain Trentingrana cheese. The amount of milk per milking collected from the associated herds was strongly affected by year of production; in particular, an increase was observed over years ($P < 0.001$; data not shown), confirming the process of farming intensification in Trento province. The amount of milk processed daily, as well as the number of wheels produced in a 2-mo period, were strongly affected by season of production. As mentioned above, the main reason for this effect is the practice of using alpine pastures 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 dairy factories, 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-mo period. 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

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

Item	Dairy	Year	Season	DF × YP	DF × SP	RMSE	R^2
df	9	6	5	54	45	266	
Production trait							
Herds, n/dairy	6,348***	101***	528***	9.5***	129***	1.6	0.996
Milk, kg/herd per milking	3,956***	161***	31.3***	24.9***	5.4***	14.8	0.993
Milk, ton/dairy per day	1,308***	23.2***	365***	12.0***	52.8***	0.7	0.985
Wheels, n/dairy per 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. DF × YP is the fixed interaction effect between dairy factory and year of production; DF × SP is the fixed interaction effect between dairy factory and season of production; RMSE is the root mean square error.

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

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

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

Dairy	Herds, n/dairy	Milk, kg/herd per milking	Milk, ton/dairy per day	Wheels, n/dairy per 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
J	15 ± 0.26	265 ± 2.3	8.0 ± 0.11	987 ± 18

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 a 2-mo period 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 with QW_{9mo} (12%) and QW_{18mo} (17%). Values of skewness were close to 1 and excess kurtosis had relatively small values, indicating that traits approached a normal distribution.

Factors included in the model significantly ($P < 0.05$; Table 2) explained the variability of QW_{9mo}, QW_{18mo}, and QW_{tot}. In particular, dairy factory was the most important source of variation, followed by season and year of production. The coefficients of determination were 0.57 for QW_{9mo}, 0.68 for QW_{18mo}, and 0.67 for QW_{tot}, which can be regarded as moderate to high.

Least squares means of the traits across dairy factories are shown in Figure 1. Dairy factories were ordered according to decreasing estimates of QW_{tot} and this resulted in similar trends for QW_{9mo} and QW_{18mo}. The correlation between least squares means 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). The difference between the

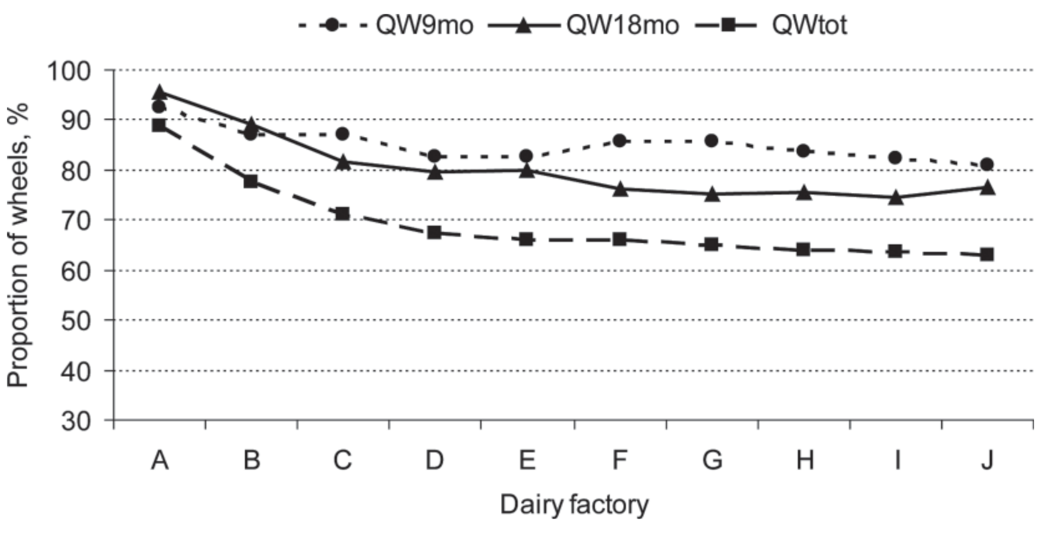

Figure 1. Least squares means of first-quality wheels of Trentingrana cheese across dairy factories. QW_{9mo} is the percentage of first-quality wheels of total wheels examined at 9 ± 1 mo of ripening, QW_{18mo} is the percentage of first-quality wheels of total wheels examined at 18 ± 1 mo of ripening, and QW_{tot} is the percentage of first-quality wheels at 18 ± 1 mo of ripening of the number of wheels evaluated at 9 ± 1 mo of ripening. Standard errors of estimates ranged from 1.2 to 3.5.

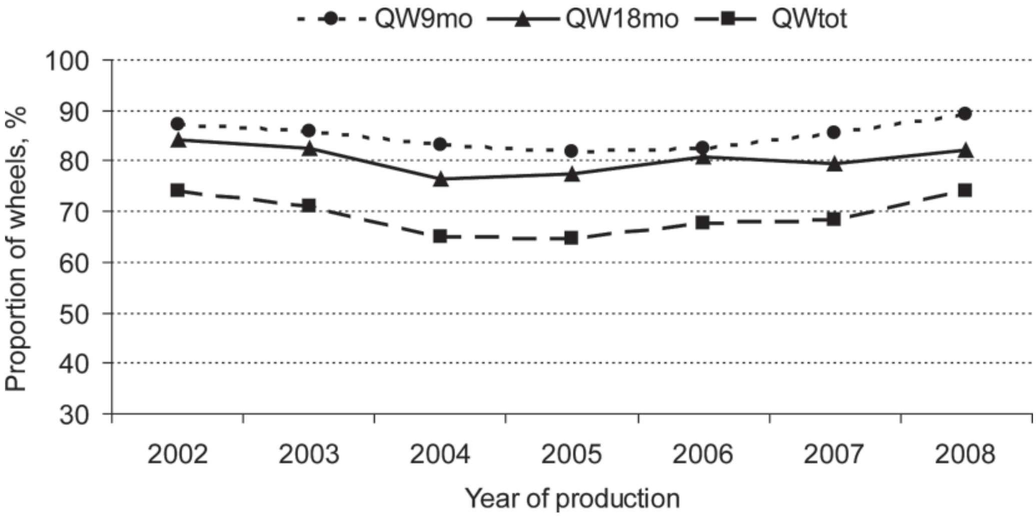

Figure 2. Least squares means of first-quality wheels of Trentingrana cheese across years of production. QW_{9mo} is the percentage of first-quality wheels of total wheels examined at 9 ± 1 mo of ripening, QW_{18mo} is the percentage of first-quality wheels of total wheels examined at 18 ± 1 mo of ripening,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

best and the worst dairy was 11.5, 21.1, and 25.6% for QW_{9mo}, QW_{18mo}, and QW_{tot}, respectively ($P < 0.001$). As reported in Table 1, about one-third of the wheels was not selected as first quality. Nevertheless, 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 and their associated farms produced less milk than the mean (Table 3). Also, they are located in different valleys of Trento Province, characterized by heterogeneous environmental conditions and proportion 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.

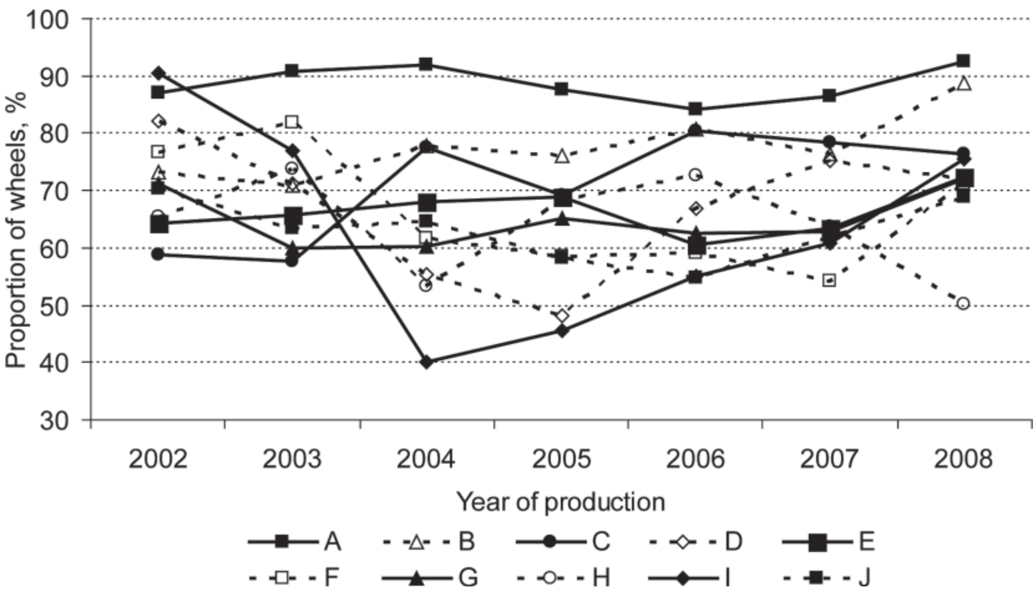

Figure 3. Least squares means of the percentage of first-quality wheels at 18 ± 1 mo of ripening of the number of wheels evaluated at 9 ± 1 mo of ripening (QW_{tot}) of Trentingrana cheese across dairy factories and years of production. Standard errors of estimates ranged from 4.7 to 12.6.

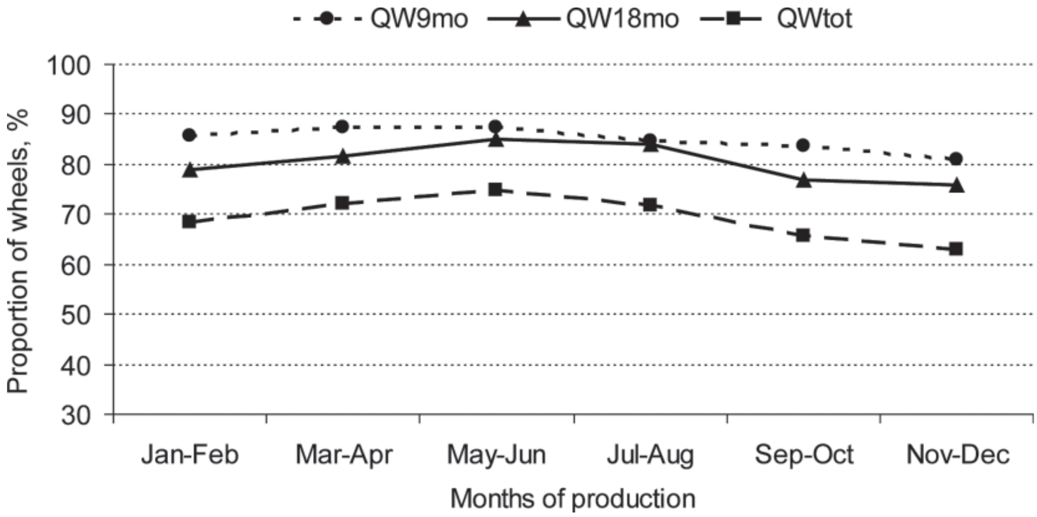

Figure 4. Least squares means of first-quality wheels of Trentingrana cheese across seasons of production. QW_{9mo} is the percentage of first-quality wheels of total wheels examined at 9 ± 1 mo of ripening, QW_{18mo} is the percentage of first-quality wheels of total wheels examined at 18 ± 1 mo of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

Dairy B is located 831 m above sea level and dairy C is located 204 m above sea level; they collect milk from 24 and 33 associated herds, respectively, rearing 50% Brown Swiss cows and 50% other breeds (mainly Holstein-Friesian).

Several studies reported that coagulation properties of milk, namely rennet coagulation time and curd firmness, are important for cheese making and the quality of the final product (Ng-Kwai-Hang et al., 1989; Martin et al., 1997; Johnson et al., 2001). They are affected by casein genotypes (Davoli et al., 1990; Comin et al., 2008; Penasa et al., 2010) and breed of cows, which can explain part of the variability among dairy factories found in our research. Also, several studies reported

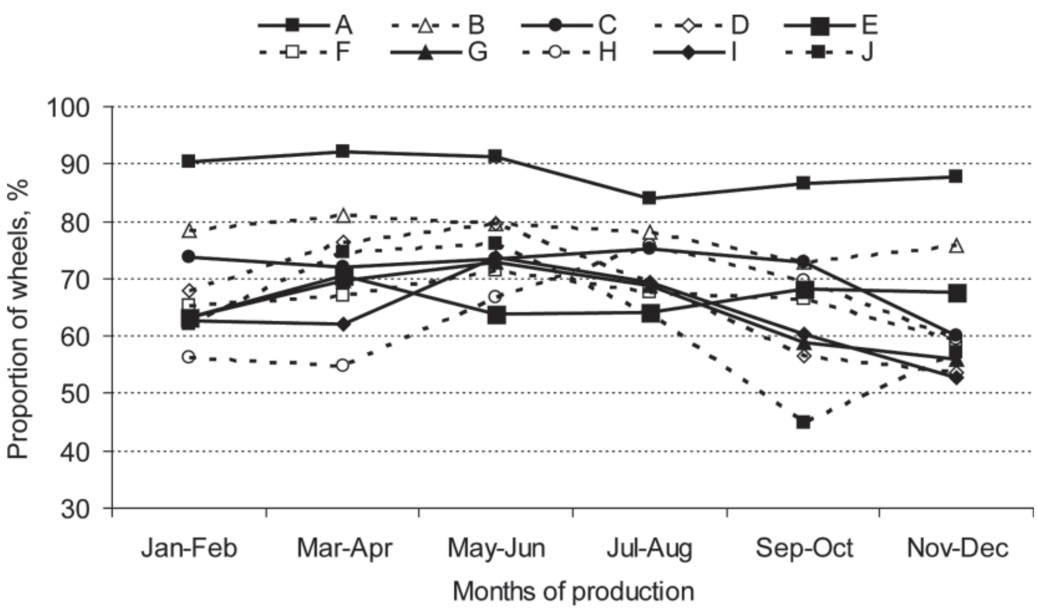

Figure 5. Least squares means of the percentage of first-quality wheels at 18 ± 1 mo of ripening of the number of wheels evaluated at 9 ± 1 mo of ripening (QW_{tot}) of Trentingrana cheese across dairy factories and seasons of production. Standard errors of estimates ranged from 4.3 to 12.8.

that a genetic basis for rennet coagulation time and curd firmness exists (Ikonen et al., 1999; Comin et al., 2005; Cassandro et al., 2008; Vallas et al., 2010) and the improvement of these traits through selection is feasible (Dal Zotto et al., 2008; Cecchinato et al., 2009; De Marchi et al., 2009).

Least squares means of first-quality wheels across years of production depicted a peculiar trend (Figure 2). In particular, QW_{9mo} and QW_{tot} decreased from 2002 to 2005 ($P < 0.01$) and recovered completely in 2008, whereas QW_{18mo} decreased from 2002 to 2004 ($P < 0.01$) and recovered in the following years, but not completely. In general, the first 4 yr led to relevant losses of production for the dairy factories, whereas years 2006, 2007, and 2008 showed an improvement of the percentage of wheels selected as first quality. Reasons for the negative trend in early years are not clear. The technology of production of Trentingrana cheese is strictly regulated by PDO label and monitored by the Consortium of Dairy Factories. The year 2003 was abnormal; a very hot and dry summer (Trento Province Weather Forecast, 2011) decreased the quantity and the quality of forages on the whole alpine region and this had an effect on 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 over the period of the study. The number of Holstein-Friesian cows has increased, whereas the trend for traditional alpine dairy and dual-purpose breeds was opposite. Moreover, the management of dairy farms has changed and the number of large herds increased. As many factors may have led to a loss of quality between 2002 and 2005, the relationship between these aspects and quality of Trentingrana cheese requires further investigation.

Results of the interaction effect between dairy factory and year of production for QW_{tot} are displayed in Figure 3. It is worth noting that the best dairy factory (A) for this trait showed also the lowest variation across years.

Least squares means of first-quality wheels across seasons of production are shown in Figure 4. All traits achieved the highest percentages in spring and summer, and the worst in autumn and winter. Opposite trends were found for quality of milk used to produce cheese, with the highest values in winter and the lowest in summer (Cologna et al., 2010). Changes of the diet, climatic factors, and relatively high concentration 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; Fernández-García et al., 2004), Cantal (Agabriel et al., 2004), Crottin (Tamagnini et al., 2006), and Asiago (Segato et al., 2007).

Results of the interaction effect between dairy factory and season of production for QW_{tot} are displayed in Figure 5. The significance found for this effect was probably because of 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 within the province. Overall, dairy factories performed better in spring and early summer than autumn, and 3 of them (A, B, and E) showed very low variation across months of production.

CONCLUSIONS

Sources of variation in the percentage of wheels selected as first quality at 9 ± 1 (mid-evaluation) and 18 ± 1 (final evaluation) mo of ripening were investigated. Dairy factory was the most important effect for the studied traits. The 3 best dairy factories for quality evaluation accounted for small traditional associated farms and produced fewer wheels of Trentingrana cheese than other dairies. A decrease in the percentage of first-quality wheels was observed between 2002 and 2005, followed by a recovery, but reasons for this trend are not well known; climatic factors and the evolution of the management and characteristics of associated dairy herds may only partially explain the changes and, hence, further research is needed. The present study supported the importance of assessing and monitoring the quality of Trentingrana PDO hard cheese and future studies will focus on the relationship between wheels selected as first quality and milk aspects.

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