Estimation of economic values for milk coagulation properties in Italian Holstein-Friesian cattle

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ABSTRACT

The economic values (EV) of production traits, rennet coagulation time (RCT, min), and curd firmness (a_{30} , mm) were derived for Italian Holstein-Friesian dairy cattle, based on the Grana Padano cheese industry. Three different sets of EV for RCT and a_{30} were estimated, assuming +2.5% (scenario 1), +5% (scenario 2), and +10% (scenario 3) increment in cheese yield due to the effect of milk coagulation properties (MCP). A model was developed to simulate the transformation of milk into Grana Padano cheese. The EV of RCT and a_{30} were –€2.213, –€4.426, and –€8.852/min, and €0.877, €1.755, and €3.509/mm for scenarios 1, 2, and 3, respectively. Relative emphasis of traits in the breeding objectives of the Italian Holstein-Friesian dairy cattle population should account for the effect of MCP on cheese yield. Economic values for milk components and MCP were affected by changes of dairy products, whereas variations of feed prices did not influence EV of RCT and a_{30} .

Key words: economic value, milk coagulation property, milk production, Italian Holstein-Friesian cattle

INTRODUCTION

Animal breeding is an economic activity based on the definition of breeding objectives that include traits aimed at improving the profit of the production system. The breeding objectives are prone to change over time, along with the trait focus and the economic perspective, and as a consequence, traits included in a selection index can also change (Groen, 1989). In this context, selection indices are continuously improved as new technologies and information become available (Shook, 2006). A breeding scheme based on progeny testing and a selection index giving large emphasis on milk, fat,

and protein production per cow were defined in Italian Holstein dairy cattle in 1985 (Burnside et al., 1992) and several changes in the selection index have occurred during the years to include functional and type traits. The economic value (EV) of a trait can be defined as the change in profit of the farm expressed per lactating cow per year, as a consequence of one unit of change in the genetic merit of the trait considered, keeping all other traits in the aggregate genotype constant (Hazel, 1943).

In Italy, the amount of cheese manufactured per year is 1,171,000 t (274,000 t are exported; ISTAT, 2011), which represents 6.1% of worldwide cheese production, and the amount of butter produced is 102,400 t (ISTAT, 2011). The Italian Holstein-Friesian is the most important dairy cattle breed and it accounts for 1,128,626 herd-tested cows reared in 12,922 farms, which means an average herd size of 87 cows. The breed is spread across the country, but 80% of animals are concentrated in the north. Italy has a peculiar and specialized structure of dairy industry, producing many high value and traditional cheeses, in particular Protected Designation of Origin (PDO) products such as the Grana Padano, Parmigiano-Reggiano, Gorgonzola, and Asiago (Pieri, 2010). Therefore, the quality of milk used for cheese production is very important in Italy and milk coagulation properties (MCP) are of particular interest (Cassandro et al., 2008). The MCP have been widely studied in recent years and have been proposed as technological traits to increase the efficiency of the dairy industry (De Marchi et al., 2008; Pretto et al., 2012, 2013). Also, MCP can be rapidly and cheaply predicted using mid-infrared spectroscopy, which allows the collection of phenotypes at the population level (De Marchi et al., 2014).

The genetic background for MCP has been investigated in several studies that have examined breed effects (De Marchi et al., 2008; Varotto et al., 2015) and exploitable additive genetic variation for the aptitude of milk to coagulate (Cassandro et al., 2008; Tiezzi et al., 2013). Moreover, Pretto et al. (2012) estimated

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the genetic responses for MCP in the Italian Holstein-Friesian dairy population under the current and alternative selection indices and breeding objectives. Those authors demonstrated the possibility of including MCP in the selection index to obtain annual genetic gains for rennet coagulation time (**RCT**) and curd firmness (**a₃₀**) without deteriorating the annual genetic response for milk, fat, and protein yields.

Few studies have estimated the effect of MCP on cheese yield under field conditions, that is, at an industry level where milk with good MCP can produce between 2 to 10% more cheese than milk with poorer suitability to coagulate (Aleandri et al., 1989; Pretto et al., 2013). Due to the importance of MCP in Italy, interest is notable to include MCP in milk payment systems and selection indices. Estimates of EV are necessary to determine the relative importance of the traits in the breeding objective (Hazel, 1943). Therefore, the aim of this study was to calculate the EV for RCT, **a₃₀**, and production traits of milk destined for the manufacture of Grana Padano cheese in Italian Holstein-Friesian dairy cattle.

MATERIALS AND METHODS

Basic Situation

Production parameters used in this study as the basic situation (Table 1) reflect the structure of the Italian dairy industry where the pure breed system is largely adopted, Italian Holstein-Friesian is the main dairy cattle breed, and Grana Padano is the most popular dairy product. The average Italian Holstein-Friesian cow reared in a typical herd of the Grana Padano area had a predicted BW of 668 kg (Cassandro et al., 1997), and a median for days open of 147 d (AIA, 2012). Average 305-d milk production, fat content, and protein content were 9,072 kg, 3.66%, and 3.31%, respectively (AIA, 2012). Mean values of MCP were retrieved from Cassandro et al. (2008) and casein content was calculated from protein content assuming a casein-to-protein ratio of 0.78 (Norman et al., 1991).

According to Pieri (2010), about 16% of total Italian milk is used to produce Grana Padano, a hard and long-ripened PDO cheese obtained from partially skimmed raw milk. The production follows a strict protocol according to European regulations (no. 2081/92 and no. 1107/96) and the Grana Padano Consortium. Full details of the cheese-making process can be obtained from Pretto et al. (2013). Briefly, after collection, the milk is stored in shallow settling tanks for about 12 h so that the fat can naturally rise to the surface (natural creaming). This process is driven to obtain a partially skim

milk with fat-to-casein ratio (**F:C**) of about 1. The cream resulting from the natural creaming is usually destined for the production of butter. Partially skim milk is then transferred to copper bell-shaped vats that contain 1,000 kg of milk and processed according to the following steps: (1) addition of natural whey starter, (2) heating of milk to 30°C; (3) addition of powder calf rennet, (4) breaking up of the curd, and (5) cooking of the curd until temperature reaches 53.5°C. Two wheels are obtained for each vat. After 2 d of drainage, the wheels are placed into brine for approximately 3 wk and then transferred to the warehouse for a minimum ripening period of 9 mo, under controlled conditions of temperature and humidity.

Profit Function

The profit per cow per year (**Π**) was calculated using the following function:

$$\Pi = R - C, \tag{1}$$

where R are revenues and C are costs per cow. In the present study, only revenues from selling of Grana Padano cheese, butter and whey, and only costs for feed related to milk production, milk collection, and cheese processing were assumed to be a function of the evaluated milk traits. All other revenues and costs on farms were not considered in the profit function because their partial derivative with respect to these milk traits is zero.

The dairy market in Europe has been restricted by a quota system, which was introduced by the European Union and was in place from 1984 to April 2015. In

Table 1. Production parameters in the basic situation

Production parameter ¹	Mean
305-d milk production, kg	9,072 ²
Fat, %	3.66 ²
Protein, %	3.31 ²
Casein, %	2.58 ³
305-d fat production, kg	332
305-d protein production, kg	300
305-d milk carrier production, kg	8,440 ⁴
RCT, min	16.90 ⁵
a ₃₀ , mm	32.00 ⁵

¹RCT = rennet coagulation time; a₃₀ = curd firmness 30 min after rennet addition.

²AIA (2012).

³Assuming a protein to casein ratio of 0.78 (Norman et al., 1991).

⁴Calculated as milk production – (fat production + protein production).

⁵Cassandro et al. (2008).

this situation, a reformulation of the profit equation should be done with the addition of a scaling factor that considers the total amount of output constant and any increase in milk or fat production per cow is then reflected by a decrease in the number of cows (Pieters et al., 1997; Wolfová et al., 2007). Currently, a market liberalization is applied in the entire European Union. For these reasons, EV were calculated in a nonquota restriction and in a nonsaturated market.

Revenues and costs from milk products were calculated as follows:

$$R = (P_{\text{cheese}} \times Y_{\text{cheese}} \times MY) + (P_{\text{butter}} \times Y_{\text{butter}} \times MY) + (P_{\text{whey}} \times Y_{\text{whey}} \times MY) \quad [2]$$

and

$$C = (C_{\text{cheese}} \times Y_{\text{cheese}} \times MY) + (C_{\text{collection}} \times MY) + C_{\text{maintenance}} + C_{\text{carrier}} + C_{\text{fat}} + C_{\text{protein}}, \quad [3]$$

where P_{cheese} , P_{butter} , and P_{whey} are prices (€) per kilogram of cheese, butter, and whey, respectively; Y_{cheese} , Y_{butter} , and Y_{whey} are yields of cheese, butter, and whey, respectively, expressed as kilogram of product per 100 kg of milk processed; MY is the annual milk production (kg) per cow; C_{cheese} are costs (€/kg of cheese) for cheese processing; $C_{\text{collection}}$ are costs for milk collection from dairy farm to dairy plant (€/kg of milk); and $C_{\text{maintenance}}$, C_{carrier} , C_{fat} , and C_{protein} are annual feed costs (€/cow) for maintenance, milk carrier, milk fat, and milk protein, respectively. Production of milk carrier per cow was calculated as total milk production minus the sum of production of fat plus protein per cow.

Grana Padano cheese industry parameters, costs, and prices considered in the present study are summarized in Table 2. Cheese yield was estimated according to the formula of Aleandri et al. (1989), modified to account for the effect of MCP on Y_{cheese} and corrected for a coefficient to calculate Y_{cheese} on full milk:

$$Y_{\text{cheese}} = [2.83329 + 0.9877 \times \% \text{Fat}_{\text{SM}} + 0.179 \times (\% \text{Protein}_{\text{SM}})^2 + \text{Eff}_{\text{RCT}} + \text{Eff}_{\text{a30}}] \times (100 - Y_{\text{cream}}), \quad [4]$$

where $\% \text{Fat}_{\text{SM}}$ and $\% \text{Protein}_{\text{SM}}$ are fat and protein contents in partially skim milk, respectively; Eff_{RCT} and Eff_{a30} are estimated effects of RCT and a_{30} on Y_{cheese} ; and Y_{cream} is the amount of cream obtained from natural creaming of full milk. The effects of MCP on Y_{cheese} were calculated using the following equations:

$$\text{Eff}_{\text{RCT}} = [(Y_{\text{cheeseB}} \times \text{Eff}_{\text{MCPmax}} \times 0.5) / (\max_{\text{RCT}} - \min_{\text{RCT}})] \times [-(\text{RCT}_B - \text{RCT})], \quad [5]$$

$$\text{Eff}_{\text{a30}} = [(Y_{\text{cheeseB}} \times \text{Eff}_{\text{MCPmax}} \times 0.5) / (\max_{\text{a30}} - \min_{\text{a30}})] \times (a_{30B} - a_{30}), \quad [6]$$

where Y_{cheeseB} is cheese yield in the basic situation (7.31 kg/100 kg of full milk); $\text{Eff}_{\text{MCPmax}}$ is the maximum effect of MCP on Y_{cheese} , assuming 3 different scenarios (2.5, 5.0, and 10%; Aleandri et al., 1989; Pretto et al., 2012); RCT_B and a_{30B} are MCP traits in the basic situation; and min and max are the minimum and maximum values for RCT and a_{30} in the population, which were set to 7.20 and 29.40 min for RCT and 4.00 and 60.00 mm for a_{30} (Cassandro et al., 2008). The same importance (50%) was attributed to RCT and a_{30} . The choice of giving the same relevance (50/50) to these traits was arbitrary in the context of the paper and the ratio can be changed according to different applications, cheese productions, or both. The minus sign before the equation for RCT is because short RCT values are desired.

The Y_{cream} was calculated as follows:

$$Y_{\text{cream}} = [\% \text{Fat}_{\text{FM}} - (\% \text{Casein}_{\text{FM}} \times F:C)] / (\% \text{Fat}_{\text{cream}} / 100), \quad [7]$$

Table 2. Grana Padano cheese industry parameters in the basic situation

Parameter	Value
Grana Padano cheese	
Type of cheese	Hard
Type of milk used	Partially skimmed
Ripening, mo	9
Fat in partially skim milk, %	2.70
Protein in partially skim milk, %	3.46
Casein in partially skim milk, %	2.70
Fat-to-casein ratio for partially skim milk	1.00
Fat in the cream, %	25
Fat in the butter, %	82
Cheese yield, kg/100 kg of milk	7.31
Cream yield, kg/100 kg of milk	4.31
Butter yield, kg/100 kg of milk	1.31
Whey yield, kg/100 kg of milk	91.37
Costs	
Milk collection, €/kg of milk	0.007 ¹
Cheese processing, €/kg of cheese	1.383 ¹
Prices, €/kg	
Cheese	7.17 ²
Whey	0.025 ³
Butter	2.83 ⁴

¹CRPA (2010).

²Average of prices retrieved from CLAL (2012) and ISMEA (2012).

³Average of prices from 2 dairy cooperatives of Veneto region (Italy) in 2012 and 2013.

⁴ISMEA (2012).

where %Fat_{FM} and %Casein_{FM} are fat and casein content of full milk, respectively (Table 1); %Fat_{cream} is the percentage of fat in the cream, assumed as 25%; and F:C was assumed to be 1.00, as suggested by Grana Padano Consortium (2011).

The amount of butter (Y_{butter}) from full milk was estimated using the following equation:

$$Y_{\text{butter}} = Y_{\text{cream}} \times (\% \text{Fat}_{\text{cream}} / \% \text{Fat}_{\text{butter}}), \quad [8]$$

where %Fat_{butter} is the percentage of fat in the butter, which was set to 82%. Finally, the amount of whey (Y_{whey}) from full milk was estimated as

$$Y_{\text{whey}} = 100 - Y_{\text{cheese}} - Y_{\text{butter}}. \quad [9]$$

Feed costs for maintenance were calculated as

$$C_{\text{maintenance}} = 365 \times [(Fm + Ac)/k_m] \times C_{\text{MJME}}, \quad [10]$$

where Fm is the fasting metabolism energy requirements per day calculated as $Fm = 0.53 \times (BW/1.08)^{0.67}$; Ac is the ME required for activity calculated as $Ac = 0.016 \times BW$; k_m is the efficiency of ME used for maintenance assumed as $k_m = 0.71$; and C_{MJME} is the cost per MJ of ME. Feed prices and energy content of the ration are reported in Table 3. The typical ration in terms of DM is based on 60% forages and 40% concentrates. The energy level of the ration was 11.06 MJ of ME/kg of DM. The costs of carrier, fat, and protein were calculated as

$$C_{\text{carrier}} = [(MCY \times 0.948)/k_l] \times C_{\text{MJME}}, \quad [11]$$

$$C_{\text{fat}} = [(FY \times 37.60)/k_l] \times C_{\text{MJME}}, \quad [12]$$

$$C_{\text{protein}} = [(PY \times 20.90)/k_l] \times C_{\text{MJME}}, \quad [13]$$

where MCY, FY, and PY are the annual productions per cow of milk carrier, fat, and protein; and k_l is the efficiency of ME used for milk production assumed as $k_l = 0.63$.

Costs for Grana Padano cheese production were retrieved from Centro Ricerche Produzioni Animali

(CRPA, 2010) and included costs for raw materials, electricity, commercialization, labor, depreciation charge, and other general expenses. The cost of processing cheese considered the standard protocol to produce the Grana Padano cheese and was estimated as 19.3% of the price of 1 kg of cheese (Table 2). Prices per kilogram of butter and whey were assumed to be 39.5 and 0.35% of the price of 1 kg of cheese, respectively. Costs for milk collection were obtained from CRPA (2010) and were included as a function of milk production.

Estimation of Economic Values and Sensitivity Analysis

The EV of trait i was obtained using (1) as the change in profit per cow per year as a consequence of one unit of change in the genetic merit of the trait i , keeping all other parameters constant. In addition, the relative contribution of trait i to the breeding objective was calculated as the relative standardized economic weight (**rEW**) according to Komlósi et al. (2010):

$$\text{rEW}_i = 100 \times |EV_i \times \sigma_{g_i}| / \sum_i |EV_i \times \sigma_{g_i}|, \quad [14]$$

where σ_{g_i} is the genetic standard deviation of trait i .

A sensitivity analysis was carried out to analyze the robustness of the EV, changing the price of dairy products or feed ($\pm 20\%$). Sensitivity of the EV was investigated by changing one input parameter at a time and recalculating the EV.

RESULTS AND DISCUSSION

Economic Model for the Grana Padano Production System

The main purpose of this work was to support a possible implementation of MCP in the selection index of the Italian Holstein-Friesian breed and contribute to decision making on diversification of the breeding goal in Italy to meet the requirements of a cheese index in a market without quota system. In the basic situ-

Table 3. Feed price and energy content of the ration assumed for dairy cows

Feed	Price, ¹ €/t	DM, ² %	ME, ² MJ/kg of DM	DM in ration, %
Alfalfa hay	132.50	86.5	8.5	30
Mix hay	110.00	85.0	9.2	30
Maize	235.40	86.0	13.8	25
Soybean	488.11	89.0	15.3	15

¹ISMEA (2012).

²AFCR (1993).

ation of Grana Padano cheese production system, the total revenue from dairy products was €5,454/cow per year, and cheese, butter, and whey contributed 89.7, 6.4, and 3.9% to this amount, respectively. The total cost was €2,485/cow per year and was composed of feed (59.4%), cheese manufacturing (38.0%), and milk collection expenses (2.6%). Therefore, the net profit of Grana Padano cheese production system was €2,969/cow per year. Considering that yearly milk production per cow was 9,338 kg, the daily net profit per animal was €0.318. Buza et al. (2014) estimated the income over feed cost (IOFC) of 1 kg of milk using data from 95 lactating dairy herds in Pennsylvania and reported an average value of €0.225. In the present study, the IOFC was €0.426/kg of milk. The greater IOFC of our work compared with Buza et al. (2014) might be explained by the added value that a PDO cheese like Grana Padano can provide respect to the milk fluid production.

Economic Values for Milk Production Traits and MCP

Economic values for fat, protein, and carrier production were positive and equal to €2.109, €8.627, and €0.027/kg, respectively (Table 4). Approximately 20 yr ago, Pieters et al. (1997) estimated negative EV for carrier and fat in Italian Holstein-Friesian under quota system. In the present study, a quota system was not considered and the EV for carrier was low but positive with rWE of 7.2%. The positive EV for the carrier can also be due to the market price of whey, which was positive and equal to €0.025/kg (Table 2). In agreement with Groen (1989), EV can change according to production and market circumstances.

Comparison of EV calculated in the present study with those reported in the literature is difficult due to differences in trait definition, methods used for deriv-

ing EV, management systems, and milk destination. Krupová et al. (2016) reported EV for fat and protein percentages in the Slovak Pinzgau breed of €29.47 and €92.71/%, respectively. In the present paper, EV were calculated for fat and protein yields, and not percentages (Table 4). However, it is worth noting that both studies attributed more emphasis to protein than fat, as suggested by the ratio of the marginal EV for fat and protein yields obtained in our study (1:4.1) and for fat and protein percentages calculated in Krupová et al. (2016; 1:3.1). Some other recent European research on different cattle populations reported ratios of the marginal EV for fat and protein contents that ranged from 1:2.2 to 1:3.7 (Wolfová et al., 2007; Komlósi et al., 2010; Hietala et al., 2014). The greater emphasis on protein content was also reported in dairy sheep breeds (Krupová et al., 2009). Finally, it is worth mentioning that the ratio of fat and protein yields of the present work (1:4.1) reflects the ratio of weights for fat and protein yields (1:4.5) in the current selection index for Italian Holstein-Friesian (ANAFI, 2012): in fact, the relative emphasis given to protein and fat yields in the index is 36 and 8%, respectively.

In Italy, the proportion of available milk destined to produce cheese is about 75% (Pieri, 2010) and thus MCP are important traits in the cheese-making process. Pretto et al. (2013) demonstrated that a_{30} was associated with Grana Padano cheese yield and concluded that MCP can be used as indicators of cheese-making efficiency in field conditions. Similar considerations were reported by Aleandri et al. (1989), Ng-Kwai-Hang et al. (1989), and Martin et al. (1997); those authors showed that milk with shorter RCT and firmer curd resulted in greater cheese yield. For these reasons, the estimation of EV for MCP is of great importance to the Italian dairy industry. In the present study, EV for RCT were negative and EV for a_{30} were positive

Table 4. Economic values (EV, €/unit of the trait) and relative standardized economic weight (rEW, %) of milk coagulation properties (MCP) and production traits¹

Trait ²	σ_g^3	0%		2.5%		5%		10%	
		EV	rEW	EV	rEW	EV	rEW	EV	rEW
RCT, min	2.22			−2.213	1.5	−4.426	2.8	−8.852	5.4
a_{30} , mm	4.06			0.877	1.1	1.755	2.1	3.509	3.9
305-d fat production, kg	33.7	2.109	21.6	2.109	21.1	2.109	20.6	2.109	19.6
305-d protein production, kg	27.1	8.627	71.2	8.627	69.3	8.627	67.7	8.627	64.6
305-d carrier production, kg	875.4	0.027	7.2	0.027	7.0	0.027	6.8	0.027	6.5

¹Different scenarios (0, 2.5, 5, and 10%) of increments in cheese yield due to the effect of MCP are presented. Relative standardized economic weight for trait i calculated as $rEW_i = 100 \times |EV_i \times \sigma_{g_i}| / \sum_i |EV_i \times \sigma_{g_i}|$ (Komlósi et al., 2010).

²RCT = rennet coagulation time; a_{30} = curd firmness 30 min after rennet addition.

³Genetic standard deviation. Values for MCP and production traits were retrieved from Cassandro et al. (2008) and Interbull (2011), respectively.

and they changed linearly moving from +2.5 to +10% increments in cheese yield due to the effect of MCP (Table 4). Also, the rEW increased from 1.5 to 5.4% for RCT, and from 1.1. to 3.9% for a_{30} , respectively, moving from +2.5 to +10% increments in cheese yield due to the effect of MCP. As a consequence, the rEW of production traits decreased and the strongest reduction was observed for protein production (71.2 to 64.6%), followed by fat production (21.6 to 19.6%) and carrier production (7.2 to 6.5%). Despite this, the protein to fat production ratio, and fat plus protein to carrier production ratio did not change as the rEW of RCT and a_{30} increased (Table 4). This is a positive result in a cheese production system where the main objective is to produce more cheese with less water to transport and process (Bangstra et al., 1988). However, in the international market of milk products, whey is often worth a value greater than zero. This is especially due to the valorization of its components such as whey proteins (Sturaro et al., 2016) and, in perspective, antioxidants and lactose, which can be extracted and commercialized as by-products with a high added value.

Sensitivity Analysis

Estimated effects of changing prices of dairy products and feed on EV for milk components and MCP are summarized in Table 5. Increasing the prices of dairy products by 20% in scenario +2.5%, led to changes of EV for fat, protein, and carrier production from €2.109 to €2.788 (+32%), €8.627 to €11.080 (+28%), and €0.027 to €0.042 (+55%) per kg, respectively. Under the same scenario (+2.5%), EV for RCT and a_{30} changed from -€2.213 to -€2.762 (-25%)/min and €0.877 to €1.095 (+25%)/mm, respectively. The variation of EV for MCP moving from scenario +2.5% to scenario +10% was linear. The reduction of prices of dairy products by 20%, led to the same percentage changes, but of opposite sign compared with those calculated for +20% price increment (Table 5).

Increasing feed prices by 20% in scenario +2.5%, reduced the EV for fat, protein, and carrier production from €2.109 to €1.848 (-12%), €8.627 to €8.482 (-2%), and €0.027 to €0.020 (-26%) per kg, respectively. When feed prices were decreased by 20%, the same percentage changes, but of opposite sign, were obtained. Economic values for MCP were not affected by changes of feed prices (Table 5). Indeed, feed costs are associated with cow BW, milk carrier, and fat and protein yields, and not with RCT and a_{30} , which are technological characteristics of milk affecting the efficiency of the cheese-making process and thus they help limiting the losses of nutrients in the whey.

Table 5. Sensitivity analysis of economic values for milk components and milk coagulation traits, changing ($\pm 20\%$) for prices of dairy products and feed, and considering different scenarios (2.5, 5, and +10%) of increments in cheese yield due to the effect of milk coagulation properties

Trait	Dairy product prices						Feed prices					
	+20%			-20%			+20%			-20%		
	2.5%	5%	10%	2.5%	5%	10%	2.5%	5%	10%	2.5%	5%	10%
RCT, €/min	-2.762	-5.524	-11.048	-1.664	-3.328	-6.656	-2.213	-4.426	-8.852	-2.213	-4.426	-8.852
a_{30} , €/mm	1.095	2.190	4.380	0.660	1.319	2.639	0.877	1.755	3.509	0.877	1.755	3.509
305-d fat production, €/kg	2.788	2.788	2.788	1.430	1.430	1.430	1.848	1.848	1.848	2.371	2.371	2.371
305-d protein production, €/kg	11.080	11.080	11.080	6.175	6.175	6.175	8.482	8.482	8.482	8.773	8.773	8.773
305-d carrier production, €/kg	0.042	0.042	0.042	0.012	0.012	0.012	0.020	0.020	0.020	0.033	0.033	0.033

¹RCT = rennet coagulation time; a_{30} = curd firmness 30 min after rennet addition.

CONCLUSIONS

In the present study, EV for production traits and MCP of Italian Holstein-Friesian dairy cattle were estimated using a profit equation. Milk was destined to produce Grana Padano cheese. Economic values for MCP were not available in the literature and their estimation is crucial to address proper selection strategies to improve coagulation traits, especially in the case of milk destined for cheese production. Therefore, relative emphasis of traits in the breeding objectives of the Italian Holstein-Friesian dairy cattle population should account for the effect of MCP on cheese yield. Overall, EV for MCP were sensitive to changes of dairy products prices, whereas they were not affected by changes of feed prices.

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REFERENCES

- AFCR. 1993. Energy and Protein Requirements of Ruminants. An Advisory Manual Prepared by the AFCR Technical Committee on Responses to Nutrients. CAB International, Wallingford, UK.
- AIA. 2012. Milk recording activity: Official Statistics. Italian Breeders Association (AIA), Roma, Italy.
- Aleandri, R., J. C. Schneider, and L. G. Buttazzoni. 1989. Evaluation of milk for cheese production based on milk characteristics and Formagraph measures. *J. Dairy Sci.* 72:1967–1975.
- ANAFI. 2012. Herd-Book Statistics 2012. Genetic Improvement–Genetic Trend for Cows. Accessed Mar. 11, 2016. <http://www.anafi.it/english/Statistics2012/pag12-13.pdf>.
- Bangstra, B. A., P. J. Berger, A. E. Freeman, R. E. Deiter, and W. S. La Grange. 1988. Economic value of milk components for fluid milk, cheese, butter, and nonfat dry milk and responses to selection. *J. Dairy Sci.* 71:1789–1798.
- Burnside, E. B., G. B. Jansen, G. Civati, and E. Dadati. 1992. Observed and theoretical genetic trends in a large dairy population under intensive selection. *J. Dairy Sci.* 75:2242–2253.
- Buza, M. H., L. A. Holden, R. A. White, and V. A. Ishler. 2014. Evaluating the effect of ration composition on income over feed cost and milk yield. *J. Dairy Sci.* 97:3073–3080.
- Cassandro, M., P. Carnier, F. Canavesi, F. Miglior, and G. Bittante. 1997. Stima di parametri genetici tra caratteri produttivi e morfologici e risposta alla selezione di indici aggregati nella razza Frisona. Pages 97–98 in *Proc. XII Natl. Congr. Sci. Assoc. Anim. Prod.*, Pisa, Italy. Centro Stampa Università di Pisa, Italy.
- Cassandro, M., A. Comin, M. Ojala, R. Dal Zotto, M. De Marchi, L. Gallo, P. Carnier, and G. Bittante. 2008. Genetic parameters of milk coagulation properties and their relationships with milk yield and quality traits in Italian Holstein cows. *J. Dairy Sci.* 91:371–376.
- CLAL. 2012. Il mercato del latte. Accessed Dec. 4, 2012. <http://www.clal.it>.
- CRPA. 2010. Costi di produzione e di trasformazione del Grana Padano in Emilia-Romagna. Opuscolo Centro Ricerche per la Produzione Animale (C.R.P.A.) Notizie 2.63-7:1–12.
- De Marchi, M., G. Bittante, R. Dal Zotto, C. Dalvit, and M. Cassandro. 2008. Effect of Holstein-Friesian and Brown Swiss breeds on quality of milk and cheese. *J. Dairy Sci.* 91:4092–4102.
- De Marchi, M., V. Toffanin, M. Cassandro, and M. Penasa. 2014. *Invited review*: Mid-infrared spectroscopy as phenotyping tool for milk traits. *J. Dairy Sci.* 97:1171–1186.
- Grana Padano Consortium. 2011. Consorzio per la tutela del Formaggio Grana Padano. Accessed Jul. 31, 2013. <http://www.granapadano.it>.
- Groen, A. F. 1989. Economic values in cattle breeding. II. Influences of production circumstances in situations with output limitations. *Livest. Prod. Sci.* 22:17–30.
- Hazel, L. N. 1943. The genetic basis for constructing selection indexes. *Genetics* 28:476–490.
- Hietala, P., M. Wolfová, J. Wolf, J. Kantanen, and J. Juga. 2014. Economic values of production and functional traits, including residual feed intake, in Finnish milk production. *J. Dairy Sci.* 97:1092–1106.
- Interbull. 2011. National Genetic Evaluation Service information. Accessed Nov. 15, 2013. <http://www.interbull.org/>.
- ISMEA. 2012. Istituto di servizi per il mercato agricolo alimentare. Accessed Oct. 1, 2014. <http://www.ismea.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/188>.
- ISTAT. 2011. 2010 Agricultural Census. Accessed Dec. 4, 2012. <http://dati-censimentoagricoltura.istat.it/?lang=en>.
- Komlósi, I., M. Wolfová, J. Wolf, B. Farkas, Z. Szendrei, and B. Béri. 2010. Economic weights of production and functional traits for Holstein-Friesian cattle in Hungary. *J. Anim. Breed. Genet.* 127:143–153.
- Krupová, Z., E. Krupa, M. Michalíková, M. Wolfová, and R. Kasarda. 2016. Economic values for health and feed efficiency traits of dual-purpose cattle in marginal areas. *J. Dairy Sci.* 99:644–656.
- Krupová, Z., M. Wolfová, J. Wolf, M. Oravcová, M. Margetín, D. Peškovičová, E. Krupa, and J. Daňo. 2009. Economic values for dairy sheep breeds in Slovakia. *Asian-australas. J. Anim. Sci.* 22:1693–1702.
- Martin, B., J.-F. Chamba, J.-B. Coulon, and E. Perreard. 1997. Effect of milk chemical composition and clotting characteristics on chemical and sensory properties of Reblochon de Savoie cheese. *J. Dairy Res.* 64:157–162.
- Ng-Kwai-Hang, K. F., I. Politis, R. I. Cue, and A. S. Marziali. 1989. Correlations between coagulation properties of milk and cheese yielding capacity and cheese composition. *Can. Inst. Food Sci. Technol. J.* 22:291–294.
- Norman, H. D., J. R. Wright, C. B. Covington, E. P. Barton, and C. A. Ernstrom. 1991. Potential for segregating milk: Herd differences in milk value for fluid and five manufactured products. *J. Dairy Sci.* 74:2353–2361.
- Pieri, R. 2010. Il Mercato del Latte. Rapporto 2010. Franco Angeli, Milano, Italy.
- Pieters, T., F. Canavesi, M. Cassandro, E. Dadati, and J. A. M. van Arendonk. 1997. Consequences of differences in pricing systems between regions on economic values and revenues of a national dairy cattle breeding scheme in Italy. *Livest. Prod. Sci.* 49:23–32.
- Pretto, D., M. De Marchi, M. Penasa, and M. Cassandro. 2013. Effect of milk composition and coagulation traits on Grana Padano cheese yield under field conditions. *J. Dairy Res.* 80:1–5.

- Pretto, D., N. López-Villalobos, M. Penasa, and M. Cassandro. 2012. Genetic response for milk production traits, somatic cell score, acidity and coagulation properties in Italian Holstein-Friesian population under current and alternative selection indices and breeding objectives. *Livest. Sci.* 150:59–66.
- Shook, G. E. 2006. Major advances in determining appropriate selection goals. *J. Dairy Sci.* 89:1349–1361.
- Sturaro, A., M. De Marchi, A. Masi, and M. Cassandro. 2016. Quantification of whey proteins by reversed phase-HPLC and effectiveness of mid-infrared spectroscopy for their rapid prediction in sweet whey. *J. Dairy Sci.* 99:68–76.
- Tiezzi, F., D. Pretto, M. De Marchi, M. Penasa, and M. Cassandro. 2013. Heritability and repeatability of milk coagulation properties predicted by mid-infrared spectroscopy during routine data recording, and their relationships with milk yield and quality traits. *Animal* 7:1592–1599.
- Varotto, A., M. De Marchi, M. Penasa, and M. Cassandro. 2015. A comparison of milk clotting characteristics and quality traits of Rendena and Holstein-Friesian cows. *Ital. J. Anim. Sci.* 14:202–206.
- Wolfová, M., J. Wolf, J. Kvapilík, and J. Kica. 2007. Selection for profit in cattle: I. Economic weights for purebred dairy cattle in the Czech Republic. *J. Dairy Sci.* 90:2442–2455.