Genetic variability of meat quality traits in Chianina beef cattle

Francesca Cecchi, Claudia Russo, Giovanna Preziuso, Dario Cianci

Dipartimento di Produzioni Animali. Università di Pisa, Italy.

Corresponding author: Dr. Francesca Cecchi. Dipartimento di Produzioni Animali. Facoltà di Medicina Veterinaria, Università di Pisa. Viale delle Piagge 2, 56124 Pisa, Italy – Tel. +39 050 3139401 – Fax: +39 050 3139433 – Email: fcecchi@vet.unipi.it

Paper received October 17, 2003; accepted February 2, 2004

ABSTRACT

The heritability of quality traits (chemical composition, colour, tenderness and water-holding capacity) of the meat deriving from three muscles (*Triceps brachii, Longissimus dorsi and Semitendinosus*) was evaluated in 92 young Chianina bulls. The animals were raised on two farms with different feeding programs, and were slaughtered at approximately 19 months of age. Single pair correlations were considered in order to evidence the relationships between the same traits detected in the three muscles and between all the traits of the same muscle.
The h^2 values range from 0.00 to 0.24 for the chemical composition, from 0.00 to 0.19 for colour parameters, from 0.03 to 0.31 for those observed after 48 h, and from 0.00 to 0.08 for tenderness and water-holding capacity. The values were not homogeneous for the three muscles. The most heritable trait was yellowness (b*48) in all three muscles, with values of 0.11 in the *Longissimus dorsi*, 0.23 in the *Semitendinosus*, and 0.31 in the *Triceps brachii*. Conversely, tenderness appeared to have a low heritability, as did the parameters relating to the water-holding capacity. Colour traits observed before and after 48 h of storage generally were significantly and positively correlated, indicating that certain colour characteristics are maintained even after 48 h of storage. There was not always a close relationship between the traits of each muscles: significant correlations existed between the *Triceps brachii* and the *Longissimus dorsi* muscles, confirming the similar quality traits of their meat, while there were considerable differences between these muscles and the *Semitendinosus*.

Key words: Heritability, Correlations, Meat quality, Chianina breed.

RIASSUNTO
IL MIGLIORAMENTO GENETICO DELLA QUALITÀ DELLA CARNE DELLA RAZZA CHIANINA: L'EREDITABILITÀ.

Numerosi studi hanno riportato stime di parametri genetici e fenotipici per l'efficienza riproduttiva, l'accrescimento, la composizione e qualità della carcassa, mentre sono molto scarse le ricerche sulla variabilità genetica della qualità della carne, per la quale si considerano preponderanti le influenze di origine ambientale. Scopo della presente ricerca è stato quindi quello di stimare l'ereditabilità dei parametri di qualità della carne della razza Chianina.
*Su tre muscoli (*Triceps brachii, Longissimus dorsi e Semitendinosus*) di 92 vitelloni Chianini, macellati a circa 19 mesi di età e provenienti da due allevamenti che adottavano diete diverse, sono stati quindi analizzati i parametri di composizione chimica, di colore, di tenerezza e di capacità di ritenzione idrica. Per evidenziare le relazioni esistenti tra tali parametri sono state impiegate le correlazioni semplici. I valori di* h^2 *ottenuti variano da 0,00 a 0,24 per la composizione chimica, da 0,00 a 0,19 per i parametri di colore, da 0,03 a 0,31 per quelli rilevati dopo la conservazione e da 0,00 a 0,08 per i parametri di tenerezza e di potere di ritenzione idrica. Tali valori non sono risultati omogenei fra i tre muscoli. Il parametro più ereditabile è risultato l'indice del giallo rilevato dopo 48 ore (b*48) in tutti e tre i muscoli, con valori di 0,11 nel* Longissimus dorsi*, 0,23 nel* Semitendinosus *e 0,31 nel* Triceps brachii*. La tenerezza sembra invece poco ereditabile, così come i parametri relativi alla capacità di ritenzione idrica. Sono da evidenziare correlazioni significative e posi-*

tive tra i parametri relativi al colore, prima e dopo conservazione, indicando che alcune caratteristiche colorimetriche si mantengono inalterate anche dopo 48 ore di conservazione in frigorifero. In questa ricerca viene inoltre confermata la differenza qualitativa tra il muscolo Semitendinosus *e gli altri muscoli analizzati. I risultati ottenuti evidenziano che non è possibile disporre, attualmente, di uno o pochi parametri di semplice determinazione, che permettano di esprimere un giudizio complessivo sulla qualità della carne, ma che sarebbe necessario identificare un indice globale che prenda in considerazione più parametri qualitativi.*

Parole chiave: *Ereditabilità, Correlazioni, Qualità carne, Razza Chianina.*

Introduction

Meat from Chianina cattle is of excellent quality (Lucifero *et al.*, 1991; Poli, 1997; Russo and Preziuso, 2000) and is highly appreciated on the domestic market (Lucifero and Giorgetti, 1980; Tartari and Benatti, 1990). However, quality traits are extremely variable and operations regarding genetic improvement as well as rearing technique should be considered. The difficulties of any steps taken in this direction are compounded by the high number of traits that determine the quality, and the need to choose the ones that are most pertinent to the evaluations. An initial approach to the problem concerns the establishing of a successful program of genetic improvement with an acceptable hereditary base for the chosen parameters. Numerous studies have reported values of genetic or phenotypic traits for reproductive efficiency, growth, composition and carcass traits (Sartore and Di Stasio, 1990; Mohiuddin, 1993; Koots *et al.*, 1994), but very little research has been carried out on the genetic variability of quality traits, which are considered to be influenced mainly by environmental factors.

Up until now therefore, the estimation of the genetic aspect of variability has not been addressed in a decisive manner, and little information is available in literature. Heritability studies have been performed almost exclusively for tenderness because it is a critical aspect of beef palatability (Morgan *et al.*, 1991; Brooks *et al.*, 2000), however they offer varying results, ranging from low to moderately high (Shackelford *et al.*, 1994; Gregory *et al.*, 1995; Barkhouse *et al.*, 1996; Wheeler *et al.*, 1996; O'Connor *et al.*, 1997; Elzo *et al.*, 1998). Johnston *et al.* (2001) reports values for heritability coefficients ranging from 0.19 to 0.39 for shear force, observed on the *Longissimus dorsi* muscle in three cattle breeds (Belmont Red, Brahman, and Santa Gertrudis). Marshall (1994) reports heritability values for Warner-Blatzler shear force ranging from 0.09 to 0.71, with an average of 0.37; similar values (h^2=0.26-0.31) were summarized by Koch *et al.* (1982), Koots *et al.* (1994) and Splan *et al.* (1998).

Recent estimates carried out on a large number of carcasses (Burrow *et al.*, 2001) showed that h^2 values for meat tenderness were 0.19 in *Bos taurus* cattle and 0.23 in both *Bos taurus* and *Bos indicus* straightbred and their crossbreds. Wheeler *et al.* (2001) reports 0.22 for tenderness in crossbred cattle, while Riley et al (2003) reported h^2 values of 0.14, 0.14 and 0.03 for shear force measured after 7, 14 and 21 days respectively. Instead, for parameters relative to colour (L*, a* and b*), Aass (1996) reports values ranging from 0.08 to 0.27.

As far as Chianina cattle are concerned, Franci *et al.* (1996) reports non-homogeneous values in the ten muscles analysed, with low heritability coefficients for the meat colour traits ranging from 0.00 for L* and b* to 0.07 for a* and medium-low coefficients for shear force on cooked meat (0.12) and free water (0.26).

Considering these uncertainties, together with the inherent risk in transferring results obtained from different breeds and breeding conditions, the aim of this work is to contribute to the knowledge of the hereditary transmission of the Chianina breed meat quality traits, by estimating heritability and correlations.

Material and methods

Animals and meat instrumental measurements and chemical analysis

Meat from three muscles *(Triceps brachii,* *Longissimus dorsi* and *Semitendinosus)* of 92 young Chianina non-consanguineous bulls raised in Tuscany on two breeding-farms was analysed. Neither the sires nor the dams of each family were related. Animals had been slaughtered at approximately 19 months of age, after attaining a live weight of about 770 kg. The farms which supplied the bulls used in the test followed different feeding systems; the first farm used corn-silage as the basic fodder, while the second provided hay.

Animals were chosen according to their genealogical data, in order to form paternal half-sib groups.

In accordance with the commercial ageing periods for Chianina carcasses, the *Triceps brachii* (TB) muscle was excised from the forequarters after about 10 days of ageing, while the *Longissimus dorsi* (Ld) and *Semitendinosus* (St) muscles were taken from the hindquarters after 19 days of ageing.

In order to assess meat quality each muscle was instrumentally analyzed (ASPA, 1991) as follows:

Meat colour, using a Minolta CR300 colourmeter (illuminant C), calibrated against a standard white tile in the CIE L*a*b* system, which measures the value of lightness (L*), redness (a*), yellowness (b*), Croma (C*) and Hue (H*) coordinates (Renerre, 1982), by making three readings for each sample consisting of a 2.5-cm thick slice of meat covered with a polyethylene film and refrigerated for 45 min. at 4°C.

Meat colour after 48 h, on the same sample kept at 4°C for 48 h to show any possible colour changes during meat storage (L*48, a*48, b*48, C*48 and H*48).

Water-holding capacity (WHC), determined using two different methods:

- Drip loss, that is the percentage of water lost from meat during storage at 4°C for 48 h in a double-bottomed plastic container;
- Cooking loss, on the meat sample used for drip loss and then cooked on a metal tray in an oven at 180°C to an internal temperature of 75°C.

Tenderness measured as the shear force (kg) using Warner Bratzler Shear applied to an Instron 1011, on 1-inch-diameter cylinders of raw and cooked meat.

Chemical analysis: dry matter (%), ether extract (%), crude protein (%) and ash (%) (A.O.A.C., 1990).

Statistical analysis

For the evaluation of the heritability, the following mixed linear sire model was performed using JMP, ver. 5.0 for PC, of the SAS Institute (2002):

$Y_{ijk} = \mu + s_i + H_j + bX_{ijk} + \varepsilon_{ijk}$ where Y_{ijk}= considered parameters; μ = overall mean; s_i = random effect of the i^{th} sire (i=1, ..., 6); H_j = fixed effect of the j^{th} herd (j=1, 2); b= regression coefficient on slaughter age in days; X_{ijk}= slaughter age in days; ε_{ijk} = residual error.

All estimates of variance components for estimates of heritability were obtained with a derivate-free REML algorithm (JMP of the SAS Institute, 2002). Because a sire model was used, estimates of ratios of sire to total variance were multiplied by four to yield heritability estimates.

Standard errors of heritabilities were approximated according to Becker (1984).

Single pair correlations were considered in order to evidence the relationships between the same trait detected in the three muscles, and between all the traits of the same muscle, as well as to estimate the correlations of colour parameters measured before and after 48h storage.

Results and discussion

Heritability

Heritability coefficients varied from 0.00 to 0.24 for chemical composition, from 0.00 to 0.19 for colour parameters before storage, from 0.03 to 0.31 for colour parameters observed after 48h of storage, and from 0.00 to 0.08 for traits of tenderness and water-holding capacity (Table 1).

For the three muscles, the heritability coefficients of the colour observed before storage were in agreement with those determined by Franci *et al.* (1996) for Chianina cattle, but lower than those reported by Aass (1996). Nonetheless, heritability coefficients improved after meat storage for 48 h at +4°C; this was especially evident in the *Triceps brachii*, for which there was an increase in values that ranged from 0.02 to 0.05 for colour parameters measured before storage and from 0.08 to 0.31 for those observed after 48h.

The most heritable trait was the yellowness measured after 48 h (b*48) in all three muscles, with values of 0.11 in the *Longissimus dorsi*, 0.23 in the *Semitendinosus*, and 0.31 in the *Triceps brachii*.

The "L*" and "L*48" parameters also gave moderately elevated values, especially in the *Semitendinosus*, with coefficients equivalent to 0.19 and 0.30 respectively.

On the other hand, tenderness had low heritability, with coefficients falling within the range reported by Barkhouse *et al.* (1996) and Riley *et al.* (2003), though not compliant with those indicated by Burrow *et al.* (2001), and other Authors (Koch *et al.*, 1982; Koots *et al.*, 1994; Splan *et al.*, 1998; Johnston *et al.*, 2001 and 2003).

Parameters relating to the water-holding capacity (drip loss and cooking loss) also appeared to have low heritability.

Correlations

Correlations among traits (Tables 2, 3, 4) confirm that the dry matter of meat is always positively linked to the ether extract (P≤0.01) and to the crude proteins (P≤0.01), while the latter two parameters are negatively correlated to each other (P≤0.01), as reported in the literature for other breeds (Russo and Preziuso, 1999).

As is to be expected, in the *Triceps brachii* and *Longissimus dorsi* muscles the parameters relating to meat colour measured before and after storage for 48 h are correlated positively with each other in a highly significant manner. This is partly explained by the fact that some of them, such as Chroma (C*) and Hue (H*), derive from the combination between the redness (a*) and the yellowness (b*); the positive correlations between lightness (L*) and the other traits were also interesting, indicating that paler meat colour is usually accompa-

Table 1. Heritability coefficients and standard error (SE) estimates for meat quality traits in the three muscles.

	Muscle					
	Triceps brachii		*Longissimus dorsi*		*Semitendinosus*	
	h^2	SE	h^2	SE	h^2	SE
Chemical composition:						
Dry matter	0.02	0.267	0.01	0.238	0.00	0.233
Ether extract	0.02	0.269	0.00	0.237	0.24	0.289
Ash	0.01	0.282	0.03	0.257	0.00	0.234
Crude protein	0.01	0.267	0.00	0.234	0.12	0.263
Meat colour:						
L*	0.02	0.269	0.02	0.260	0.19	0.277
a*	0.02	0.268	0.00	0.234	0.05	0.244
b*	0.04	0.272	0.00	0.233	0.12	0.262
C*	0.02	0.269	0.00	0.233	0.05	0.246
H*	0.05	0.273	0.05	0.246	0.05	0.245
After 48 h of storage:						
L*	0.08	0.279	0.03	0.240	0.03	0.301
a*	0.19	0.297	0.04	0.244	0.09	0.255
b*	0.31	0.313	0.11	0.259	0.23	0.285
C*	0.19	0.297	0.03	0.239	0.08	0.252
H*	0.13	0.288	0.12	0.261	0.06	0.247
Shear force:						
on raw meat	0.08	0.278	0.00	0.233	0.00	0.232
on cooked meat	0.00	0.265	0.01	0.235	0.03	0.241
Water-holding capacity:						
Drip loss	0.05	0.273	0.01	0.246	0.00	0.233
Cooking loss	0.01	0.267	0.01	0.239	0.05	0.245

Table 2. Significant correlations between parameters revealed on *Triceps brachii* muscle.

	Chemical composition				Meat colour					After 48 h of storage					Shear force		Water-holding capacity	
	Dry matter	Ether extract	Ash	Crude protein	L*	a*	b*	C*	H*	L*48	a*48	b*48	C*48	H*48	raw meat	cooked meat	Drip loss	Cooking loss
Chemical composition:																		
Dry matter	1.00																	
Ether extract	0.56**	1.00																
Ash	- 0.28**		1.00															
Crude protein	0.56**	- 0.37**		1.00														
Meat colour:																		
L*					1.00													
a*					0.31**	1.00												
b*					0.52**	0.92**	1.00											
C*					0.37**	0.99**	0.95**	1.00										
H*					0.66**	0.55**	0.83**	0.63**	1.00									
After 48 h of storage:																		
L*				- 0.22*	0.63**	0.23**	0.37**	0.27**	0.45**	1.00								
a*						0.47**	0.35**	0.45**		0.34**	1.00							
b*						0.46**	0.38**	0.45**	0.20*	0.52**	0.92**	1.00						
C*						0.46**	0.35**	0.44**		0.39**	0.99**	0.95**	1.00					
H*			0.20*		0.33**		0.22*		0.25**	0.55**		0.48**	0.21*	1.00				
Shear force:																		
on raw meat	- 0.29**					0.22*					0.22*		0.20*		1.00			
on cooked meat											0.22*		0.21*		0.52**	1.00		
Water-holding capacity:																		
Drip loss					0.24*						- 0.31**	- 0.26**	- 0.31**				1.00	
Cooking loss				- 0.21*		0.20*	0.19*	0.20*		0.21*	0.40**	0.41**	0.39**					1.00

*: P<0.05; **: P<0.01

Table 3. Significant correlations between parameters revealed on *Longissimus dorsi* muscle.

	Chemical composition				Meat colour					After 48 h of storage					Shear force		Water-holding capacity	
	Dry matter	Ether extract	Ash	Crude protein	L*	a*	b*	C*	H*	L*48	a*48	b*48	C*48	H*48	raw meat	cooked meat	drip loss	cooking loss
Chemical composition:																		
Dry matter	1.00																	
Ether extract	0.72**	1.00																
Ash			1.00															
Crude protein	0.41**	- 0.33**		1.00														
Meat colour:																		
L*					1.00													
a*					0.35**	1.00												
b*	0.21*	0.20*			0.61**	0.90**	1.00											
C*	0.21*				0.42**	0.98**	0.94**	1.00										
H*					0.78**	0.41**	0.75**	0.51**	1.00									
After 48 h of storage:																		
L*					0.83**	0.27**	0.56**	0.36**	0.76**	1.00								
a*						0.55**	0.46**	0.52**		0.23*	1.00							
b*					0.40**	0.50**	0.57**	0.54**	0.44**	0.54**	0.91**	1.00						
C*					0.20*	0.54**	0.51**	0.59**	0.24**	0.32**	0.97**	0.93**	1.00					
H*					0.73**		0.42**		0.69**	0.82**		0.49**	0.21*	1.00				
Shear force:																		
on raw meat			0.44**												1.00			
on cooked meat						- 0.18*										1.00		
Water-holding capacity:																		
Drip loss										- 0.24**				- 0.20*			1.00	
Cooking loss				- 0.22*					0.20*		0.21*	0.23*	0.23*			0.27**		1.00

*: P<0.05; **: P<0.01

Table 4. Significant correlations between parameters revealed on *Semitendinosus* muscle.

	Chemical composition				Meat colour					After 48 h of storage					Shear force		Water-holding capacity	
	Dry matter	Ether extract	Ash	Crude protein	L*	a*	b*	C*	H*	L*48	a*48	b*48	C*48	H*48	raw meat	cooked meat	drip loss	cooking loss
Chemical composition:																		
Dry matter	1.00																	
Ether extract	0.34**	1.00																
Ash			1.00															
Crude protein	0.79**	- 0.32**		1.00														
Meat colour:																		
L*	0.29**			0.33**	1.00													
a*			0.25**		- 0.22*	1.00												
b*					0.38**	0.70**	1.00											
C*			0.22*			0.98**	0.82**	1.00										
H*	0.25**			0.31**	0.78**		0.59**		1.00									
After 48 h of storage:																		
L*				0.26**	0.88**		0.38**		0.73**	1.00								
a*					- 0.24**	0.42**	0.23*	0.44**	-0.23*		1.00							
b*						0.44**	0.49**	0.48**	0.20*	0.31**	0.81**	1.00						
C*		- 0.22**			- 0.20*	0.49**	0.29**	0.44**			0.95**	0.89**	1.00					
H*					0.56**		0.24*		0.40**	0.54**	- 0.50**		- 0.47**	1.00				
Shear force:																		
on raw meat		- 0.25**													1.00			
on cooked meat																1.00		
Water-holding capacity:																		
Drip loss	0.26**	0.26*									- 0.25**		- 0.27**	0.35**			1.00	
Cooking loss																		1.00

**: P<0.05; **: P<0.01*

nied by greater luminosity, which contributes to conferring a “brilliant” aspect to the product.

In all muscles (Tables 2, 3, 4) the colour parameters measured before storage were correlated in a positive and significant manner with those evaluated after 48 h of conservation, in particular lightness (r= 0.63, 0.83 and 0.88 respectively in *Triceps brachii*, in *Longissimus dorsi* and in *Semitendinosus*).

Moreover, in the *Triceps brachii* and *Longissimus dorsi* muscles, a*, b*, and C* measured after 48 h are significantly and positively correlated with water loss after cooking.

Significant correlations between tenderness and redness (a* and a*48) and between tenderness and Croma (C*48) are only observed in the *Triceps brachii* muscle; furthermore, there is a significant and positive correlation between shear force on raw and cooked meat (r=0.52; P≤0.01).

Table 5 illustrates the correlations for each quality trait among the three muscles: as can be observed, the only parameters always correlated in a significant manner were a*48, C*48 and drip loss, while no significant correlations are recorded for b*48, H* 48, and cooking loss.

The majority of significant correlations between the *Triceps brachii* and *Longissimus dorsi* muscles confirms the similar quality traits in meat deriving from these two muscles, also in accordance with the findings of another study (Russo and Preziuso, 2000).

Conclusions

An examination of the results of heritability coefficients and correlations between quality traits led us to draw the following conclusions:

- many of the quality traits of Chianina meat are affected by somatic variability factors: only the heritability coefficients of the colour parameters observed after storage are moderately-high, the most heritable trait being the yellowness measured after 48 h (b*48) in all three muscles. The heritability values for tenderness parameters are low, indicating that their selective improvement would be slow;
- in order to improve meat quality there are difficulties involved in reducing the number of traits to be analysed: correlations are normally

Table 5. Correlation for each parameter between muscles.

	Tb[1] *vs* Ld[2]	Tb[1] *vs* St[3]	Ld[2] *vs* St[3]
Meat colour:			
L*	0.330**	0.332**	0.199
a*	0.291**	0.115	0.321**
b*	0.258*	0.009	0.181
C*	0.272**	0.083	0.259*
H*	0.221*	0.154	0.170
After 48 h of storage:			
L*	0.330**	0.196	0.121
a*	0.283**	0.315**	0.268**
b*	0.096	0.145	0.108
C*	0.246*	0.268**	0.252*
H*	0.143	0.165	0.096
Shear force:			
on raw meat	0.137	0.162	0.235*
on cooked meat	0.153	0.215*	0.198
Water-holding capacity:			
Drip loss	0.246*	0.302**	0.368**
Cooking loss	0.150	0.055	0.021

**. P<0.05; **. P<0.01.*
[1] *Tb: Triceps brachii;*
[2] *Ld: Longissimus dorsi;*
[3] *St: Semitendinosus.*

observed in each of the three muscles within the same group of parameters (i.e. composition parameters, colour parameters);
- the improvement of tenderness for the consumer is not easy either since the shear force measured on raw meat is not related to the shear force measured on cooked meat; only the *Triceps brachii* presents a positive relationship between tenderness both before and after cooking.

These results underline the fact that, at the moment, for improving quality traits of Chianina meat it is important to pay particular attention to the management problems in order to optimise the heritable fraction of the variability. Moreover, it is not possible to utilise one or two easily identified traits alone for obtaining a complex evaluation of meat quality, it is instead necessary to consider a variety of different traits.

It would be interesting to identify a comprehensive index capable of outlining the qualitative aspects, but which also shows an acceptable heritability, thus furthering prospects of genetic progress.

Research supported by "ARSIA": "Plan for the increase in value of the Tuscan bovine genetic material and meat production".

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