Genetic and Phenotypic Analysis of Meat Quality Traits in Buffalo Beef and Correlations to Carcass Composition

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Abstract: Meat quality traits in buffalo beef were examined and their genetic parameters and genetic correlations to carcass composition were estimated. Dissection was performed on 40 buffalo beef carcasses and all traits recorded for each animal, as well as the weight on muscle lungissimus dorsi (LD). The temperature and pH were recorded at 1 and 48h post-slaughter. Intramuscular fat, protein, dry matter, meat colour (redness, a*, yellowness b* and lightness L*) were recorded. Hereditability estimates ranged from 0.12 and 0.99 for dissection traits and 0.61 and 0.68 for meat quality traits, which was significant for all traits except for ultimate pH and b*. Genetic correlation with L* were negative for a* and high and positive for b*. Intramuscular fat was moderate to highly genetically correlated to the a*, b* and half hot carcass weight. The not significant genetic correlation found between several of the meat quality traits, and between meat quality traits and carcasses composition traits, suggests that the meat quality traits analyzed should be implemented into breeding programme with care since their full effect on the other traits under selection cannot be accurately estimated. For more accurate estimates, further studies that especially include a large number of records for colour meat measures are needed.

Keywords: Buffalo beef, genetic parameter, meat quality, carcass composition.

INTRODUCTION

Compared to cattle/beef in particular [1, 2] as well as swine [3, 4], very few studies have been reported on meat quality traits and their genetic parameters in buffalo beef.

The buffalo population in the Mediterranean area, typical for the climatic and cultural conditions, which includes Europe and the countries of the Near East, where the FAO Inter-Regional Cooperative Research Network on buffalo is operating, is about 5.5 million head, 3.4 percent of the world buffalo population, which is now about 168 million head.

A decrease in the number of buffaloes is occurring in some countries in the world and in Europe and the Near East (Bulgaria, Romania, Turkey) associated with three factors: holsteinization i.e. the substitution of low production cows and buffaloes with high production Holstein Friesian cows; mechanization, i.e. the substitution of draught animals with tractors and the poor market demand for buffalo products. On the contrary in Egypt, Iran and particularly in Italy buffalo numbers have increased due to the demand for particular products obtained only from buffalo milk and because the buffalo has changed from a rustic triple purpose animal to become a dairy purpose animal. However, with the advent of more and more tractors, buffalo numbers have decreased.

In countries of the Near East, where dairy cows give an average milk yield lower or similar to buffaloes, buffalo decline has not been registered and in Egypt they are still useful animals for draught. In Egypt, Iran and Azerbaijan there is a consumer preference for buffalo dairy products rather than for those derived from cow's milk. In Iran and Egypt the increase in buffalo numbers seems to be associated with a global improvement of animal production since the increase affected cattle to the same extent, whereas in Bulgaria and Turkey, alongside the consistent reduction in buffaloes, there has also been a drastic reduction in cattle. In the 2000s the average consumption of meat were 17 kg/ head per year for sub-Saharan Africa, 23 kg/head per year for Asia and 54 kg/head per year for Latin America [5] compared to an average of 76 kg/head per year in developed countries. Although a number of factors affect the long-term estimates for per capita demand for livestock products, the scenario predicted for changes in consumption patterns based on economic development has been considered [6] and the per capita demand (kg/year) for all the developing countries will increase from 25 kg in 2010 to 30 kg in 2025. It is considered that buffalo meat has a strong potential for meeting this requirement for increased per capita consumption [7]. The production of buffalo meat has high growth possibilities and poses a minimal level of risk from pesticides and veterinary drugs when compared to beef production in developed countries.

Buffalo meat is produced primarily in Asia. The contribution of buffalo meat to world total meat production is only 1.3 percent. India produces 1.43

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million tonnes of buffalo meat annually and accounts for 36 percent of total meat production contributing significantly to human nutrition.

As the meat produced is mainly from spent animals, it is coarse and fibrous. The demand for buffalo meat is high as it is relatively lean with a fat content below 2 percent and it is free from Mad Cow Disease as the animals are only fed grass and farm by-products. The functional proprieties of buffalo meat for product processing could be improved by increasing its popularity on the Indian market. For these reasons the future potential for buffalo meat and meat products is promising for India both on the domestic and international markets [8].

The quality and quantity of buffalo meat depend on many factors, the most important of which are the water buffalo type and breed, age, feeding intensity, management system and environmental conditions.

The buffalo performances for meat production i.e. growth, feed efficiency, conversion ratio, dressing percentage, carcass evaluation and composition and meat quality cuts, are very important in economic terms but the priority focus for expanding the buffalo meat market is meat quality, which means chemical, physical, organoleptic and hygienic characteristics and a good presentation to the consumer.

For some consumers, meat colour is considered a very important influence on purchasing decision, as it is used as an indication of freshness [9].

The objective of the present study was to estimate the heritability of the meat quality traits of buffalo beef and to assess the genetic correlations, both among and between meat quality and carcass composition traits of buffalo beef carcasses.

MATERIAL AND METHODS

The bulls, born and bred in a farm located near Salerno (Italy), after colostrums administration**,** received a milk replacer until weaning (10 weeks old). So until 5 months old, they received starter concentrate (from 0.9 to 1.5 kg/day), alfalfa hay (0.5 - 1 kg/day), mais silage (*ad libitum)*. Later the animals were provided ad libitum access to a concentrate fed (49% mais silage, 32% lolium, 7% alfalfa hay, 6% barley flaked and 5% soybean meal). The ration was calculated assigning .87 Meat Forage Units, 15% crude protein, 50% NDF and was supplemented with of vitaminic-mineral integrator. The animals were kept in experiment for 14 months and were slaughtered at 18 months of age.

The animals were placed in boxes with slatted floor.

During the test were recorded live weight and all measures somatic, every 28 days, depending on when the Commission suggested ASPA "Methodologies for the slaughter of farm animals and assessment of their housing" (1996).

Slaughtering and dissection were made according to the ASPA Commission [10].

The sample cut was taken from left side of sides at the 10th thoracic vertebra level, according to Lanari's indication [11]. On *Longissimus dorsi* section (LD), located between the skull margin of 9th and caudal margin of the last thoracic vertebra of right side, was executed the chemical-nutritional characteristics of meat according to the ASPA Commission [10].

The physical and chemical analyzes were performed on samples of the longissimus dorsi both raw and cooked in a water bath for 1 hour at 75 °C. It has been determined the colour, by Minolta CM-2006d on samples exposed to air for 1 hour, using illuminant D 65; the parameters considered were the brightness (L), the index of the yellow (a) of red (b) and reflectance (RA) in the visible spectrum (360-740nm) at intervals of 10 nm. It is also determined, the shear stress (WBS), using the apparatus Instron 1011 on cores of an inch in diameter and the loss of liquid to drip and cooking [10]. Determination of the reflectance was calculated the percentage of myoglobin (DMG), oxymyoglobin (OMG) and metmyoglobin (MMg) according to the instructions contained in the AMSA [12] was also calculated for the degradation of myoglobin cooking as reported in Van Laack *et al*. [13].

The chemical analyzes centesimal (dry matter, ash, protein, ether extract) were carried out on freeze-dried meat [14]; also has analyzed the amount of total collagen, by multiplying the content of hydroxyproline to 7.5, and insoluble collagen [10], and finally it was determined the amount of alkaline haematin only on the raw samples.

The temperature and pH were measured for the right side. The pH was measured using an insertion pH electrode calibrated in pH 4.01 and 7.00 pH buffer. Ultimate pH was defined from pH measures recorded 48 h post slaughter.

The identification of fixed effects and covariates were initially analyzed in SPSS [15].

The fixed effects analyzed included live weight at bird (LB) and live weight at slaughter (LS). Age at slaughter was fitted as a covariate for all traits in addition to the number of days between slaughter and dissection for carcass composition traits, the number of days between slaughter and recording of meat colour traits for a*, b* and L* and the number of day between slaughter and recording of intramuscular fat of the LD, moisture and protein. For ultimate pH measures, the order of pH recording of carcasses within groups of slaughter was included as a second covariate. Interactions of fixed effects were not examined due to the limited size of the dataset.

Model: Y_{ij} means + LB_i + LS_j + covariate + e_{ij}

Where: Y_{ij} = traits analyzed (dissection and meat quality traits)

Mean = is the general mean of Y_{ij}

e_{ij} = random residual effect

Genetic parameters for each trait were estimated using a mixed-linear animal model, including the fixed effect of LB, LS fitted as a covariate, and a random effect for buffalo. For meat colour traits, a second covariate (number of day between slaughter and recording) was included. The model was limited to one random effect because of the size of the dataset.

Heritability was estimated by univariate models and genetic and phenotypic correlations by bivariate models, by the application of restricted maximum likelihood (REML) using SPSS software.

RESULTS AND DISCUSSION

Estimate means and standard deviation (STD), min and max for traits analyzed are reported in Table **1**.

The range of pH found in this trial is considered ordinary for LD muscle following normal post-mortem metabolism. A very limited variability of ultimate pH was also reported by Page *et al*. [16] in bull.

The meat is light (42.77) with a good colour intensity, the values of chrome and hue (18.97 and 15.58) are similar to those reported in the literature [17, 18].

For other parameters the results showed in Table **1** are similar to reported in literature.

The Table **2** showed the significance of fixed effects and covariates, amount of variation described by the model (R^2) and coefficient of variation (CV) for each trait analyzed.

Table 1: Estimate Means and Standard Deviation (STD), Min and Max for Traits Analyzed

	Trait	Mean	Std	Min	Max
	LB (kg)	44.10	4.16	34	52
	LS (kg)	427.5	52.98	315.0	495.0
Dissection	pH_death	6.98	0.35	6	8
	Half hot carcass weight (kg)	116.64	16.57	82.10	143.0
	length (kg)	120.31	2.74	114.5	125.5
	Width (cm)	40.29	2.09	37.0	43.5
	Weight LD (kg)	4.21	0.58	3.31	5.5
Meat quality	Dry matter (%)	24.16	0.76	22.36	25.56
	Ash (%)	4.45	0.11	4.27	4.62
	Intramuscular fat (%)	5.11	1.19	2.45	6.60
	Protein	90.44	1.15	88.93	92.95
	L*	42.77	2.68	38.71	48.28
	a*	18.97	1.73	15.43	22.05
	b*	15.58	1.51	13.00	18.27
	Ultimate pH	5.55	0.07	5.42	5.65

Table 2: Significance of Fixed Effects and Covariates, Amount of Variation Described by the Model (R^2) and Coefficient of Variation (CV) for Each Trait Analyzed

	Trait	R^2	CV	LB	LD	Cov
Dissection	pH_death	0.59	0.12	ns	*	*
	Half hot carcass weight	0.66	274.4	ns	**	**
	length	0.23	7.49	ns	**	**
	Width	0.14	4.37	ns	ns	*
	Weight LD	0.97	0.34	ns	**	**
Meat quality	Dry matter	0.60	0.58	ns	**	**
	Ash	0.18	0.01	ns	**	**
	Intramuscular fat	0.14	1.43	ns	*	*
	Protein	0.11	1.33	ns	*	*
	L*	0.31	7.19	ns	ns	*
	a*	0.36	2.98	ns	*	*
	b*	0.11	2.27	ns	ns	*
	Ultimate pH	0.25	0.005	ns	ns	ns

For all traits analyzed in Model, a non significant effect for LB was found. For LD a significant effect was found apart from width side, L*, b* and ultimate pH.

The amount of variation described by the model (R2) varied from 0.11 for protein content and b* to 0.97 for weight LD.

The coefficient of variation (CV) was highest for half hot carcass weight. The CV for L* (7.19) was significantly higher compared to the CV of a* (2.98) and b* (2.27).

The lowest CV was found for the ph_death (0.12), ash content (0.01) and ultimate pH (0.005).

Figure **1** shows the graph of the reflectance in the visible.

Looking at the graph, for raw meat, there are a low presence of metamyoglobin (0.55%) and a good percentage of oxymyoglobin (1.25%) highlighted by a bright red colour. With the cooking have a degradation of myoglobin equal to 41.55% ± 6.16 and the presence of compounds that increase gray brown with respect to the raw meat of 28.74% ± 9.44 due to the sulfomioglobin [19].

The percentage of colour loss due to degradation of myoglobin with the baking is very low compared to that found in cattle (60%; van Laack *et al*. [13]).

In Table **3** are reported the physical determinations and spectrophotometric data for myoglobin (DMg), oximyoglobin (OMg) e di metamyoglobin (MMg) after cooking.

The amount of myoglobin, its limited degree of degradation with the cooking, the loss of fluids and good solubilization of collagen with subsequent softening of the flesh, show a good ability of buffalo meat to undergo transformation processes.

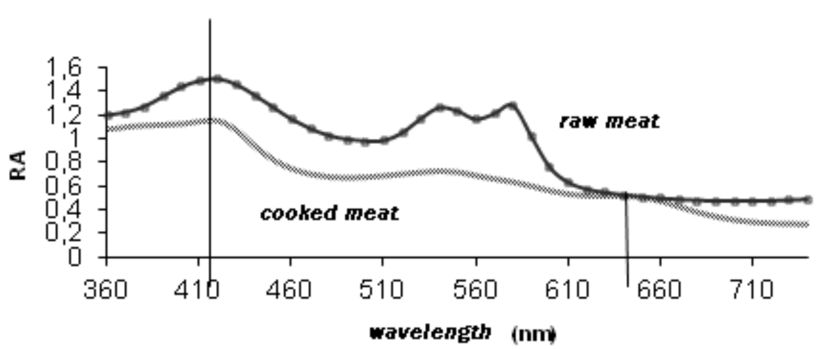

Figure 1: Graph of the reflectance in the visible.

Table 3: Physical Determinations and Spectrophotometric Data for Mioglobin (DMg), Oximioglobin (OMg) of the Metamioglobin (MMg) after Cooking

	loss of fluids %	hardness Kg	DeMg %	OMg %	MMg %
Meat raw	0.98	13.18	1.51	1.25	0.55
Meat cooking	27.77	10.31	1.15	0.73	0.52
means	14.376	11.750	1.33	0.99	0.54
se	2.265	2.791	0.51	0.060	0.037

The hardness of the meat is high and decreases with the cooking (13.18 kg vs 10.31 kg) with a good percentage of solubilization of collagen by cooking (-25% compared to raw) and a high degradation of myofibrils. Lower the loss of fluids, both on raw and cooked meat (0.98%, 27.8%) indicating a good juicy.

Table **4** reported the component of additive genetic variance ($\sigma^2_{a,}$), permanent environmental (σ^2_c), residual (σ^2_e) and estimates of heritability ± se

As shows in Table **4** the high heritability was found for all traits considerate.

The heritability for ultimate pH and b* were not significant; for other parameter was significant (P<0.01).

The study of the component of variance is the first step for the genetic evaluation of the animals and concurs to determine how much the phenotypic variable is influenced from the genetic and environmental aspects. These results pointed out that a great part of total phenotypic variation is due to the additive genetic action of the genes. Therefore, considerable genetic gain is expected if selection is applied for any trait.

In Table **5** are reported the genetic and phenotypic correlations between the meat quality traits calculated from bivariate REML analysis.

A strong positive correlation was found between a* and b* (0.635) and L* and b* (0.638). The results indicate that redder meat is darker, and lighter meat is yellows. Nothing correlation was found between the ultimate pH and colour factors, thereby suggesting that the ultimate pH is not influenced by colour characteristics.

Protein content was negatively genetically correlated to all traits considerate. Significant correlation was found between protein content and a* and b* indicated that when the protein content in meat

Table 4: Component of Additive Genetic Variance ($\sigma^2_{a,}$), Permanent Environmental (σ^2_c), Residual (σ^2_e) and Estimates of Heritability ± se

	Trait	$\sigma^2_{a,}$	σ^2_c	σ^2_e	h^2	± se
Dissection	pH_death	8.45	0.106	0.21	0.99	0.27
	Half hot carcass weight	663.0	315.7	12.5	0.68	0.10
	length	0.9	6.60	8.41	0.12	0.31
	Width	13.9	4.02	2.0	0.78	0.13
	Weight LD	0.22	0.43	0.054	0.34	3.60
Meat quality	Dry matter	1.195	0.78	0.05	0.61	1.19
	Ash	0.02	0.012	0.006	0.63	0.73
	Intramuscular fat	2.9	1.43	0.303	0.67	0.54
	Protein	2.75	1.32	0.346	0.68	0.58
	L*	14.86	7.19	1.876	0.67	0.11
	a*	6.16	2.98	2.367	0.67	0.26
	b*	4.69	2.27	0.516	0.67	0.34
	Ultimate pH	0.01	0.005	0.003	0.67	0.16

Table 5: Genetic and Phenotypic Correlations Between the Meat Quality Traits

	Protein	DM	L*	a*	b*	Ultimate pH
intramuscular fat	0.996**	0.309	0.064	0.562**	0.416*	0.182
Protein		-0.271	-0.064	-0.522**	-0.395*	-0.179
DM			-0.610**	0.335	-0.238	0.026
L*				-0.028	0.638*	-0.337
a*					0.635*	0.272
b*						-0.124

**P<0.01.
*P<0.05.

is low, the meat is reader and yellow, whereas the negative genetic correlation found between protein and the ultimate pH suggests a lower ultimate pH of the muscle when the protein level in the muscle is high.

Intramuscular fat was positively correlated with all traits, however, the genetic correlations between intramuscular fat and a* and b* were significant.

In Table **6** are reported the genetic and phenotypic correlations between the meat quality traits and the carcasses composition calculated from bivariate REML analysis.

As shown in Table **6**, intramuscular fat was moderate to highly genetically correlate to all traits considerate. These correlations reach significance for LS and half hot carcass weight. These findings suggest that an increase or decrease in carcass fat will result in a corresponding relative change in intramuscular fat.

A strong positive genetic correlation was found between DM and all traits indicating that an increase in carcass DM will increase the level of all traits. These correlations reach significance for LS, half hot carcass weight and length.

Ultimate pH was negatively related to all parameter except for length, but this relation was moderate.

Colour parameters was significantly related to a* and LS and half hot carcass weight. Hence, the weight of carcass to influence the lightness of the meat. Further, the significantly correlation between a* and LD weight shows a tendency toward a high genetic correlation, which could imply that the relative size of the LD muscle exerted a particular influence on the colour of the muscle.

CONCLUSION

The present study has shown that there is genetic correlation for meat quality traits in buffalo that allows for a selection of improved meat quality in the breed analyzed, especially for intramuscular fat and a* and b*, as both traits have moderate heritability.

The not significant genetic correlation found between several of the meat quality traits, and between meat quality traits and carcasses composition traits, suggests that the meat quality traits analyzed should be implemented into breeding programme with care since their full effect on the other traits under selection cannot be accurately estimated. For more accurate

Table 6: Genetic and Phenotypic Correlations Between the Meat Quality Traits and the Carcasses Composition

	Protein	DM	L*	a*	b*	Intramuscular fat	Ultimate pH
LS	-0.391	0.611**	-0.261	0.399*	0.123	0.425*	-0.225
LB	0.061	0.162	0.299	0.198	0.206	0.162	-0.275
Half hot carcass weight	-0.440*	0.542**	-0.174	0.413*	0.192	0.468**	-0.269
length	-0.034	0.546**	-0.256	0.037	-0.048	0.043	-0.365*
Width	-0.382	0.287	-0.123	0.098	-0.095	0.380	0.161
Weight LD	-0.185	0.387	0.078	0.434*	0.347	0.245	-0.120

**P<0.01.
*P<0.05.

estimates, further studies that especially include a large number of records for colour meat measures are needed.

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