COLOUR OF MEAT BROTH AS AN INDICATOR OF THE BEEF QUALITY

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Abstract – Meat quality evaluation does not usually include a colorimetric analysis of broths, nevertheless it has been tested how this analysis may be used to discriminate productive factors and how it is related to other analytical parameters. Samples of beef of different origin and production were characterized for quality parameters (tenderness, pH, colour, raw and cooked water holding capacity) and colour of broth. The L* and chroma measured on broth were useful to discriminate samples, but not as much as hoped. However, it is worth deepening this analysis as it can be performed simultaneously with the electronic tongue analysis.

Key Words – broth, meat quality, colour.

I. INTRODUCTION

Meat quality evaluation is important to improve meat production and a large number of analyses are available [1]. Some analyses are performed on meat liquid extract, such as pH [2], and very rarely on cooked meat broth, *eg* in microbiological analysis for food safety aims [3, 4].
In a previous research the Electronic Tongue [5] was used as an inexpensive tool for the qualitative analysis of fresh meat. Analyses were mainly conducted on meat's raw liquid extract and cooked beef broth. During the development of the EN method, it was noted how variable the colour of broth was, even within the same experimental group of beefs. This event has aroused curiosity and the work presented here is a first attempt to investigate it. It has been questioned whether the colorimetric analysis of broths may be used to discriminate productive factors and how much it is related to other analytical parameters related to the meat quality evaluation.

II. MATERIALS AND METHODS

A total of 43 beef samples were analyzed. Samples of *longissimus thoracis* were obtained from 10 Argentinean steers (Ar_S), purchased at a supermarket, and 33 Piedmontese animals. The Italian ones were 23 steers (It_S) and 10 bulls (It_B) fed on a cereal-based diet. The ten Argentinean steaks of *longissimus thoracis* were bought at different times in a great supermarket, manufactured and vacuum-packed by the same importer, and immediately frozen. It has been supposed that beef is coming from steers, the typical Argentinean production. The Italian beef samples were collected after two days from slaughtering. A 3cm thick sample of *longissimus thoracis* was collected from the left side of each carcass, between the 9^{th} and 11^{th} rib, it was vacuum-packed, aged for a total of 7d from slaughtering at 2-4°C, and then frozen.
The rheological and physical traits measured on meat were the following ones: pH, thawing loss, WHC_{trend} and its parameters, total water loss, drip loss, total cooking loss, cooking loss, cooling loss, residual water, Meat Cooking Shrinkage (MCS), fat score, tenderness and colour [6, 7, 8, 9]. When samples were used for meat analysis, they were thawed for 48h at 2-4°C. Thawing loss was measured as a percentage of the liquid out of the frozen meat lost during thawing. The meat pH was measured in laboratory using a Crison pH25+ (Crison Instruments, S.A., Alella, Spain), equipped with an electrode and an automatic temperature compensator. The drip loss was expressed as weight lost from the muscle sample (40x40x10 mm) which was kept at 4°C for 48h in a double bottom plastic container. The WHC_{trend} was determined under a compression of 500N, and measured every 15s by means of 41 visual imaged areas, during a period of 600s. Three parameters were obtained using the following equation

$$[area=k_0 + k_1*time +k_2*Ln(time)]$$

which describes the time-dependent water release over time, where: "k_0", or the intercept, is the meat area observed immediately after a compression of 250 mg started at time=0s; "k_1" is the linear coefficient that shows the slope; "k_2" is the coefficient that indicates the convexity of the

curve till the maximum height [7]. A fourth parameter was the total area (WHC_{trend} - ta) at the end of the compression. The warming losses were then measured by considering the fluid lost during 10min of cooking, until a pre-fixed internal temperature of 70°C was reached (cooking loss). Then, the cooked samples were cooled down at room temperature for 20min (cooling loss). The total cooking loss (TCL) was calculated as the sum of these two components [9]. The residual liquid available in the cooked meat (residual water) was obtained from three small cylinders (Ø 10mm), extracted from the sample used for the MCS. They were compressed to measure tenderness, according to the SRR method [6]. Each cylinder was weighed before and after compression and the difference in weight, expressed as the percentage out of the cooked cylinder weight, indicates the liquid still available to the consumer when chewing the cooked meat. MCS was measured using a Video Image Analyser:

[MCS=(raw area - cooked area)/raw area*100]

by assessing the meat area shrinkage, due to cooking and cooling [8]. The intramuscular fat marbling content was rated visually: a score of 1 was assigned to meat without marbling fat and a score of 5 to meat containing abundant marbling fat. Meat colour was evaluated by a Spectrophotometer CM-600d (Minolta Camera Co., Tokio, Japan), using a standard white tile (Illuminant D65, 10° Observer) in the CIELAB system (lightness L^*, redness a^*, yellowness b^*, Chroma or saturation index, Hue angle), by taking three readings for each sample. The sample consisted of a 1cm thick slice of meat analysed after 60min of exposure to the environmental temperature. The percentage of surface myoglobin forms (deoxymyglobin DMb, metmyglobin MMb, oxymyoglobin OMB) was estimated by spectral data obtained in the range 360-740nm in interval of 10nm [10].

The broth was obtained from the residual meat trimmed off during the rheological tests. Twenty grams of muscle were cooked in 100 mL of deionized water at 85°C for 15min in an agitator at 60rpm. After 60min of cooling, the filtered liquid was examined in colour and spectra properties in reflectance mode, by means of the Spectrophotometer CM-600d, using a 20mm deep quartz cuvette.

Statistical analysis compared the three levels (AR_S, It_S, It_B) by GLM and Canonical Discriminant Analysis (STEPDISC and CANDISC) with the software SAS/STAT SAS 9.4 [11]. The results are expressed as the estimated means (LSMean and MSE) and then compared with the Tukey-Kramer Test adjusted for multiple comparisons. Pearson correlation coefficients (r) between colour of broth and meat parameters were analyzed by PROC CORR.

III. RESULTS AND DISCUSSION

The results of the qualitative analysis on beef samples are reported in Table 1.

Table 1. Broth and meat quality parameters (LSMeans, DFE=40).

Parameters		Ar_S	It_S	It_B	RMSE
BROTH					
L^*		10.3^{b}	8.7^{bB}	15.2^{aA}	3.909
a^*		-0.60^{bB}	-0.68^{b}	-0.90^{aA}	0.203
b^*		1.4^{a}	0.4^{bB}	1.6^{aA}	0.941
Chroma		1.6^{AB}	0.9^{B}	2.0^{A}	0.806
Hue	°	118.5^{B}	155.7^{A}	140.9^{AB}	27.19
MEAT					
L^*		41.2^{B}	39.3^{B}	46.1^{A}	3.247
a^*		17.4	16.4	16.2	1.688
b^*		15.0^{b}	14.4^{bB}	17.4^{aA}	1.784
Chroma		23.0^{ab}	21.9^{b}	23.8^{a}	1.918
Hue	°	40.6^{B}	41.2^{B}	47.2^{A}	4.013
MMb	%	23.4^{A}	18.1^{B}	16.6^{B}	3.047
DMb	%	17.1^{B}	27.1^{A}	29.4^{A}	6.022
OMb	%	59.4	54.9	54.1	5.606
pH		5.5	5.6	5.6	0.121
Thawing loss	%	4.8	5.8	7.9	2.939
WHC_{trend} - k_0		714^{A}	660^{B}	650^{B}	39.05
WHC_{trend} - k_1		0.375^{A}	0.157^{B}	0.089^{B}	0.102
WHC_{trend} - k_2		67.98^{C}	82.68^{B}	100.38^{A}	11.88
WHC_{trend} - ta	mm^2	1347^{A}	1271^{B}	1340^{A}	36.21
Total water loss	%	47.0^{A}	40.9^{B}	43.3^{AB}	4.406
Drip loss	%	3.9	6.0	5.8	2.448
TCL	%	28.2^{A}	23.5^{B}	28.2^{A}	3.687
Cooking loss	%	23.4^{A}	17.4^{B}	23.3^{A}	4.325
Cooling loss	%	4.8	6.1	4.8	1.657
Residual water	%	18.8^{a}	17.3^{ab}	15.1^{b}	3.264
MCS	%	18.8	16.0	15.9	3.898
Fat score[#]	n	3.5^{A}	1.3^{B}	1.1^{B}	0.770
Tenderness	N	18.4	18.7	20.2	4.875

LSMeans by parameter in the same row with different letters are significantly different (a, b, c: P<=.05; A, B, C: P<=.01)
[#] Fat score range: 1 absent - 5 abundant fat.

The color analysis results on broths are similar to those on meat but with different significance. L^* and chroma of broth match with meat while b^* and hue are not. The a^* is significant in broths, but not

for beefs. It would appear that broth's colour measure more closely the differences among the groups as they are less dependent on the marbling.
The Argentinean beef is significantly different from IT_B and IT_S for a higher fat score, therefore the measured beef colour appears less dark, as it is impossible not to include fat in the measured area. Visually, the Argentinean meat is different from It_S, but in the meat section in Table 1 this does not appear obvious. The broth would seem to measure it with the hue significantly lower in Ar_S *vs* It_S, even if it is not significant for It_B. The % of MMb significantly higher and the DMb lower in Ar_S confirm a dull meat than in Italian meat.
Correlations with broth's colour and measured meat parameters were analysed and in table 2 those significantly (P<=.05) correlated are shown. The parameters L^*, chroma and hue are correlated among them, as you would expect, not a^* and b^*. This could be interpreted as a confirmation of what was seen with the comparison among the groups. Interestingly, the broth's hue is negatively correlated with MMb and positively with DMb. These correlations could be used to estimate these two forms of myoglobin directly from the broth.

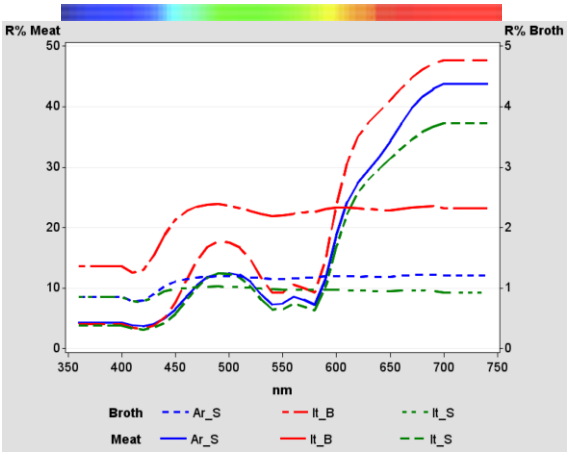
Table 2. Pearson correlation coefficients between broth and some meat parameters (N=43).

	Broth				
Parameters	L^*	a^*	b^*	Chr	Hue
Meat					
WHC_{trend} - ta	.379[a]	NS	.389[a]	.356[a]	-.382[a]
TCL	.433[A]	NS	.495[A]	.477[A]	-.342[a]
Fat score[#]	NS	.400[A]	NS	NS	-.297[a]
L^*	.333[a]	NS	NS	NS	NS
a^*	NS	NS	.358[a]	NS	-.410[A]
b^*	.357[a]	NS	NS	.295[a]	NS
Chroma	.339[a]	-.307[a]	.394[A]	.388[a]	NS
Hue	NS	NS	NS	NS	.307[a]
MMb	NS	NS	.331[a]	NS	-.607[A]
DMb	NS	NS	-.305[a]	NS	.444[A]

[a] P<=.05; [A] P<=.01)

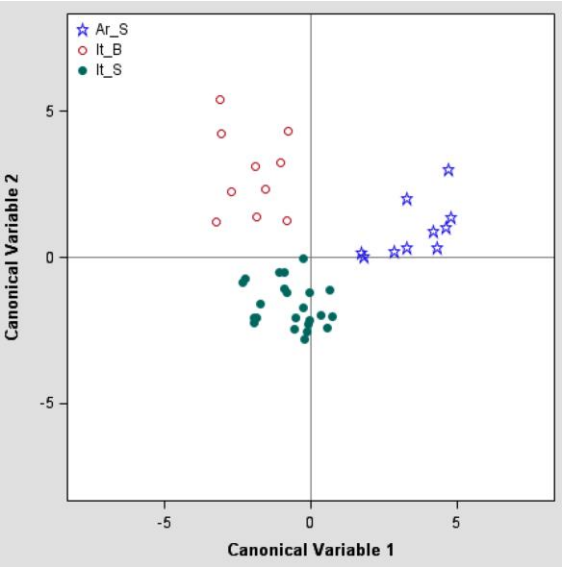
On the other hand, there is no correlation with the other parameters, such as fluid losses, cooking shrinkage and tenderness. In figure 1 the spectra of the broths and raw meats show, in a clear way, the difference among the three groups.
Canonical Discriminant Analysis (CDA) was performed to analyze the contribution of the parameters related to the broth, in order to identify the three groups. After a selection among the 28 measured parameters with the procedure STEPDISC, seven parameters were retained: "WHC_{trend}-ta" and k_1, L^* of meat, L^* and chroma measured on broth, MMb and OMb. The results of the analysis are shown in Figure 2. The clear separation is due to the fluid losses on the first axis and colour on the second axis.
The R^2 between the first canonical variable (Can1) and classificatory variable is equal to 0.816 and 0.793 with Can2. This indicates a very strong contribution of the selected parameters on the two axes. The Can1 separates the Italian beef from the Argentinean beef, in particular from bulls, and the largest contribution was due to the k_1 and L^* of broth (raw coefficient 6.8398 and 4.7150). The Can2 separates the Argentinean steers from the Italian steers thanks to chroma of broth and L^* of meat.

Figure 1. Visible spectra (Reflectance %) in broth and raw meat



Two other CDA were performed to evaluate the specific spectra ability of beef and broth in discriminating the three groups. After a selection among the 39 wavelengths measured to obtain the spectra with the procedure STEPDISC, few of them were retained. Regarding the broth, only 3 wavelengths were considered: 460, 530 e 540 nm. The R^2 between the first canonical variable (Can1) and classificatory variable is equal to 0.520 and 0.302 with Can2. For the beef 12 wavelengths were selected: 360, 410, 420, 460, 480, 490, 520, 540, 570, 580, 650 e 660 nm. The R^2 between Can1 and classificatory variable is equal to 0.927 and 0.808 with Can2.
In figure 3 is evident the greater discrimination ability of the beef's spectra compared to the broth's

Figure 2. Canonical Discriminat Analysis with contribution of two broth's parameters.



ones. However, the analysis of the broth contribution should not be underestimated, since the contribution in the overall CDA.

IV. CONCLUSION

In meat quality evaluation raw liquid extract or broth are used very rarely and the colorimetric analysis of broths was applied and analyzed how it is related to other analytical parameters.
It would appear that broth's colour measure more closely the differences among the groups as broth's colour is less dependent on the marbling. The L^* and chroma measured on broth were useful as discriminative parameters, but they were not as interesting as hoped. However, it is worth deepening this analysis as it can be integrated in the electronic tongue protocol at no additional cost and time.

REFERENCES

1. Hocquette, J. F., Botreau, R., Picard, B., Jacquet, A., Pethick, D. W., & Scollan, N. D. (2012). Opportunities for predicting and manipulating beef quality. Meat Science, 92: 197-209.
2. ASPA, C. (1996). Metodiche per la determinazione delle caratteristiche qualitative della carne. Centro Stampa dell'Università degli Studi di Perugia, Italy.
3. Apostolidis, E., Kwon, Y. I., & Shetty, K. (2008). Inhibition of Listeria monocytogenes by oregano, cranberry and sodium lactate combination in broth and cooked ground beef systems and likely mode of action through proline metabolism. International Journal of Food Microbiology, 128: 317-24.
4. Vidova, J., Drobny, J., & Sovjak, R. (2012). Selected microbiological and organoleptic changes in vacuum packed imported beef. Agricultura Tropica et Subtropica, 45: 126-133.
5. Cenci Goga, B., Ferraro, M., & Barbera, S. (2011). Electronic Tongue applied to beef quality: a first approach. In Proceedings 57th International Congress of Meat Science and Technology (P097 pp. 1-4), 7-12 August 2011, Ghent, Belgium.
6. Prandi, M., & Barbera, S. (2009). Stress resistance and relaxation: an instrumental method for the texture analysis and sensory evaluation of meat. In Proceedings 55th International Congress of Meat Science and Technology (pp. 621-626), 16-21 August 2009, Copenhagen, Denmark.
7. Barbera, S. (2009). WHC trend, a dinamic parameter based on the filter paper press method to measure water holding capacity in meat. In Proceedings 55th International Congress of Meat Science and Technology (pp. 717-721), 16-21 August 2009, Copenhagen, Denmark.
8. Barbera, S., & Tassone, S. (2006). Meat cooking shrinkage: measurement of a new meat quality parameter. Meat Science, 73: 467-474.
9. Barbera, S., & Grigioni, G. (2015). A protocol to measure the free water in raw and cooked meat. Archivos Latinoamericanos de Producción Animal, 22: 125-128. ISSN 1022-1301.
10. AMSA (2012). AMSA Meat Color Measurement Guidelines. American Meat Science Association, Illinois, USA.
11. SAS (2016). The SAS System for Windows, Release 9.4. SAS Institute Inc., Cary, NC, USA. http://support.sas.com/documentation .

Figure 3. Comparaison between Canonical Discriminant Analysis by spectra of broths and beefs.