On-line Objective Evaluation of Pork Quality

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SUMMARY: A research has been undertaken in which various methods for meat quality evaluation have been compared. The techniques employed were pH (by homogenization and by combination electrode), light diffraction, conductivity, dielectric loss factor and colour. The results have shown a very low incidence of PSE and DFD cases and a limited correlation between pH measures by homogenization and by combination electrodes. Dielectric loss factor as measured by the MS Tester, appears to be specifically suited for PSE diagnosis. On the other hand light diffraction and conductivity measured at 24h post mortem seemed to be apt for meat quality evaluation outside strict PSE. Colour measurements have given interesting hints, especially with the parameters L*, a* and Hue. Meat could, in fact, be classified by red colour (a*), type of colour (Hue) and lightness (L*).

INTRODUCTION: Industrial ways of meat production and marketing have created the need for quality evaluation techniques specifically dedicated to the demands of bulk manufacturing. The first requirement is that such techniques should be instrumental, that is objective, but other important features are the ability to deal with a great number of samples in a short time and the possibility to be employed at a very early stage of production. A research has been undertaken to evaluate the ability of some objective measurements to predict technological quality of pork at the slaughterhouse. The techniques employed were pH, light scattering, conductivity, dielectric loss factor and colour.

MATERIALS AND METHODS: The study was carried out on over 700 pigs mainly of the heavy type, that is animals of a liveweight exceeding 150 Kg. All measures were taken on M. Semimembranosus (SM) at 45' and 24h post mortem. pH has been measured by homogenization and by combined electrode. The sample (50-100g) has been homogenized in a solution of 0.01M iodoacetic acid and 0.15M KCl buffered at pH 7.0 (1/10 muscle/solution ratio)(Bendall, 1973). Combined electrode was filled with Xerolit (Ingold, 406M6 DXKS7/25). Light scattering was measured with the Fiber Optic Probe (F.O.P.)(Premier Electronics Northern Ltd, Halifax, West Yorkshire, England); conductivity with the Conductimeter LF191 Digi 550 (WTW, Munich, Germany); the dielectric loss factor with the Meat Structure Tester (M.S. Tester)(Testron, Vienna, Austria). The probes have been inserted in two places into the SM in a direction parallel to the muscle fibres for about 3 cm. Surface colour was assessed with a Minolta Chromameter Reflectance II CR100/08 used with illuminant C and an internal standard obtained with a pink tile (Gardner No CG 6625). Four measurements were taken on a fresh cut and results were expressed as C.I.E. L*a*b* (1976). Statistical analyses were performed with the S.A.S. package (1985). Results significantly different at the Scheffe' test ($P<0.05$) are accompanied by different superscripts.

RESULTS AND DISCUSSION: pH by homogenization (Table 1) has average values higher than combined electrode one. The reason is probably due to the iodoacetic acid solution and to a temperature effect (Bendall and Swatland, 1988). The measurements are linked by a correlation coefficient of 0.70. As for 24h p.m. measures, average values of homogenization and combined electrodes techniques do not differ appreciably. Correlation coefficient (0.63) is lower than at 45' p.m.. Only 1% could be qualified as PSE, 1.94% cases had a final pH >6.20. A correct evaluation of a possible "Hampshire effect" is not possible since no threshold values have been stated (Monin and Sellier, 1985). 0.83% of the cases, though, showed a final pH <5.40, while 8.16% were the samples with pH <5.50.
Light scattering measures at 45' (Tab. 1) have average values well within the normal range while at 24h p.m. values are very close to PSE threshold. At 45' 2.24% of the cases fall in the PSE class. Results at 24h p.m. show just one DFD case and 41.26% of the samples with readings belonging to what would be considered a PSE range at 45' p.m.. It has been reported (Warris et al., 1989) that light diffraction at 20h p.m. is better related to ac-

tual final pork quality than 45'. 24h FOP readings >45 (F3) were split into three groups: one (F3-1) between 45.00 and 49.99, one (F3-2) between 50.00 and 59.99 and one (F3-3) over 60.00. Such groups have been proposed by Mac Dougall (1984) for measures at 45' p.m. to indicate, respectively, intermediate quality, typical PSE and seriously PSE meat. The third of such groups (F3-3) made up 12.28% of the total, a more acceptable figure as regards real incidence of unsatisfactory meat. The same group was characterized by a low 45' pH (6.28; average value 6.55). If high measures are to be considered indicative of protein denaturation and lower water holding capacity, 24h FOP measures might be useful to evaluate "meat technological quality" besides standard PSE problems.

Average 45' p.m. values for conductivity and dielectric loss factor are placed inside the normal range (Tab. 1). Very few samples fall into the PSE class. Data collected at 24h p.m. are on average higher than corresponding 45' ones, just as FOP measures. Both intermediate and PSE-type readings are greatly increased; in the case of conductivity the latter group amounts to 13.33% while as regards dielectric loss factor the group exceeds 60% of the total. The two groups can be split in three levels ranging from what could be classified light PSE to very severe PSE. Only 1.72% among the conductimeter readings fall into the extreme class. 57.24% of the MS Tester measures, instead, fall in such a group probably for the non-linear reading scale of the instrument based on a 9 diodes system. It would seem, therefore, that the MS Tester has been studied esclusively for early PSE detection with a scale that magnifies post mortem loss of membrane functionality. In the case of the Conductimeter, instead, the use of standard units appears to put it in a position similar to FOP.

Colour measurements at 45' differ substantially from 24h ones. The latter are constantly higher, a phenomenon which can be ascribed to the "maturation process" due to the conversion of muscle to meat. Correlation coefficients between 45' and 24h measures vary from 0.57 for a* to 0.34 for L*, whith no relationship (R= 0.04) in the case of b*. The first two coefficients are significant for P<0.0001 but their actual values clearly suggest that final colour cannot be foreseen at 45'. Consequently only 24h p.m. colour measures have been kept and discussed.

A correct evaluation and understanding of colour measures is rather difficult because no international scale exists for the instrument here adopted. Murray and Jones (1988) have published data on Longissimus dorsi colour obtained with a Minolta Chromameter II at 24h p.m. and have related them to subjective pork quality standards. In their work PSE meat is associated with high L* and b* values and, as meat moves towards DFD, all values decrease but the one which decreases most is b* (over 5 times). The data (Tab. 2) suggest the existence of a few cases with extreme values. That is, for instance, high L* measures, very low a* and Chroma, elevated yellow tones (high Hue). It was decided to take a closer look at the extreme cases. These were chosen arbitrarily by creating two subgroups, one of which corresponded to the samples belonging to the lower 5% of the total samples (i.e. from 0 to 5%) and the second one made by the higher 5% (i.e. from 95 to 100%). The samples belonging to the lower 5% do not show any distinctive feature with the only exception that low L* values seem to be linked with low b* and Hue values. In the case of the upper 5%, instead, L* values came out to be associated with 45' pH below and with FOP, MS Tester, Conductimeter, b* and Hue measures clearly above the general means. Similar features can be found with b*, while high Hue is clearly linked only with elevated L* values; very high Chroma and a* measures appear to go along with extremely high levels of light scatter and moderately high conductivity. It is interesting that L* and b* higher than 95% fall within classes 1/1 and 2/2 of Murray and Jones (1988).

Correlation coefficients between measures of pH, light scattering and electrical parameters, when existing, are rather low. The reason lies probably in the extremely low incidence of PSE and DFD observed in this research. Similar consideration have been put forward by Dubois et al. (1988) and can also be recognized in the curvilinear relationships mentioned by Bendall and Swatland (1988)(Tab. 3,4).

As for the relationship existing between colour and the other measures most of them are rather weak. Some, though appear to be interesting (Tab. 4). Among them are those linking light scattering with a*, b* and Chroma on one side and those between L* and b* and Hue on the other. The latter ones can be interpreted to substantiate what has been said during the discussion on colour measures. On this subject it can be observed that b* is related with L* and a* while a* is not related with L*. The b* coordinate, therefore, appears to be able to express both the cromatic (like a*) and the lightness (or exudative) aspects of meat colour (like L*). This is probably the reason why the balance between a* and b* (Hue) can be as much, or more, important of L* for the evaluation of meat quality.

The results have been discussed, also, use of Principal Component and Cluster analyses performed on measures of colour at 24h p.m. and of homogenization pH, light scattering and conductivity at 45' and 24h p.m.. In this way a set made up by 4 Principal Components (PC) was able to explain 78.3% of the variance. Eigenvectors (Tab. 5) show that colour measures, are very important in PC1 and PC2, followed by light scatter, conductivity and pH at 24h p.m.. Measures taken at 45' prevail over the 24h ones in PC3 and PC4, but, among the latter, conductivity and pH are not negligible.

The whole sample was divided in 5 Clusters (Tab. 6). Cluster 2 has low 45' pH, high 45' light scatter and conductivity, moderately high 24h FOP, high L* and a tendency of the remaining colour parameters to be slightly higher than average. Cluster 3 is characterised by high 24h pH associated with low 24h FOP and low colour attributes. Cluster 4 presents the highest values of light scatter and conductivity at 24h and of a*, b* and Chroma. Cluster 1 and 5 are very similar for all variables except colour; the differences being evident in the case of L*, a*, b* and Hue. Cluster 5 probably rapresents meat of top quality, Cluster 2 the worst one followed by Cluster 1 (for L*, a* and Hue) and 4 (for FOP and Conductimeter 24h). Cluster 3, to a great extent, is made up by animals treated with a beta-agonist, a specific case in which final pH was a little high and meat was pale.

Cluster analysis was applied, also, on a set made up only by 24h pH and colour (Tab. 7). The peculiar features of such a partition are: the disappearance of a Cluster based on 45' pH; the presence of a Cluster (n.2) very similar to Cluster 3 of the previous analysis (high final pH and pale meat); Cluster 1 (high L* and Hue, low a* and Chroma) which recalls the earlier one with the same number; Cluster 3 reminiscent of Cluster 4, the nearly complete coincidence of Cluster 4 with the preceeding Cluster 5; the appearance of a Cluster (n.5) characterised by high light scatter, conductivity, L* and Hue.

CONCLUSIONS: The research has shown the limited importance of PSE and DFD phenomena in heavy pigs. The measures performed, though, appear to suggest the possibility of evaluating meat quality outside such standard cases. Some interest could lie in 24h measures of light scatter and conductivity when falling in the upper range of the scale.

The Meat Structure Tester does not seem to be usefull outside standard PSE detection. Colour measures at 24h p.m. have a good potential in meat quality grading as they are able to classify meat on the basis of colour intensity per se , type of colour and lightness.

REFERENCES: BENDALL J.R. (1973) In "Structure and function of Muscle", ed. G.H.Bourne, 2°Edit., Vol. II, part 2, 243-309. BENDALL J.R., SWATLAND H.J. (1988) Meat Science, 24, 85-126. C.I.E. (1976) mentioned by McLaren (1980). DUBOIS M., ZERT P., CARIOU N., JOANNIC P. (1988) Journées de Rech. Porc. France, 20, 221-226. MacDOUGALL D.B. (1984) Proc.Meet."Biophysical PSE-Muscle analysis", Vienna 26-27 Aprile, 162-168. McLAREN K. (1980) In "Developments in food colours", Applied Science Publishers, London, 27-45. MONIN G., SELLIER P. (1985) Meat Science, 13, 49-63. MURRAY A.C., JONES S.D.M. (1988) In "Pork quality: a technical review" by Jones S.D.M., Murray A.C., Sather,A.P., Jeremiah L.E., Greer G.G.; Technical Bulletin 1988-11E, Lacombe Technical Bulletin No 2, Agriculture Canada, Research Branch, 3-8. SAS (1985) SAS User's Guide: Statistics, SAS Institute Inc., Box 8000, Cary, North Carolina 27511-8000. WARRIS P.D., BROWN S.N., LOPEZ-BOTE C., BEVIS E.A., ADAMS S.J.M. (1989) Meat Science, 25, 281-291.

Table 1. Summary of the data collected with the measurements of pH, light scattering (FOP), conductivity (COND) and dielectric loss factor (MS) at 45' (1) and 24h (2) post mortem. pHO= by homogenization; pHC= by combined electrode

	pHO1	pHC1	pHO2	pHC2	FOP1	FOP2	COND1	COND2	MS1	MS2
Mean	6.55	6.40	5.68	5.70	26.45	44.68	3.93	6.57	3.48	28.09
S.D.	0.24	0.29	0.17	0.12	6.93	12.37	1.76	2.65	5.71	18.03
Minim	5.60	5.40	5.32	5.53	15.00	18.00	2.05	1.52	2.30	2.30
Maxim	6.99	6.71	6.97	6.46	67.20	86.40	23.37	12.68	43.00	43.00
PSE%	1.00				2.24	41.26	2.09	13.33	3.18	66.44
DFD%			1.94			0.16				

Table 2. Colour measures at 24h post mortem.

	L*	a*	b*	Hue	Chroma
Mean	48.30	8.53	4.81	0.51	9.85
S.D.	3.81	1.79	1.26	0.11	1.92
Minim	37.59	1.94	1.99	0.25	2.90
Maxim	61.01	14.65	8.99	1.07	16.30

Table 3. Correlation coefficients between 45' p.m. measures

	FOP	COND	MS
pHO		-0.225***	
FOP		0.304***	0.366***
COND			0.434***

Table 4. Correlation coefficients between 24h p.m. measures

	FOP	COND	MS	L*	a*	b*	Hue	Chroma
pHO	-0.213***				-0178***	-0.181*		-0.200***
FOP		0.396***	0.452***	0.339***	0.415***	0.365***		0.452***
COND			0.768***	0.417***	0.210***	0.213***		0.244***
MS				0.116*	0.252***	0.158**		0.271***
L*						0.616***	-0.671***	0.191***
a*						0.456***	0.322***	0.950***
b*							-0.640***	0.694***

Table 5. Principal Component Analysis. Eigenvectors

	PC1	PC2	PC3	PC4
pHO45'	-0.028	-0.120	-0.489	0.422
FOP 45'	-0.084	0.021	0.509	0.451
COND 45'	-0.057	0.018	0.615	0.277
pHO24h	-0.215	0.099	0.053	-0.445
FOP 24h	0.387	-0.065	0.227	-0.093
COND 24h	0.291	0.145	0.206	-0.476
L*	0.293	0.516	-0.014	-0.049
a*	0.422	-0.413	0.005	0.007
b*	0.448	0.247	-0.103	0.230
Hue	0.489	-0.256	-0.032	0.078
Chroma	0.068	0.622	-0.119	0.215

Table 6. Cluster analysis: average values of the quality parameters for each Cluster (All variables)

	CL 1	CL 2	CL 3	CL 4	CL 5
Incid.%	20.75	5.54	10.06	29.06	34.59
pHO1	6.60a	6.20c	6.47bb	6.52ab	6.62a
pHO2	5.67b	5.64b	5.99a	5.64b	5.63b
FOP1	25.28b	55.40a	27.19b	26.03b	25.83b
FOP2	42.10c	49.27b	32.28d	56.19a	41.43c
COND1	3.64b	14.84a	3.88b	3.86b	3.65b
COND2	6.96ab	6.05b	5.91b	8.26a	5.42b
L*	51.23a	52.33a	45.88c	46.92b	45.23c
a*	6.93c	8.21b	6.72c	10.23a	8.65b
b*	5.03b	5.31b	3.56d	5.97a	3.99c
Hue	0.63a	0.57b	0.49c	0.53c	0.43d
Chroma	8.60c	9.82b	7.64d	11.88a	9.55b

Table 7. Cluster analysis: average values of the quality parameters for each Cluster (24h pH and Colour)

	CL 1	CL 2	CL 3	CL 4	CL 5
Incid.%	12.35	7.93	22.55	35.26	21.91
pHO1	6.58a	6.49a	6.57a	6.56a	6.55a
FOP1	26.37a	26.02a	25.49a	27.22a	26.27a
COND1	3.55a	4.11a	3.77a	4.12a	3.92a
pHO2	5.69b	6.06a	5.64c	5.64c	5.64bc
FOP2	39.44b	32.70c	51.76a	43.18b	48.96a
COND2	6.06bc	5.82c	7.19ab	6.08bc	7.61a
L*	51.10b	45.41d	48.00c	45.74d	52.21a
a*	5.88e	7.07d	10.75a	8.28c	8.75b
b*	4.47c	3.60e	5.48b	3.93d	6.21a
Hue	0.65a	0.48c	0.47cd	0.44d	0.62b
Chroma	7.43e	7.96d	12.09a	9.19c	10.75b