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Preliminary investigation of the use of digital image analysis for raw ham evaluation

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ABSTRACT: In order to find objective parameters for the evaluation of pig thighs to be used for PDO processing, digital images of the external surface of 384 left thighs were acquired, to be used for multivariate image analysis. The following parameters were also measured on the same samples: weight, length, circumference, thickness of fat and thigh, globosity index and colour of skin. Moreover, a subjective evaluation of veining and red skin defects was also made by an expert assessor. Multivariate analysis of the digital images showed a separation of the analysed samples in two clusters, whose differences were then investigated on the basis of the other traits. Various differences between the two clusters where found, mainly for the size-related parameters.

Key words: Parma ham, Defects evaluation, Digital images, Multivariate analysis.

INTRODUCTION - The evaluation of qualitative characteristics of fresh pig thighs to be used for processing, is assuming paramount importance in the PDO dry-cured ham production. In fact, this can offer the possibility of performing *a priori* classification and of finding any defects or imperfections that could influence the final quality of the seasoned product. At present, evaluation is based on weight measurements and on subjective estimations, expressed by expert inspectors at the moment of trimming. In the last years, the number of defects found at trimming has increased (Lo Fiego *et.al*., 2003; Lo Fiego *et al*., 2006; Nanni Costa *et al*., 2005; Russo *et al*., 2003; Tassone *et al*., 2006), thus the need of automated evaluation methods, giving objective parameters possibly at low costs, is becoming increasingly urgent. Digital image analysis could represent an opportunity in order to evaluate objectively some characteristics of raw hams. This tool has already been used to evaluate pork colour (Tan *et al*., 2000) and dry-cured ham characteristics (Carnier *et al*., 2004), while Antonelli *et al*. (2004) developed a new method for the classification of pesto sauce on the basis of its colour, as evaluated by multivariate analysis of digital images. Following this latter approach, in the present work, which is part of a wider research project aiming to develop objective evaluation methods of raw ham, we preliminarily tested the applicability of an automated digital image-based colour analysis of pig thighs photographs taken at trimming, in a controlled environment.

MATERIAL AND METHODS - For this study, 384 left thighs destined to the Parma ham dry-curing production, coming from heavy pigs slaughtered in two plants during 10 different days, were used. After 24 hours of cooling at 0-4°C, on each thigh the fat thickness beneath the femur head was measured, and after trimming the thigh was weighted and subjected to the evaluation of veining and red skin defects by an expert assessor, which used photographic scale as reference standard (Russo *et al*., 2003; Lo Fiego *et al*., 2006). Moreover, some morphological characteristics like length, circumference and thickness were measured, and the globosity index was calculated following Bertolini *et al*. (2003). The skin colour was also measured on each thigh as reported by Lo Fiego *et al*. (2006). Then, by means of a Nikon Coolpix 5400 digital camera equipped with a lens with 5.8-24 mm focal length (Nikon corp., Tokyo, Japan), digital images of both the external and internal surface of the thighs were acquired. In the present study only image of external thigh surface was considered. With the aim of having as much as possible con-

stant and homogeneous lighting conditions, the camera was mounted on a white painted wooden box equipped with 8?25W tungsten lamps, where each raw ham was placed in order to be photographed. Digital images were taken in JPEG format with a spatial resolution of 2592?1924 pixels, using white balance, with a 1/125s shutter speed and an f/5.6 lens aperture. Each digital image was then used as input to the algorithm described by Antonelli *et al*. (2004), which leads to an output corresponding to a monodimensional signal named colourgram, which bears all the colour-related information of the original image. Each one of the 384 colourgrams obtained from the corresponding images and composed by 4900 points, was considered as a separate object and analysed by means of Principal Component Analysis (PCA). This procedure was adopted in order to check if the representation of the digital images in the colourgrams space could highlight some distinctive characteristics of raw ham. ANOVA was then used in order to evaluate the results of multivariate image analysis in terms of differences for the other considered parameters. All calculations were performed by means of Matlab ver. 6.5 (MathWorks Inc., Natick, MA, USA) and of PLS Toolbox ver. 3.5 (Eigenvector Research Inc., WA, USA).

RESULTS AND CONCLUSIONS – Figure 1 reports the scores plot of the first two Principal Components (PCs) obtained by PCA applied to the colourgram matrix, where the analysed samples are clearly separated in two distinct clusters, represented with different symbols. Considering the high number of original variables (each colourgram is composed by 4900 points), the variance explained by these two PCs, which is about 26% of the total variance, is a considerable amount. Moreover, it must be underlined that the same clusters are also present in some further PCs. The reasons for this grouping of the 384 colourgrams were then investigated by means of ANOVA applied to the morphological and quality parameters of the same thighs.

Figure 1. Scores plot of the first 2 PCs obtained by PCA performed on the colourgrams matrix

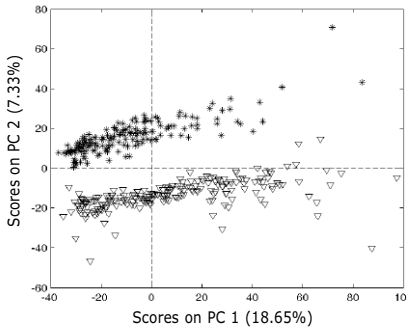

Table 1 reports the mean values of ANOVA results. No difference is observed relatively to the carcass weight and carcass lean meat content estimated by Fat o Meater, while trimmed thighs of cluster 1 show higher mean values of weight, circumference, length and of the thigh/total image surface ratio. Conversely, for the same cluster fat thickness and globosity index result to be lower. Cluster 1, where the average weight of the trimmed ham is higher, includes a higher percentage of thighs with weight > 14.8 kg (27.7 *vs.* 20.1%), which is considered to be not optimal for Parma ham production. Instead, the percentage of thighs belonging to the 12-14.8 kg weight class, which is ideal for this kind of production, is higher for cluster 2 (71.8 *vs.* 69.4%); however, also the percentage of thighs in the 10-12 kg weight class, which is included in the PDO limits though not optimal, is higher for cluster 2 (7.5 *vs.* 2.4%) (data not shown in table). Relatively to the qualitative traits, the skin colour of thighs of cluster 2 shows lower mean values of b*, indicating a lower yellowness, and a higher mean value of both red skin and veining defects. Thighs of this cluster, therefore, with lower mean values of the weight-related characteristics in comparison to those of cluster 1, show, on the average, higher globosity index values and higher incidence of the evaluated defects. Globosity index represents a relevant parameter for Parma ham dry-cured production, and the observed values, for both the clusters, lie within the limits suggested by some Authors (Bertolini *et al*., 2003). However, the higher incidence of both veining and red skin defects in correspondence of a higher mean globosity index value, supports, in an objective manner, the empirical considerations made since a long time by the experts of pig industry, relatively to a lower processing suitability of the most globose thighs. It must be stressed out that the results obtained in this

preliminary phase do not allow a classification of the analysed thighs, but the multivariate image analysis made by means of colourgrams allowed the subdivision of thighs in two groups, whose mean values of many parameters (mainly those related to dimensions) are significantly different. Future efforts will be made with the aim of evaluating the applicability of a classification of the raw ham defects, applying proper multivariate classification algorithms to the colourgrams obtained also from the images taken from the internal thigh surface.

Table 1. Carcass and thigh traits in the two clusters.

		Mean		P	MSE[1]
		Clust. 1	Clust. 2		
Carcass weight	Kg	134.40	132.72	0.19	12.56
Lean meat content	%	49.84	49.60	0.56	3.95
Left thigh:					
- trimmed weight	Kg	14.16	13.76	<0.01	1.23
- thickness	cm	18.52	18.64	0.34	1.16
- circumference	"	88.78	86.01	<0.01	4.18
- length	"	48.92	47.97	<0.01	2.02
- fat thickness	"	2.98	3.17	0.01	0.75
- globosity index		1.10	1.13	0.02	0.11
- surface ratio[2]	%	64.46	63.66	0.06	4.06
- skin colour:					
L*		64.72	64.32	0.26	3.44
a*		10.50	10.63	0.66	2.56
b*		10.15	9.71	<0.01	1.26
- red skin defect (mean value)[3]		1.84	2.01	0.01	0.68
- veining defect (mean value)[4]		2.28	2.42	0.05	0.72

[1]:382 d.f.; [2]:n. of pixels of thigh surface/n. of pixels of total image; [3]:Score: 1= no defect, 2=light, 3=serious; [4]: Score: 1= no defect, 2=light, 3=evident, 4= serious;

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