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M. Bianchi[1], M. Petracci[1], M. Pascual[2], C. Cavani[1]

[1] Dipartimento di Scienze degli Alimenti. Università di Bologna, Italy
[2] Departamento de Ciencia Animal. Universidad Politécnica de Valencia, Spain

Corresponding author: Maurizio Bianchi. Dipartimento di Scienze degli Alimenti. Università di Bologna. Piazza Goidanich 60, 47023 Cesena (FC), Italy - Tel. +39 0547-338128 - Fax: +39 0547-382348 - Email: maurizio.bianchi@unibo.it

ABSTRACT - A study was conducted to compare Allo-Kramer (AK) and Warner-Bratzler (WB) devices to evaluate rabbit meat texture and to assess their correlations with sensory tenderness. Meat samples characterized by a wide range of tenderness were prepared by boning *longissimus lumborum* muscles from 90 carcasses at different *post mortem* times (1, 3, 24h). The right loin of each carcass was used for WB and AK tests, whereas the left loin to assess sensory tenderness and juiciness. The sensory test indicated a higher tenderness and juiciness of rabbit meat obtained from carcasses boned at 24h *post mortem* in comparison with 1 and 3h *post mortem*. Both AK and WB methods were able to detect these differences. The AK shear force as well as the WB shear force and area were significantly correlated to meat sensory tenderness (r=-0.58, -0.43 and -0.56, respectively; P<0.001) and juiciness, whereas no correlation was found between sensory tenderness and WB firmness. These results indicate that both WB and AK methods can be used to evaluate the rabbit meat tenderness and give similar levels of correlation with sensory scores. However, AK method is characterized by a sample preparation procedure easier to standardize and less time consuming than WB method.

Key words: Rabbit, Meat, Tenderness, Measurement methods.

INTRODUCTION - Among the meat sensory attributes, tenderness and juiciness are considered the most important traits. Besides the structural and chemical changes occurring during the "ageing period" of meat, the main factors affecting meat tenderness are the collagen content and its chemical state (e.g. cross-linkage) as well as the miofibrillar "density", determined by the degree of overlapping of sarcomeres. The toughening of meat boned before the complete onset of *rigor mortis* is a well known problem observed in many speciesand is determined by the shortening of muscles due to the contraction of sarcomeres when muscles are separated by bones prior to complete the *rigor mortis* phase (Rees et al., 2002; Sams, 2002). The main physical methods to evaluate meat tenderness are based on the measurement of the force required to shear a meat sample across muscle fibre direction and can be performed with different devices and sample preparation procedures. The most popular device (especially for beef) is Warner-Bratzler (WB), which is represented by a single blade. Allo-Kramer (AK) is a multi-blade device largely used for poultry. For rabbit meat, WB has been widely adopted since years and its use has been recommended by Ouhayoun and Dalle Zotte (1996). However, the use of WB in rabbit requires the preparation of small meat samples with difficulties to obtain samples of precise size, location, and uniform geometry. On the other hand, with AK, the meat samples can be more easily prepared since whole (without any other manipulation) pieces of cooked meat can be used. Finally, the comparison of WB with other devices as well as the correlation between physical and sensory measurements of meat tenderness in rabbit are lacking. The aim of this study was to compare AK and WB devices for the evaluation of rabbit meat tenderness and to assess the correlation between textural variables and sensory properties of *longissimus lumborum* (*l. lumborum*) muscles boned at different *post mortem* times (1,3 and 24 h). These times were previously adopted by Bianchi *et al.* (2005) and correspond to the "hot boning" (1 h *post mortem*); the on line boning (3h *post mortem*), carried out immediately after the exit of carcasses from the chilling tunnel; or "delayed boning", done after 24h carcass storage.

MATERIAL AND METHODS - The study was divided in three consecutive sessions of trial separated by 7 days. Thirty 12 week-old rabbits reared and slaughtered under commercial conditions were used during each session for a total of 90 rabbits. In order to produce meat samples with a wide range of tenderness, during each session the l. mumborum muscles were boned at different post mortem times (one third after 1h, one third after 3 h and one third after 24h). Meat samples were stored at 2-4°C pending analyses. At 24h post mortem, the loins were packaged in plastic bags under slight vacuum and cooked in a constant temperature water-bath at 80°C for 1h (Combes *et al.*, 2003). The right loin of each carcass was used for WB and AK shear test using a TA-XT2 Texture Analyser (StableMicro Systems, UK). WB measurements were carried out according to the procedure described by Ramírez *et al.* (2004). The samples for WB test were obtained by cutting two parallelepipeds of 1×1 cm of cross section (1 cm^2), and 2 cm-length along muscle fibre axis. They were completely cut using a WB shear blade with a triangular slot cutting edge with the blade travelling at 100 mm/min to the sample (Combes *et al.*, 2003). Three variables were measured: WB shear force (N/cm^2), as the pick corresponding to the maximum shear force; WB shear firmness (N/s$\times$cm^2), as the slope of a line drawn from the origin of the curve to the maximum shear force; and WB area (N$\times$s/cm^2) as the area under the curve or total work performed by the blade to cut the sample. The average values for each *l. lumborum* were calculated as the mean of the two measures made on the two meat pieces. For AK shear test, a single 2 cm long whole (without any other manipulation) piece of cooked loin was cut from the central part of the muscle and sheared with the blades perpendicular to muscle fibres direction and AK shear force expressed as kg/g of meat. Samples were sheared, using a 250 kg load cell and crosshead speed of 500 mm/min. After cooking, the left loin of each carcass was cut in two parts and used to carry out sensory analysis by using 20 untrained panellists per session of trial. In each session the panellists changed for a total of 60 panellists. An eight-point category scale to determine the level of tenderness (from extremely tough = 1 to extremely tender = 8) and juiciness (from extremely dry = 1 to extremely juicy = 8) was adopted (AMSA, 1995). Three samples, corresponding to the three boning times (1, 3 and 24h *post mortem*, presented according to a randomized block design), were served warm without salt or spices, to each panellist. Since two samples (and two sensory responses) were obtained from each loin, the tenderness and juiciness scores corresponding to one rabbit were calculated averaging the scores given by two panellists. Data were analysed by two-ways ANOVA considering the boning time (1, 3, 24h *post mortem*) and trial (1, 2, 3) as main effects as well as their interaction. Means were separated by Duncan's test. Pearson's correlation coefficients (r) among the variables were calculated.

RESULTS AND CONCLUSIONS - The sensory test evidenced a higher tenderness and juiciness of rabbit meat obtained from carcasses boned at 24h *post mortem* (Table 1). Both AK and WB methods were able to detect these differences as indicated by AK shear force (7.33 and 7.03 vs. 4.69 kg/g; for 1, 3 and 24 h, respectively; P<0.001), WB shear force (61.93 and 60.48 *vs.* 47.79 N/cm^2; for 1, 3 and 24h, respectively; P<0.001) and WB area (280.55 and 293.69 vs. 195.23 N$\times$s/cm^2; for 1, 3 and 24 h, respectively; P<0.001). However, no difference were detected by WB firmness. As expected, the boning of rabbit carcasses conducted prior to 24 h *post mortem* determined a significant toughening of the meat as detected by both textural and sensory variables. These results confirm that boning the carcasses before the complete onset of *rigor mortis* produced a loss of rabbit meat tenderness as previously found in a preliminary study (Bianchi *et al.*, 2005). The session of trial influenced the AK shear force and WB firmness (results not shown), however no interaction "*post mortem* boning time × trial" was found. In Table 2 the correlations between AK and WB textural variables and sensory traits of rabbit meat, calculated on the overall dataset (n=90), are reported. The AK shear force

Table 1. Allo-Kramer (AK) and Warner-Bratzler (WB) textural variables and sensory traits of rabbit meat (*l. lumborum*) boned at 1, 3 and 24h *post mortem.*

	Post mortem boning time				
	1 h	3 h	24 h	pooled sem	Probability
Samples no.	30	30	30		
AK shear force (kg/g)	7.33A	7.03A	4.69B	0.20	<0.001
WB shear force (N/cm2)	61.9A	60.5A	47.8B	1.79	<0.001
WB firmness (N/s×cm2)	10.90	9.56	9.66	0.27	ns
WB area (N×s/cm2)	280.5A	293.7A	195.2B	9.30	<0.001
Sensory tenderness	3.78B	3.98B	6.07A	0.16	<0.001
Sensory juiciness	3.63B	3.60B	5.23A	0.14	<0.001

ns = not significant; A, B = P<0.01.

as well as the WB shear force and area were significantly correlated to the meat tenderness (r=-0.58, -0.43 and -0.56, respectively; P<0.001) and juiciness (r=-0.41, -0.33 and -0.44, respectively; P<0.001), whereas no correlation was found with WB firmness. Also Lyon and Lyon (1996) compared the effect of broiler breast meat boning time by using both the AK and WB shear methods and correlated the results with a sensory panel. According to the present study, they found similar correlation coefficients between sensory tenderness and both AK and WB shear force.

Table 2.   Pearson's correlation coefficients (r) among sensory traits, Allo-Kramer (AK) and Warner-Bratzler (WB) textural variables of rabbit meat (*l. lumborum*) (n=90).

	Sensory juiciness	AK shear force	WB shear force	WB area	WB firmness
Sensory tenderness	+0.70***	-0.58***	-0.43***	-0.56***	-0.15 ns
Sensory juiciness		-0.41***	-0.33**	-0.44***	-0.11 ns
AK shear force			+0.63***	+0.65***	+0.42***
WB shear force				+0.93***	+0.82***
WB area					+0.62***

** = P<0.01; *** = P<0.001; ns = not significant.

These results indicate that both AK and WB can be used to assess the rabbit meat tenderness and give similar levels of correlation with sensory scores. However, AK method is characterized by a sample preparation procedure easier to standardize and less time consuming than WB method.

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