PE4.47 Stress Resistance and Relaxation: an instrumental method for the texture analysis and sensory evaluation of meat 170.00

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Abstract— The meat quality is defined by consumers as being attractive in appearance and possessing satisfying palatability. Actually, there are not any analytical technique for the evaluation and verification of tenderness, really currently applicable in the fresh meat sector. This study was designed to ideate a new instrumental method for evaluation of tenderness and texture characteristics in meat by compression, named Stress Resistance and Relaxation method (SRR). This method allow the measurement of values directly comparables with the Warner – Bratzler shear force analysis and provide a dynamic rheological profile of the sample, representative of its comportment at the mastication. The SRR at respect of WBS consent an important reduction of time of analysis (from further 24 hours to about 45 minutes), quantity of sample (from about 300 to less than 30 grams), major automation and standardisation, and than minor costs and high objectivity. Another advantage is the possibility to use the same instrument currently employed to the WBS analysis, only equipped whit the compression devices.

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Index Terms— chewiness, fresh meat, sensory analysis, tenderness, texture.

I. INTRODUCTION

In producing desiderable quality fresh meat, that aim is to provide a lean product with a consistent, acceptable quality, desiderable economic value and maximum safety [1]. The meat quality is defined by consumers as being attractive in appearance and possessing satisfying palatability. The three important parameters used to define meat quality are surface exudates, colour and texture. In particular, the most important aspect of eating quality that determines overall acceptability is tenderness. It plays also a central role in orienting consumer preference [2]. There are a number of factors that influence meat tenderness, but ageing, marbling, connective tissue content and muscle contraction can be considered the main aspects to be considered [3]. Than, texture is the sensory and functional manifestation of the structural, mechanical and technological characteristics of meat, detected trough the sense of vision, hearing, touch and kinaesthetic. In addition, tenderness is a criterion for the certification of certain food products, such as Parma Ham ('Prosciutto di Parma') as a Protected Designation of Origin and the Spanish dry-cured ham ('Jamòn Serrano') as a Guaranteed Traditional Speciality [4]. The Warner – Bratzler Shear force (WBS) is the most used method for tenderness evaluation of meat [5]. Actually, there aren't any analytical technique for the evaluation and verification of tenderness, really currently applicable in the fresh meat sector. The analytical actually methods are frequently affect of long time of work, high quantity of sample, scanty automation, sensibility of matrix heterogeneity and than high costs and poor objectivity. This study was designed to ideate a new instrumental method for evaluation of tenderness and texture characteristics in meat by compression, named Stress Resistance and Relaxation method (SRR).

II. MATERIALS AND METHODS

II.A Ideation of SRR method For the study of rheologycal properties of meat by compression, the Universal Testing Machine Instron 1011, currently applied for the Warner – Bratzler shear force analysis, was connected to a personal computer by a data - logger and the data elaboration and registration was conduced by a generic commercial software. The instrument was equipped with a compression plate and was modified the setting parameters. Various preliminary test was conduced with different instrumental settings on different materials (millboard, foam rubber) similar to meat for elastic response and rheological behaviour and then on cooked meat. By compression was impossible to measure any instrumental peak, but the evolution during analysis of the compression force value of the load cell was constantly. The trend was similar to that of Texture Profile Analysis method (TPA) and Stress Relaxation method (SR), that use the different aspects of the compression concept for the analytic evaluation. These methods are frequently applied on various alimentary matrix for the study of technological and structural characteristics and for the prediction of sensory properties [6]. Starting for the principle of compression for study the structure of material, TPA and SR procedure, was defined a preliminary protocol of SRR. SRR was defined same the response of the sample (cylinder of cooked meat) at the uniaxial descendent compression by a compression plate and at the maintenance of the final level of compression for the analysis time. The typical SRR curve is characterised by an initial phase of exponential growth to a peak, named stress curve, that correspond at the maximum level of compression (stop level of compression stroke). The trend of growth and the measure of the peak describe the hardness and the fracturability at the mastication.

The maintenance of the maximum compression level determine a response in the time of the product to the applied deformation, that is graphically characterised by an asymptotic curve, named relaxation curve. The general theory that describe this second part of SRR curve show that relaxation curve for deformed material decay rapidly to zero or to a very low level if the material is showing more liquid properties. In contrast, if most of the curves remains unrelaxated it show more of solid and elastic properties.

II.B Sample Numbers of experiments were carried out. The SRR method was applied on 225 samples of meat, different for specie and commercial category (pig: 30; calf: 107; young bull: 88). The sample muscles employed were Longissimus thoracis and lumborum and Semitendinosus. 48 Calf and 14 Beef samples were submitted at the WBS analysis for the comparison with that of SRR method.

II.C SRR Protocol After numerous application of SRR protocol for its optimisation, was defined the definitive procedure. Before the sample preparation, was necessary equip the Universal Testing Machine Instron 1011 with the compression devices (60 mm diameter compression plate, base support and Plexiglas sample support), regulate the compression stroke (2,5 mm of light compression – free distance between plate compression and Plexiglas sample support – at stop level of compression stroke and 250 mm of global compression stroke) and start it. The instrument was connected to a pc by data logger, and data acquisition was realised with the software Ez data logger basic edition version 4.1.0, configured with frequency of sampling time equal 0,5 seconds and data save interval 1 second. The instrumental parameters were setting at 50 Kg of load transducer and load range, the compression speed was regulate equal 0,2 mm s-1. The force versus time after the compression peak was recorded for 90 seconds. For the preparation of meat was implemented the Meat Cooking Shrinkage method [7], an experimental procedure for area narrowing evaluation of meat during cooking. To the original portion of meat was obtained a disk (diameter 55mm, height 10 mm). It was cooked for 10 minutes at 165 ± 1 °C, to reach an inside temperature of 68 ± 1 °C, in a ventilate oven and cooled for 20 minutes in a Petri's capsule with filter paper at ambient temperature (22 ± 2 °C). During this procedure (areas of raw and cooled cooked cylinder of meat) was conduced the measurement of MCS analysis. After the MCS procedure, to the cooked sample were extracted 3 cylinders (15 mm diameter) around the centre of the original cylinder of meat. Each specimen was placed on the plexiglas support with the lateral face parallel at the plexiglas support surface, in such a way as to the compression was perpendicular to the fibre bundle direction. In this way height of sample was more constant. SRR analysis was conduced.

II.D Statistical analysis. Three models were employed for the statistical analysis of SRR curves. In the first one, the SRR curves were characterised by the load (N) at 3 and 7 mm of compression with respect to original dimension of sample, the peak and the force decay at 2 and 90 second after the peak. In the second one, the portion of SRR curve before and after the peak was described with the linear Maxwell model [6]. This method consent the characterisation of the SRR curves with the measure of peak and four coefficients (absolutely values) that indicate the intensity of increase or decrease of load versus time (absolutely values; "K1" and "K2" before peak, "K1" and "K2" after peak). The typical shape of the linear function, described by "K1" and "K2" coefficients, versus time was derived using the experimental data. Moreover, was tested the mathematical Mickley model, that calculate four different coefficients (absolutely values; "a" and "b" before peak and "a" and "b" after peak) on the base of Maxwell model's coefficients [8]. The elaborations of SRR and WBS data were conduced with SAS software version 9.3.1. The procedures PROC CORR and PROC GLM were employed. A covariate model with weight of sample (psrr) as covariate and category as indipendent variable was used. Tukey test for multiple Lsmean comparisons was performed.

III. RESULTS AND DISCUSSION

The results show that the SRR affords the discrimination among the different specie and commercial category samples, by significant differences of peak and force decay at 2 and 90 second after the peak (table 1 and graph 1). Peak is a parameter relative to the meet tenderness and the force decay is representative of the chewiness at the mastication [9]. The increase of the SRR curves at different level of compression detected significant difference between samples, (the load at 7 mm of compression is the parameter most efficiently).

The correlation analysis of SRR parameters indicate that existed a high significant correlation of load at 3 and 7 mm of compression and the force decay at 2 and 90 second after the peak with the peak value. The correlation between force decay at 2 and 90 second after the peak is high, and probably, a time shorter than 90 seconds would also be useful and more suitable for an industrial scale on – line classification of fresh meat.

Reciprocal of “K1” represents the force increasing or decreasing rate. An increasing in absolute value of “K1” represents the decrease in resistance to elastic deformation of the sample. An increase in the value of “K2” means the elastic component present in the sample is increasing. The coefficient “a” (K2-1) means that level of force that increase or decrease during stress and constant compression [6]. If “a” is 0 the sample represents an ideal elastic solid. If “a” is equal 1, it means the response of a liquid. Lower values of “b” (K2 * K1-1) indicate that the elastic response is slow. The coefficients “K1”, “K2”, “a” and “b” calculated for the portion of SRR curve subsequent the peak were significant correlated with the peak.

The equations obtained with the Maxwell and Mickley models describe correctly the increase or decrease of the force near the peak SRR, but they overestimate the asymptotic tendency. In order to improve the precision of the mathematical models, additional parameters could be added [10]. The area under the SRR curve was correlated with the peak. Moreover the peaks of Stress Resistance and Relaxation method were significantly correlate whit the WBS parameters (P < 0,001) and the coefficient of variations were similar for both methods (table 2a and 2b).

IV. CONCLUSIONS

The Stress Resistance and Relaxation method allows the measurement of values directly comparables with the Warner – Bratzler shear force analysis and provide a dynamic rheological profile of the sample, representative of its comportment at the mastication. The SRR compared to WBS allows an important reduction of time of analysis (from 48 hours to about 15 min.), quantity of sample (from about 300g to less than 30g), major automation and standardisation, and than minor costs and high objectivity. The correlation among different parameters is higher as measurements are done on the some sample: Meat Cooking Shrinkage, Cooking Loss, Aroma measurement, Cooling Water Loss, Compression Water Loss. Another advantage is the possibility to use the same instrument currently employed to the WBS analysis, only equipped whit the compression devices. In conclusion, the present study demonstrated that the innovative SRR method is advantageously applicable to value tenderness and chewiness of meat. The swiftness of the analysis rend this method suitable for the commercial application for the quality control in the sector of fresh meat.

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Table 1 – WBS and SRR Lsmeans of pork, calf and beef meat samples.

Parameter	Pork	Calf	Beef	EMS	DFE
Weight SRR sample (g)	1.7093^{A}	1.5470^{B}	1.5054^{B}	0.0231	211
Peak SRR (N)	111.49^{b}	91.50^{aA}	108.89^{B}	1428.75	211
Load 3 mm of compression (N)	1.4757^{A}	0.5687^{B}	0.7799^{C}	0.1853	211
Load 7 mm of compression (N)	16.45^{A}	8.00^{B}	11.17^{C}	27.70	211
Load 02 seconds after peak (N)	82.92	67.69^{A}	82.53^{B}	917.94	211
Load 90 seconds after peak (N)	30.46	25.78^{A}	32.79^{B}	165.40	197
k1 before peak	0.1808^{A}	-0.2447^{B}	-0.1145^{B}	0.1046	211
k2 before peak	0.0581^{A}	0.0628^{B}	0.0609^{B}	0.0001	211
K1 after peak	8.3516	7.9113^{A}	8.8584^{B}	2.3999	211
k2 after peak	1.3405^{a}	1.3053^{bA}	1.3333^{B}	0.0026	211
b before peak	-2.2781	1.1834	-3.6910	532.41	211
a after peak	0.7491^{a}	0.7683^{bA}	0.7519^{B}	0.0009	211
Peak WBS (N)		85.36^{A}	112.27^{B}	710.65	59
Break WBS (N)		73.21^{A}	104.08^{B}	628.85	59

Table 2a –Pearson correlation probability among WBS and SRR parameters.

	Weight sample	Peak SRR	Load 3 mm of compression	Load 7 mm of compression	Load 02 seconds after peak	Load 90 seconds after peak	k1 before peak
Weight sample		0.0029	NS	NS	0.0057	0.3162	0.0207
Peak SRR	NS		<.0001	<.0001	<.0001	<.0001	0.0139
Load 3 mm of compression	NS	<.0001		<.0001	<.0001	<.0001	<.0001
Load 7 mm of compression	0.0057	<.0001	<.0001		<.0001	<.0001	<.0001
Load 02 seconds after peak	0.0057	<.0001	<.0001	<.0001		<.0001	0.0097
Load 90 seconds after peak	NS	<.0001	<.0001	<.0001	<.0001		0.0002
k1 before peak	0.0207	0.0139	<.0001	<.0001	0.0097	0.0002	
k2 before peak	0.0215	NS	<.0001	<.0001	NS	0.0229	<.0001
k1 after peak	0.0637	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
K2 after peak	<.0001	0.0267	<.0001	<.0001	0.0044	<.0001	<.0001
b before peak	0.0029	NS	NS	NS	NS	NS	NS
a after peak	<.0001	0.0380	<.0001	<.0001	0.0069	<.0001	<.0001
b after peak	NS	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005
Peak WBS	NS	<.0001	0.0836	0.0005	<.0001	<.0001	0.0922
Break WBS	NS	<.0001	NS	0.0010	<.0001	<.0001	0.1942

Table 2b–Pearson correlation probability among WBS and SRR parameters.

	k2 before peak	k1 after peak	K2 after peak	a after peak	b after peak	Peak WBS	Break WBS
Weight sample	0.0215	0.0637	<.0001	<.0001	NS	NS	NS
Peak SRR	NS	<.0001	<.0001	<.0001	<.0001	0.0836	NS
Load 3 mm of compression	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	0.0010
Load 7 mm of compression	<.0001	<.0001	0.0044	0.0069	<.0001	<.0001	<.0001
Load 02 seconds after peak	NS	<.0001	0.0044	0.0069	<.0001	<.0001	<.0001
Load 90 seconds after peak	0.0229	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
k1 before peak	<.0001	<.0001	<.0001	<.0001	0.0005	0.0922	NS
k2 before peak		0.0065	<.0001	<.0001	0.0277	0.0986	NS
k1 after peak	0.0065		<.0001	<.0001	<.0001	0.0002	0.0019
K2 after peak	<.0001	<.0001		<.0001	<.0001	NS	NS
b before peak	NS	<.0001	0.0267	0.0380	<.0001	<.0001	<.0001
a after peak	<.0001	<.0001	<.0001		<.0001	NS	NS
b after peak	0.0277	<.0001	<.0001	<.0001		<.0001	0.0012
Peak WBS	0.0986	0.0002	NS	NS	<.0001		<.0001
Break WBS	NS	0.0019	NS	NS	0.0012	<.0001	