Texture sensory and instrumental analysis: Do they correlate?

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Abstract

Studies have indicated that beef tenderness or toughness is the sensory factor that contributes the most to eating satisfaction or dissatisfaction. Sensory tenderness is measured on a material that undergoes continuous transformation during chewing to form a bolus suitable for swallowing. This process cannot be mimic by a single measure of tenderness. The aim of this study was to correlate sensory and instrumental measurements of texture. Beef texture has been evaluated by texture profile analysis, Warner-Bratzler shear force and sensory analysis in *longissimus lumborum* of three beef types marketed in Portugal. The criteria for choosing these three types, certified, commercial, and imported beef, has been their high commercial relevance. Carnalentejana-PDO was chosen for being the certified beef with higher expression in the domestic market. Whilst, Brazilian beef was the imported beef chosen since it has gained market share in recent years. Commercial beef presented higher hardness (not different from Brazilian beef), adhesiveness and juiciness (despite not different from PDO beef), and also higher hardness variance. Brazilian beef presented higher off-flavor and lower overall acceptability. TPA parameters were not well correlate with sensory traits, regardless of the trend for a negative correlation between resilience and chewiness with tenderness. Chewiness correlated positively with WBSF. WBSF and tenderness were highly correlated. All sensory traits correlated with overall liking, being the higher correlation coefficient obtained with off-flavour, which suggests that off-flavour strongly influenced overall liking.

Keywords: Beef, Sensory analysis, Texture profile analysis

I. INTRODUCTION

Texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses (1). It is also a multi-parameter attribute that includes not only tenderness and chewiness, but a range of characteristics. Sensory attributes such as tenderness, juiciness and flavour are known to have a huge importance to the consumer influencing beef consumption. Nevertheless, sensory attributes are difficult to measure and often required the use of sensory panels in order to assess the complex parameters involved in the eating experience.

However trained panels are expensive and time consuming. Thus, to deal with this problem several methods of predicting meat tenderness have been developed. The instrumental measurement of texture is made by a dynamometer that provides mechanical energy at constant speed (2). The result is a force *versus* time curve where, the texture variation of the material is registered.

The most commonly used tests (shear force and compression), rely on measuring a single parameter, and none fully imitate the complexity of the chewing motion. Humans measure and integrate sensory perceptions on a material that undergoes continuous transformation during chewing (3). This could be the main difficulty faced when correlating panel sensory traits with mechanical objective measurements. While in sensory methods the evaluation includes several steps outside and inside the mouth, the instrumental methods involve shearing or compressing the test food. TPA compresses a bite sized food in order to simulate the chewing action of the teeth. In this method frequently called two bites test, the probe acts twice in the material in compression with a lag time between the two actions.

The main advantage of TPA is that one test can assess many variables with the double compression cycle (4), like hardness, cohesiveness, springiness, and so forth.

The aim of this study was to explore the relationship between sensory and instrumental measurements of texture.

II. MATERIAL AND METHODS

A. Animals and sample preparation

This study was performed on 16 Carnalentejana-PDO, 15 Brazilian and 15 undifferentiated national

(national from now on) samples of *longissimus lumborum* muscle.

The beef types used were chosen concerning commercial purposes. Carnalentejana-PDO is a quality branded beef certified by the European legislation. These products follow strict rules detailed in the specification book for Carnalentejana-PDO. These rules concern mainly the breed, origin and the production system.

Brazilian beef is obtained from crosses of local breeds, mainly Nelore with more exotic breeds, and is usually produced in a traditional semi-extensive production system based on pastures that could have a finishing period with concentrates.

National beef is originated from crossbred young bulls produced in a conventional intensive concentrate based system, being the most consumed in Portugal.

Three 25 mm steaks were cut from *longissimus lumborum* muscle, one for each technique WBSF, TPA and sensory panel. Samples were vacuum packaged and frozen at -18 ºC until analyses were performed.

Steaks for WBSF and TPA measurements were chilled until reached room temperature. Afterwards were cooked in a griller until reached a final internal temperature of 70 ºC. After cooking samples for TPA were vacuum packaged and immersed on ice to refrain further cooking. Afterwards cooked samples were kept overnight in the cooler at 4 ºC until de next day.

B. Instrumental analysis

For WBSF and TPA techniques, cores were removed parallel to the muscle fibre orientation and sheared or compressed perpendicular to the longitudinal orientation of the muscle fibres with a TA-TX Plus Texture Analyser (Stable Micro Systems Ltd., Surrey, UK) equipped with a Warner-Bratzler shear blade or with a cylindrical probe of 10 mm diameter, respectively. The beef sample resistance was recorded in a force-deformation plot.

In WBSF test, the maximum shear force in kg corresponded to the highest peak of the curve.

In TPA test the probe moved downwards at a constant speed of 5 mm/s, until detect the sample, then the probe continued downward to 80% of the sample original thickness.

The TPA parameters studied were:

Hardness – peak force of the first compression cycle (kg). In mouth, hardness is the force required to bite completely through sample with the molars.

Cohesiveness - extent to which the sample could be deformed prior to rupture. In mouth, cohesiveness is felt like the amount of deformation undergone by the material before rupture when biting completely through the sample with molars.

Springiness – ability of the sample to recover its original form after the deforming force is removed. In mouth, it is the force with which the sample returns to its original shape after a partial compression without failure, between the tongue and the palate.

Adhesiveness – force necessary to pull the plunger away from the beef. In mouth adhesiveness is the force required to remove product completely from palate, using tongue, after compression of the sample between tongue and palate.

Resilience – property of a material to absorb energy when is deformed elastically and then, upon unloading to have this energy recovered. It is the maximum energy per unit volume that can be elastically stored.

Chewiness – The energy necessary to chew a solid sample to a steady state of swallowing (hardness x cohesiveness x springiness).

C. Sensory analysis

Preparation of samples for sensory analysis was similar to the described for instrumental analysis. After cooking steaks for sensory analysis were cut into 2 x 2 x 2 cm^3. The panellists score the steaks on a 1 to 8 points scale for tenderness (defined as the opposite of the force required to bite the sample through the molars), juiciness (juice released from the sample after the first chews), beef flavour (the intensity with which the sample is recognized as beef), off-flavour (all flavours not considered as typical in beef, i.e., found strange for a beef sample) and overall acceptability (1 = extremely tough, dry, weak, weak, dislike extremely; 8 = extremely tender, juicy, strong, strong, like extremely, respectively).

D. Statistical Analysis

The effect of the beef type was studied by analysis of variance using the PROC MEANS procedure of Statistical Analysis Systems (SAS) software package, version 9.1 (SAS Institute Inc., Cary, USA, 2004).

The relationship between the variables was determined using the Pearson's correlation coefficients (SAS, 2004).

III.RESULTS

National beef presented higher TPA hardness (P<0.01) and a trend for a higher chewiness value (P=0.08) than PDO beef. All samples presented low adhesiveness, but national beef presented the lowest value (P<0.05) in this parameter. National beef also presented higher juiciness than Brazilian beef. Brazilian beef presented higher off-flavor and lower overall acceptability. Hardness was negatively correlated with adhesiveness (p<0.05) and highly negatively correlated with cohesiveness (p<0.001). Hardness was also highly positively correlated with chewiness (p<0.001). Cohesiveness was positively correlated with springiness (p<0.01) and resilience (p<0.01). Springiness in turn was positively correlated with adhesiveness (p<0.01), and presented a trend for a positive correlation with chewiness (p= 0.05).

WBSF presented a trend to correlate positively cohesiveness (P= 0.06) and chewiness (P=0.05), and was highly correlated with tenderness. TPA parameters were not well correlate with sensory traits, regardless of the trend for a negative correlation between resilience (P=0.07) and chewiness (P=0.06) with tenderness. The magnitude of the correlations between TPA parameters and sensory attributes were similar and ranged between 0.26 and 0.34 (absolute values).

Table 1 – Means and standard desviations of the means of *longissimus lumborum* from Carnalentejana-PDO, Brazilian and commercial beef

	PDO		Brazilian		Commercial	
	Mean	SD	Mean	SD	Mean	SD
WBSF	5.48	1.55	5.28	1.24	5.42	0.97
TPA parameters						
Hardness	4.68^{b}	0.63	5.30^{a,b}	1.08	6.08^{a}	1.63
Adhesiveness	-0.02^{b}	0.01	-0.02^{b}	0.01	-0.03^{a}	0.01
Cohesiveness	0.51	0.05	0.48	0.07	0.48	0.07
Springiness	0.76	0.05	0.77	0.03	0.75	0.04
Resilience	0.15	0.03	0.15	0.07	0.16	0.08
Chewiness	1.85	0.37	1.94	0.24	2.18	0.58
Sensory traits						
Tenderness	5.33	0.83	5.31	0.89	5.54	0.84
Juiciness	3.88	0.62	3.57	0.52	4.13	0.68
Flavour	4.46	0.56	4.19	0.67	4.38	0.59
Off-flavour	0.87^{b}	1.00	3.15^{a}	0.68	1.17^{b}	1.15
Overall acceptability	5.12^{a}	0.53	3.73^{b}	0.59	4.85^{a}	0.53

Means in the same row with different superscripts are significantly different (P<0.05); SEM, standard error of the mean; WBSF = Warner-Bratzler shear force.

There were also significant positive correlations between sensory traits. Tenderness and juiciness were correlated (p<0.01). All sensory attributes were correlated with overall acceptability. Correlation coefficient presented between overall acceptability and off-flavour was the highest one, which suggests that off-flavour was probably the main sensory attribute determining overall acceptability.

All sensory traits were correlated with overall acceptability however the correlation presented by off-flavour with overall acceptability was stronger, having the greatest coefficient of correlation.

IV.DISCUSSION

The higher TPA hardness value presented by national beef was accomplished with a trend for a higher value in chewiness. Both results indicate that this beef is probably harder to chew. Our results are similar to the result presented by Caine *et al.* (5) and lower than the result presented by Huidobro and coworkers (4) in cooked meat after 6 days of ageing.

The values obtained in this study for adhesiveness were lower and the values for cohesiveness, springiness and chewiness were similar to the ones obtained by other authors (5). Nevertheless, Huidobro *et al.* (4) obtained a higher springiness value in cooked meat. Springiness is related with collagen content and/or composition. The lack of differences obtained between beef types are in accordance with the lack of differences in collagen content and composition between beef (data not shown). When meat is cooked there is a helix to coil transition of the collagen molecules. Collagen denatures losing up the fibrillar structure due to the breakage of the hydrogen bonds, and contracts. When meat is heated above the temperature of collagen contraction, as collagen fibres and fibrils are initially wavy they can contract freely to a certain degree (6).The higher the waviness of collagen fibres and fibrils, the higher the contraction amplitude. The pressure developed by connective tissues is opposed to the resistance of fibres and fibre bundles (resilience). The balance between the pressure and the resistance leads to a state of equilibrium and to a final value of collagen contraction state which is the determinant of the elastic modulus of collagen fibres and fibrils. Hardness increases with the increase of the elastic modulus of collagen fibres and fibrils (6). The above exposed is in accordance with the trend for an inverse correlation between resilience and sensory tenderness, as well as, with the trend for a positive correlation between springiness and chewiness.

The cohesiveness values different from one indicates the absence of sample recovery after the first compression. In the second compression cycle sample lost some height so the area recorded was smaller than in the first cycle (7). A higher cohesiveness also contributes to a higher hardness as a result of a lower maturation or a higher contraction of the muscle fibres with increasing strain (6). All the above relationships could be reflected in a higher resilience.

WBSF was highly negatively correlated with sensory tenderness. The high correlation between WBSF and tenderness has been mentioned by several other authors (8). This is not surprisingly, as WBSF measures hardness the opposite of tenderness. WBSF also correlated positively with chewiness and had a trend for a positive correlation with cohesiveness. This means that a more cohesive beef also have a higher WBSF. In mouth cohesiveness is felt like the amount of deformation undergone by the material without rupture when biting completely through the sample with molars (10). Therefore more cohesive samples support higher deformations before rupture, and consequently have higher WBSF. In addition, the harder beef is more chews are needed to reach a steady state of swallowing, which is in agreement with the trend to a negative correlation between sensory tenderness and chewiness.

Regarding the high coefficient correlation between WBSF and sensory tenderness, it seems that WBSF is a better sensory tenderness predictor than TPA. It is important to notice that evaluating the human response to the eating process relies on subjective human assessment, since there are no objective means of measuring the full range of interacting characteristics contributing to the eating quality. That is why it difficult to relate instrumental and sensorial results from beef.

V.CONCLUSION

Instrumental methods used in this study do not explained totally the subjective measurements. Even though national undifferentiated beef presented the highest hardness and adhesiveness values, WBSF value and sensory tenderness score were similar between beef groups.

Variation among sensory panel members is inherent to subjective assessment of meat characteristics. So, more studies are needed to understand the possible relation between sensory and mechanical traits.

Concerning sensory attributes, off-flavour was the main sensory attribute determining overall acceptability.

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