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A comparison between Warner-Bratzler shear force measurement and texture profile analysis of meat and meat products: a review

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Abstract: Texture is one of the most important characteristics of meat and we can explain it as the human physiological–psychological awareness of a number of rheological and other properties of foods and their relations. In this paper, we discuss instrumental measurement of texture by Warner-Bratzler shear force (WBSF) and texture profile analysis (TPA). The conditions for using the device are detailed in WBSF measurements, and the influence of different parameters on the execution of the method and final results are shown. After that, the main disadvantages are reflected in the non-standardized method. Also, we introduce basic texture parameters which connect and separate TPA and WBSF methods and mention contemporary methods with their main advantage.

1. Introduction

Meat texture is a feature that can be defined by certain homogeneous properties which are detected by human senses relating to vision, hearing, somesthesia and kinesthesia [1]. These properties are perceived as hardness/firmness, gumminess, resilience, cohesiveness, springiness, adhesiveness, and viscosity. However, the textural properties of meat are often adapted by food processing, where the aim is often to make the structure of meat, and food in general, more delicate and easier to chew. The methods used for texture assessment can be separated into three groups: sensory, instrumental and indirect methods. Instrumental methods of texture assessment frequently apply mechanical analyses, measuring the food resistance, as the opposing force of the food is more solid than the strength of gravity. Since the applied power is beyond the strength of the tested sample, the sample is frequently ruined in this procedure. Therefore, the mechanical test of texture measurement is typically destructive [12]. The Warner-Bratzler Shear Force (WBSF) test and texture profile analysis are classic instrumental methods for estimation of meat tenderness (toughness). The study of Dar and Light [13] pointed out the key role of the texture when it comes to food quality identification by consumers, and also the influence of consumer attitudes. However, in this review, only the instrumental methods for analyzing meat texture will be explored.

2. Instrumental measurement of food texture

Several intrinsic and extrinsic features affect meat quality characteristics, including the trait of tenderness. These factors are separated into pre-slaughter factors and post-slaughter ones. In addition to animal stress, pre-slaughter factors include species, genotype, nutrition and age of the animal that typically affects



weight and fatness of the carcass. Post-slaughter features refer to methods of stimulation, scalding, dangling, ageing, etc. Tenderness is an attribute of meat, and food in general, which is measured as a sensory characteristic. Moreover, as well as juiciness, it contributes to the mouth-feel [14], and combined with texture, juiciness and taste, it makes up the whole sense of quality as perceived by customers. Since meat is processed in consumers' mouth, its thermo-mechanical neutral features are of great importance when it comes to the mouth-feel, as well as the perception of smell and moisture. Texture measurement can be assessed by different instrumental methods. Puncture, compression, shear and tension are the main and generally used procedures for evaluating texture, giving values of force, deformation, slope and area [2].

3. Warner-Bratzler Shear Force (WBSF)

The most frequently applied instrumental procedure for assessing meat tenderness that has been used since 1930s is the WBSF test [3]. This test measures the maximum force (N) as a function of knife movement (mm) and the compression to shear (cut off) a sample of meat (MPa). The result of this measurement shows the hardness (toughness) of meat [13]. The term shear refers to sliding of meat parallel to the plane of contact, with the applied force tangential to the segment. Nevertheless, this word is commonly used in food technology to attribute any cutting action which splits a product into two fragments.

In the WBSF method, different devices for analysis can be used with a particular head or blade attached to them. These include machines such as Texture Analyzers [4], Instron devices or other common test devices [5]. Therefore, WBSF is performed either by a unique machine or by some other automatic device with the WBSF blade mounted to it. In the examination, a blade cuts through the meat samples so that shearing is perpendicular to the longitudinal positioning of the muscle fibers [3].

It was previously stated that exact requirements should be provided for WBSF test, both regarding the meat sample and the device used. Numerous studies have been carried out testing dissimilar modifications. One such study was conducted by Voisey and Larmond [15], who observed the effect of the changing angle of the cutting edges of the blade. They came to the conclusion that if the angle of the blade extends from 30° to about 70°, it increases the shear force. On the other hand, widening of the angle over this point does not lead to more increase in shear force. Separately from this survey, the above-mentioned researchers also studied different blade thicknesses and the width between the blade and the anvil [15]. They also concluded that changes in the test performance rate caused noteworthy variations in the rupture force as well as other evaluated parameters. They proved that alternations in the rate travel of the anvil did not have an important influence on the increase of the correlation between the receptive tenderness rating and the WBSF rating.

Voisey and Larmond [15] studied differences in the features of the blades produced by various manufacturers. These differences included the blade thickness, the angle of the hole, the clearance between the head and the anvil, etc. They came to the conclusion that it was necessary to standardize the Warner-Bratzler blade dimensions and specifications in order to avoid getting inconsistent results from various laboratories which all claimed to have used a 'Warner-Bratzler' blade. The original blade was made of stainless steel. On the other hand, the modern Warner-Bratzler blades are made of aluminum alloy which is not as resistant to wear as stainless steel and therefore probably suffers changes in the dimensions more quickly than stainless steel.

The meat samples must be uniformly round and of the same diameter for the WBSF test. Specifically, beef samples and other animals' large muscles in general are supposed to be cut cylindrically with an internal diameter of either 0.5 or 1 inch (1.27 or 2.54 cm). On the other hand, smaller muscles are, without cutting, put into the triangular hole of the blade. Afterwards, the sample is sheared into two pieces. The newly obtained surface cross-section is measured and included as a correction in the WBSF calculation. This cross-section area can be evaluated by pressing the surface on a piece of filter paper, marking the line around it and later measuring it by planimeter.

Nowadays, the interrelation between the diameter of the cross-section of noncylindrical samples and the WBSF is still not evident, although there has been research on this subject. Kastner and Henrickson

[6] tested cooked pork chops and discovered a nonlinear correlation between diameter and WBSF. Nevertheless, the results change when the data is recalculated according to cross-section, and the relationship looks to be linear, meaning that the shear force linearly corresponds to the cross-section area. Pool and Klose [16] found comparable results with cooked turkey meat. They noted that the force was proportional to diameter. Other researchers used different samples and equipment but the results are variable and are not clear enough to draw evident conclusions, except that the sample diameter should be uniform for each individual study. Naturally, this makes comparisons between different institutions and machines/protocols difficult. Wheeler et al. [7] tested how sampling, cooking and coring influence WBSF values for beef, and compared the shear evaluations of five institutions. They established the necessity of standardized procedures in order to accomplish consistent results for WBSF tests on cooked beef.

Numerous requirements must be fulfilled when it comes to the automatic testing machine, as well as the blades used. They must be V-notch blades made for the WBSF machine that meet the precise specifications such as the thickness, the bevel on the cutting edge, etc. Warner-Bratzler shear blade specifications are: (1) thickness of 1.1684 mm (0.046 inches); (2) V-notched (60° angle) cutting blade; (3) cutting edge beveled to a half-round; (4) angle of V rounded to a quarter-round of a 2.363 mm diameter circle; (5) spacers providing 2.0828 mm gap for the cutting blade to slide through.

Meat must also be standardized by cooking and chilling overnight to 2-5°C. After chilling, the meat is firm enough to be adequately cored. If this standard chilling step is not used, then the meat should undergo some other procedure to provide consistent temperature, and hence, uniform diameter cores. The width should be the same for each round core; 1.27 cm (0.5 inches). The cores must be removed parallel to the longitudinal direction of the muscle fibers which provides for them to be sheared perpendicular to the muscle fiber orientation.

The automatic testing machines should be used at the crosshead speed of 200 to 250 mm/minute. Any other shear tests which are not carried out according to these specifications (for example using a different blade or a blade not appropriately beveled) or on samples with unfulfilled requirements must not be called WBSF tests.

4. Texture profile analysis (TPA)

TPA is a procedure invented in 1963 by a group of scientists at General Foods Corporation. Originally, the procedure was designed to be conducted on a specific instrument known as the General Foods Texturometer (GFT), and it was available to anyone who had access to this instrument. In 1968, the method was modified and adjusted by Bourne in order to function on an Instron Universal Testing Machine (IUTM) [8]. His adjustments changed the experimental protocol, but at the same time, he managed to overcome some instrumental difficulties of its predecessor.

The main issues with the GFT performance were deformation of food samples and unreliable instrumental readings. The device was built as a human jaw, thus reproducing the process of mastication. In the procedure, the engaged power was in a sinusoidal mode and chewing mimicry was achieved by motions of a lever with a plunger set on it. However, as the plunger moved towards the plate and mimicked about 42 bites every minute, it also deformed the food sample. The deformations were uneven due to the lever rotation and different influences of the plunger [8]. The direction of pressure changed as the lever swept through its arc. In addition to these issues, another problem with the GFT was the fact that instrumental interpretations were not solely based on deformation and stresses resulting from the food, because there was some flexibility in the construction of the strain gauges attached to the lever, which were used for measuring the stresses.

The main indicators of TPA analysis can be divided into primary and secondary (Table 1).

Table 1. Primary and secondary characteristics of meat texture [17].

Parameter	Sensorial definition	Instrumental definition
<i>Primary</i>		

characteristics

Hardness	Force obligatory to compress a food between molars. Definite as power needed to reach given deformation	Peak power of the first compression cycle
Springiness	Proportion at which a deformed material goes back to its unreformed state after deforming power is removed	Height that the food recuperates during the time that elapses between the end of the first chew and the start of the second chew
Adhesiveness	The effort needed to overwhelm the attractive forces between the superficies of the food and the superficies of other constituents with which the food derives into interaction (e.g. tongue, teeth). Work obligatory to pull food away after a superficial	The negative part for the first chew, representing the effort needed to pull compressing sound away after sample
Cohesiveness	The force of internal bonds compensates the body of the produce (superior the value the superior the cohesiveness)	The proportion of positive energy throughout the second to that of the first compression sequence (descending strokes only)

Secondary characteristics

Brittleness (Fracture force)	Power at which a material fractures. Connected to the primary parameters of hardness and cohesiveness, where fragile materials have low cohesiveness. Not all foods rupture and thus value may tell to hardness if only single peak is current. Inelastic foods are never adhesive	The first important break in the first compression round
Gumminess	Energy obligatory to crumble a semi-solid food produce to a state prepared for swallowing. Connected to foods with low hardness height	Calculated parameter: Produce of Hardness x Cohesiveness
Chewiness	Energy obligatory to chew a solid food to a state where it is prepared for swallowing. Characteristic is problematic to quantify exactly due to difficulties of mastication (shear, penetration)	Calculated Parameter: Produce of Gumminess x Springiness (basically primary parameters of Hardness x Cohesiveness x Springiness)

The TPA test imitates the chewing process similar to the one in the human mouth, and its performance speed is equivalent to that of the human jaw. Many studies aimed to check the human bite speed and calculated it to be between 33 and 66 mm/s. Nevertheless, it was proved that sensory correlations with tests are greater if the speeds are higher. If TPA parameters are applied to different types of food, the significance of standardization and protocol for the procedure used must be cited.

Barbut et al. [9] presented variations in sample length (L) from 10 to 20 mm, diameter (D) from 13 to 73 mm, and D/L ratio from 1 to 4. Furthermore, the compression ratio varied from 50 to 85% and compression speed from 5 to 200 mm/min. The effects of varying D/L, speed and compression rate on

beef wieners were studied by the same authors [9]. A decrease in D/L resulted in a decrease of hardness, cohesiveness and gumminess, and an increase in springiness and chewiness.

Increasing the compression rate causes reduced springiness, cohesiveness, gumminess and chewiness. At the same deformation rate, a shorter sample is actually deformed at a higher strain rate and, consequently, should exhibit higher stress than a longer sample under the same strain. Thus, TPA parameters are comparable only when the tests are performed by a standard procedure [9]. The values obtained for a ground salami meat product and a whole muscle corned beef product resulted in recommending the following test parameters: D/L = 1.5; compression ratio = 75%; and speed rate = 1-2 cm/min. Using these standard conditions will allow direct comparison of data from different laboratories/institutions and reduce confusion and mistakes that result from selecting inappropriate parameters [9].

5. Comparison of instrumental methods for texture evaluation

Ruiz de Huidobro [10] studied the relationship of the WBSF test and TPA to the sensory features of beef, which, of course, can be related to its texture characteristics. Overall, the authors found the TPA test to be more suitable for beef texture assessments. The TPA assessment predicted sensory hardness better than the WBSF examination. WBSF and the sensory rating of chewiness were related, showing the decline in the course of aging. However, the receptive juiciness did not fluctuate significantly with aging. On the other hand, the WBSF test had the highest coefficient of variability (27.5%). Overall, as measures of toughness, the WBSF and TPA tests were positively correlated.

TPA seems more convenient for predicting sensory texture of meat than the WBSF method, provided the study is on raw meat. When cooked meat is examined, the WBSF method is better, although it is not a very accurate predictor of meat texture [10].

Conclusion

The evaluation of texture and structure measurements for meat and meat products is significant in quality control for meat industry. This review discussed the main instrumental methods, WBSF and TPA, used to measure meat texture. Both of them are useful for instrumental measurement of meat texture, with greater importance for TPA in raw beef texture evaluations. With all these findings, it is expected that TPA will be used much more for this purpose than WBSF in the future.

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