Chapter 3

Texture Analysis

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Abstract

One of the most important quality parameters of the meat and meat products are their texture, which may be influenced by breed, sex, production system, *post-mortem* factors and/or production process. Several years ago, meat industries tested their food products with a panel of expert tasters (sensory analysis). This method alone can have problems because evaluations of the tasters could vary depending on their mood, the ambient temperature, their traditions and culture, among others. In short, this method is good but very subjective. Currently, companies are using both expert tasters and texture analyzers because they are complementary, and instrumental measurement provides more objective values. In this way, it is possible to know if a product satisfies (to a greater or lesser degree) the preferences of most consumers.

This chapter provides a comprehensive guide to instrumental texture analysis in meat and meat products. Warner-Bratzler test (WB) and Texture Profile Analysis (TPA) methods will be detailed step by step carefully.

Key words Warner-Bratzler, TPA, Shear Force, Hardness, Adhesiveness, Springiness, Cohesiveness, Gumminess, Chewiness

1 Introduction

Texture is a very important characteristic of meat and meat products since they give a lot of information about the product that consumers are going to eat or that they are eating. This fact is important, because the texture perception begins in our mind when we see the food. First of all, texture is defined as "all the mechanical, geometrical and surface attributes of a product perceptible by means of mechanical, tactile and, where appropriate, visual and auditory receptors" [1]. Texture greatly influences the perception that the consumer has and feels when eating a product. Consumers can identify several information through it, such as the type of product, its freshness, whether the product is raw or cooked,

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overcooked or undercooked, and also, it influences taste perception. Therefore, it is a key parameter that should take into account when formulating or improving a meat product [2].

There are a lot of factors (*ante-* and *post-mortem*) that can affect the texture of meat and meat products, such as animal handling [3], the type of muscle, the type of product (fresh and aged meat [4, 5], dry-cured meat products [6] and meat paste as pâté [7]), and how people usually eat it (according to their culture and tradition). In addition, many strategies to make meat products healthier could affect the texture of the products, since reducing the amount of salt, fat, or sugar, it will not only affect the taste but also the texture that consumer expects to find in this product. Therefore, it is important to note that we must analyze the sample in the same way that this product should be consumed, so that the results are a reflection of what the consumer will experience.

Among the textural characteristics, the most commonly used are hardness, cohesiveness, and juiciness. Three types of methods are applied to evaluate texture: sensory, instrumental (known as objective, physical, or mechanical), and indirect methods (collagen content, dry matter, among others) [8]. Instrumental methods are generally based on mechanical tests, which evaluate the resistance of the meat product to forces greater than gravity acting on it. Warner-Bratzler test (WB) and texture profile analysis (TPA) are the most common ways to evaluate meat tenderness. These methods simulate the conditions that the meat or meat product is exposed to in the mouth [8]. Texture analyzers are used for this purpose, usually equipped with interchangeable load cells, WB blade, and cylindrical probes. WB test consists of cutting the sample with WB blade to simulate chewing with the incisor teeth, and maximum shear force, shear firmness, and total necessary work are obtained after selecting parameters such as test speed, probe height, or contact force. The first parameter shown by the peak higher of the force-time curve, represents the maximum resistance of the sample to the cut. Shear firmness is represented by the slope from the beginning of the cut up to the highest point of the force-time curve and total work by the area under the curve [9]. TPA consists of two-cycle compression and simulates chewing with the molars. Hardness, cohesiveness, springiness, gumminess, and chewiness were obtained. Hardness represents the maximal force of the first compression of the product. Cohesiveness is represented by the ratio of work done between the second and the first deformation, whereas springiness is measured at the down stroke of the second compression. Finally, gumminess and chewiness are calculated as Hardness × Cohesiveness and Gumminess × Springiness, respectively [10].

The aim of this chapter is to be a guide for instrumental texture analysis of meat and meat products, from giving the parameters to set up the texture analyzer to the methodology to perform both

test, WB and TPA. So, this chapter will help to standardize the methodologies used, and in this way, it will facilitate the comparison of results.

2 Materials

All tests will be performed with a TA-XT Plus (Stable Micro Systems, Godalming, UK) texture analyzer (*see* **Note 1**) and its corresponding accessories (*see* **Note 2**). In addition, texture analyzer is connected to a computer equipped with a texture analysis software package "Exponent" (*see* **Note 3**).

2.1 Sample Preparation for Analysis

1. Vernier caliper (0–150 mm).
2. Cutting board.
3. Knife.

2.2 Warner-Bratzler Test

The Warner-Bratzler set (Fig. 1) consists of:

1. Warner-Bratzler Blade Set with "V" slot blade for USDA Standard (HDP/WBV).
2. Slotted blade insert.
3. Blade holder.

2.3 Texture Profile Analysis (Compression Test)

The texture profile analysis set (Fig. 2) consists of:

1. Cylinder probe of 50 mm of diameter (P/50).
2. Flat platform.
3. Probe insert.

2.4 Texture Profile Analysis (Penetration Test)

The texture profile analysis set (Fig. 3) consists of:

1. Cylinder probe of 6 mm of diameter (P/6).
2. Flat platform.
3. Probe insert.

3 Methods

All procedures will be carried out at room temperature unless otherwise specified.

3.1 Sample Preparation for Analysis

First of all, we need to prepare the sample. This step is very important because the results depend on it. How to prepare samples for one test or another is different and depends on the type of sample. As a general rule, the sample is analyzed in the same way as it is

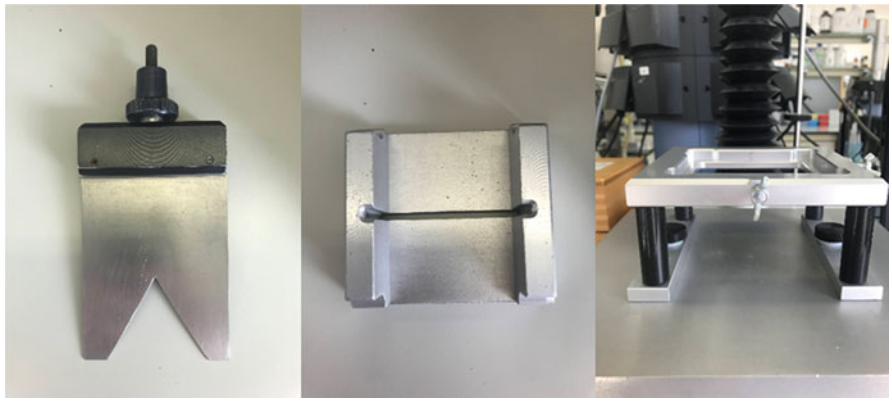

Fig. 1 Warner-Bratzler set

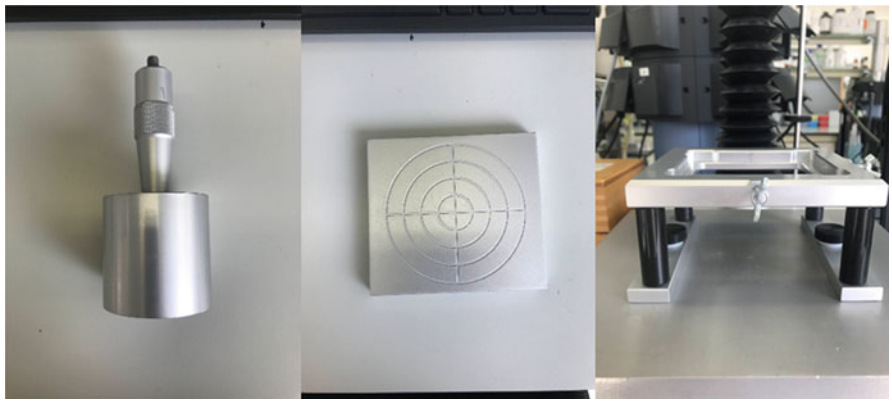

Fig. 2 TPA set (compression test)

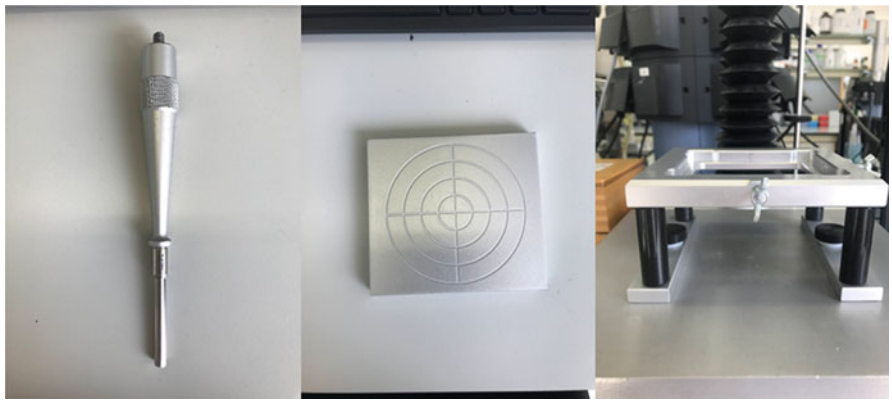

Fig. 3 TPA set (penetration test)

usually eaten, so raw meat should be cooked before. Therefore, in some samples the water holding capacity is also determined at the same time.

3.1.1 Water Holding Capacity (WHC)

The water holding capacity (WHC) of meat is determined by cooking losses according to the method proposed by Honikel (1997) [11].

1. Use steaks approximately 2.5 cm thick.
2. Once weighed, vacuum packed (80%) each fillet in a plastic bag and cooked in a water bath at 80 °C until it reaches an internal temperature of 70 °C (controlled with thermocouples) (*see* **Note 4**).
3. Then, the bags are removed from the bath and placed on a tray until they reach room temperature (approximately 30 min).
4. Finally, cooked steaks are removed from the bags and carefully dried to remove any remaining liquid on the surface. Cooking losses are expressed as the percentage of weight lost with respect to the initial one.
5. Expression of results

   Calculate the cooking loss as a percentage, using the following equation:

$$\%\text{Cooking loss} = \left[\frac{(W_0 - W_1)}{W_0}\right] \times 100$$

   where:

   - W_0 is the steak weigh before cooking (g).
   - W_1 is the steak weigh after cooking (g).

3.1.2 Sample Preparation for WB Test

Once the steak is cooked, we must cut it for carry out the WB test.

1. Firstly, remove the edges of the steak (*see* **Note 5**).
2. Next, we cut six pieces of the steak (*see* **Note 6**). Using vernier caliper, we must cut pieces with a size of 1 cm × 1 cm × 2.5 cm (high × width × length).
3. Finally, take the samples to the texture analyzer.

3.1.3 Sample Preparation for TPA (Compression Test)

In this test we must divide the samples in fresh or dry-cured sausages, and dry-cured meat products such as ham (*see* **Note 7**).

1. Fresh and dry-cured sausages.
   (a) Firstly, fresh sausages must be cooked before in the same way that fresh meat and next, remove the skin from the sausage where it was stuffed.
   (b) Then, we cut four slices of 2 cm wide using a vernier caliper in both fresh and dry-cured sausages. The skin must be also removed in dry-cured sausages.
   (c) Finally, take the samples to the texture analyzer.

2. Other dry-cured meat products

In the case of dry-cured meat products such as dry-cured ham, we must cut a representative slice from the muscle that interests us (usually in dry-cured ham *semimembranosus* or *biceps femoris* muscle).

(a) Firstly, remove the edges of the slice.

(b) Next, we cut six pieces of the steak. Using vernier caliper, we must cut pieces with a size of 1 cm × 1 cm × 1 cm (high × width × length).

(c) Finally, take the samples to the texture analyzer.

3.1.4 Sample Preparation for TPA (Penetration Test)

Usually, we carry out this analysis in spreadable paste of meat like to pâté. These products are ready for analysis, you just need open the can or glass bottle and do the analysis.

3.2 Warner-Bratzler Test

Usually, this test is used in fresh and aged meat. Warner-Bratzler test is carried out according to Honikel (1997) [11] with slight modifications. Figure 4 shows in a simplified and schematic way the steps of the WB test. Once the samples are ready for analysis:

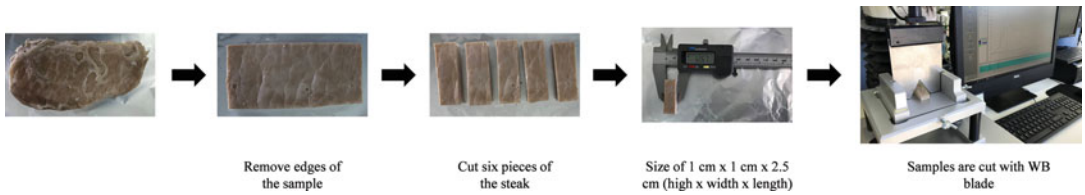

Fig. 4 Schematic and simplified representation of the steps of the WB test

Table 1
Analysis parameters to perform WB test

WB parameters	
Load cell (Kg)	30
Calibration weight (kg)	5
Return distance (mm)	50
Return speed (mm/s)	10
Contact force (g)	2
Pretest speed (mm/s)	3.33
Test speed (mm/s)	3.33
Posttest speed (mm/s)	15
Distance (mm)	30

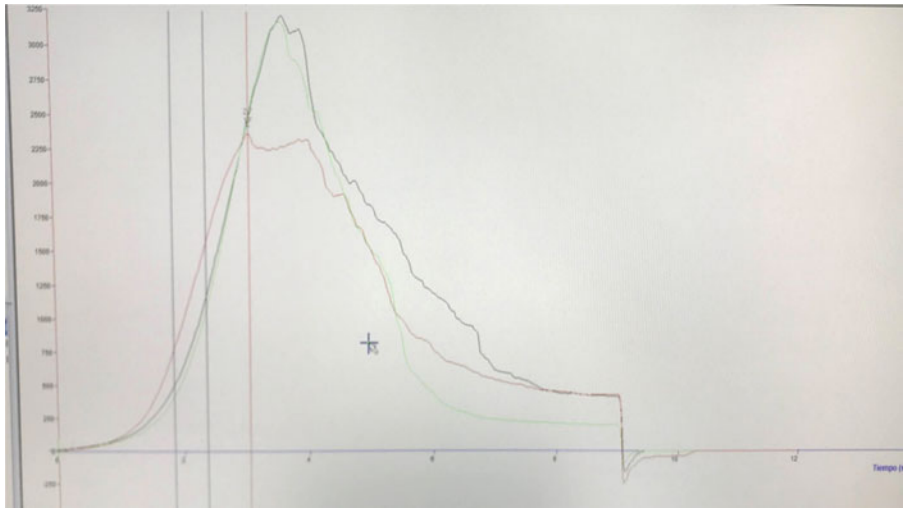

Fig. 5 Typical force deformation curve of the WB test

1. We must set up the parameters of analysis in the "Exponent" software (*see* **Note 8**). You can see the WB parameters for fresh and aged meat in Table 1.
2. Then, samples which have been prepared for the WB test can be cut with the WB blade. In order to achieve a representative result, six pieces must be tested.
3. In Fig. 5, you can see a typical force deformation curve of the WB test.
4. We analyze the curve with "Exponent" software for obtaining the following parameters: Firmness (N/s), Work (N*mm), and Shear Force (N/cm^2).
5. Finally, the result is calculated as the average of the six pieces.

3.3 Texture Profile Analysis (Compression Test)

As we explained above, this test could be carried out on fresh and dry-cured sausages, and other dry-cured meat products. Texture profile analysis is performed according to Honikel (1997) [11] and Bourne et al. (1978) [12] with slight modifications. Figure 6 shows in a simplified and schematic way the steps of the TPA (Compression test). Once the samples are ready for analysis:

1. We must set up the parameters of analysis in the "Exponent" software (*see* **Note 8**). You can see the TPA parameters for fresh and dry-cured sausages in Table 2. In Table 3 you can see the parameters for other dry-cured meat products (*see* **Note 9**).
2. Then, samples which have been prepared for the TPA can be compressed with the cylinder probe of 50 mm. In order to achieve a representative result, six pieces must be tested.
3. In Fig. 7, you can see a typical force deformation curve of the TPA test.

4. We analyze the curve with "Exponent" software to obtain the following parameters: Hardness (N), Adhesiveness (N*s), Springiness (mm), Cohesiveness, Gumminess (N), and Chewiness (N*mm).
5. Finally, the result is calculated as the average of the six pieces.

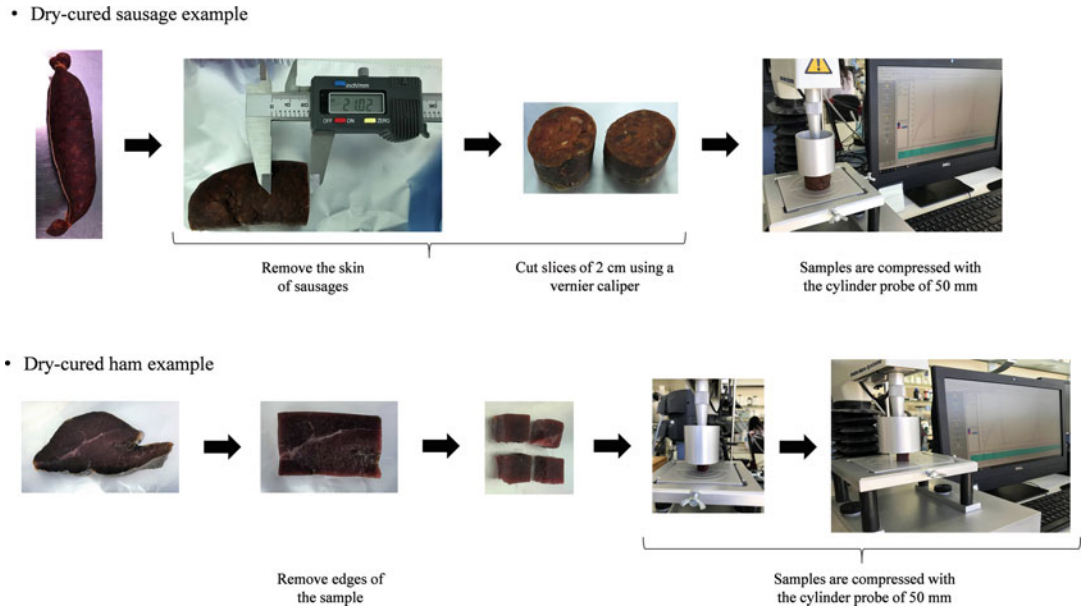

Fig. 6 Schematic and simplified representation of the steps of the TPA (compression test)

Table 2
Analysis parameters to perform TPA (Compression test) on fresh and dry-cured sausages

TPA parameters (Compression test)	
Load cell (Kg)	30–50
Calibration weight (kg)	5
Return distance (mm)	30
Return speed (mm/s)	20
Contact force (g)	2
Pretest speed (mm/s)	10
Test speed (mm/s)	1
Posttest speed (mm/s)	10
Deformation (%)	50

Table 3
Analysis parameters to perform TPA (Compression test) on other dry-cured meat products

TPA parameters (Compression test)	
Load cell (Kg)	30
Calibration weight (kg)	5
Return distance (mm)	20
Return speed (mm/s)	20
Contact force (g)	2
Pretest speed (mm/s)	3.33
Test speed (mm/s)	3.33
Posttest speed (mm/s)	3.33
Deformation (%)	60

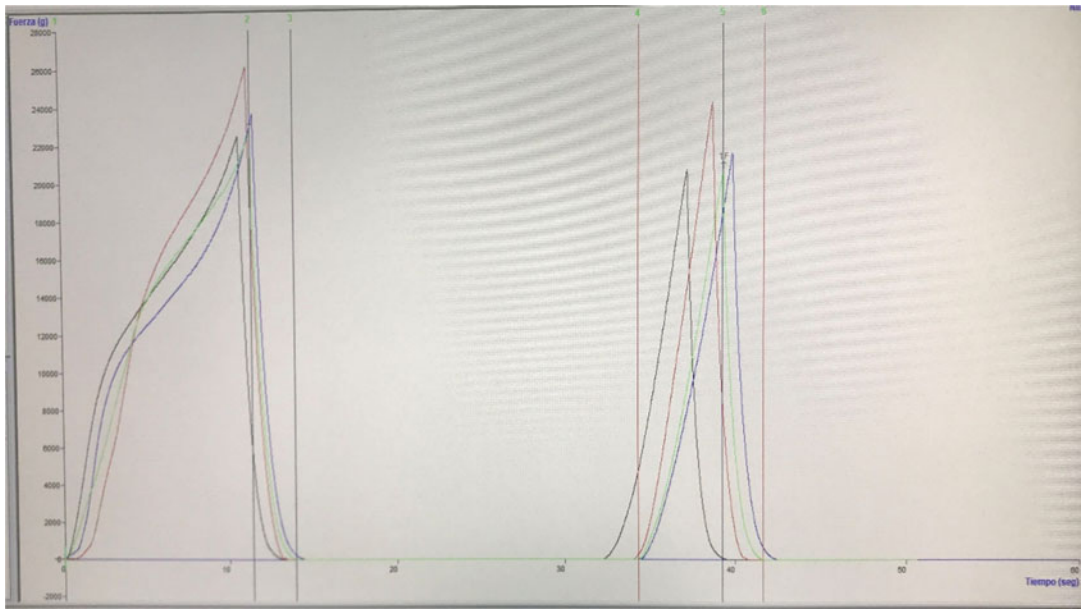

Fig. 7 Typical force deformation curve of the TPA (compression test)

3.4 Texture Profile Analysis (Penetration Test)

Usually, we carry out this analysis in products that are made from a meat paste, as in the case of pâtés. Texture profile analysis is performed according to Vargas-Ramella et al. (2020) [13]. We test this meat product directly in the commercial packaging. Figure 8 shows in a simplified and schematic way the steps of the TPA (Penetration test).

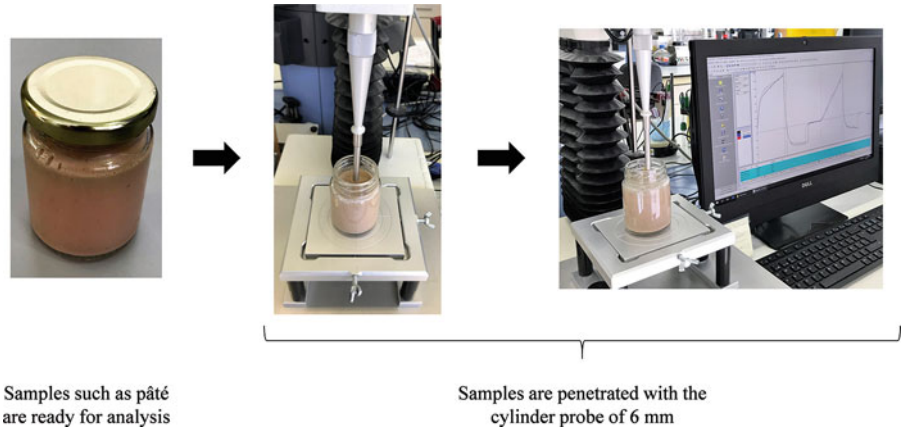

Fig. 8 Schematic and simplified representation of the steps of the TPA (penetration test)

Table 4
Analysis parameters to perform TPA (Penetration test)

TPA parameters (Penetration test)	
Load cell (Kg)	5
Calibration weight (kg)	2
Return distance (mm)	50
Return speed (mm/s)	20
Contact force (g)	2
Pretest speed (mm/s)	3.33
Test speed (mm/s)	0.80
Posttest speed (mm/s)	3.33
Distance (mm)	8

1. We must set up the parameters of analysis in the "Exponent" software (*see* **Note 8**). You can see the TPA parameters for fresh and dry-cured sausages in Table 4.
2. Then, once the container has been opened, the sample can be penetrated with the cylinder probe of 6 mm. In order to achieve a representative result, the test is performed six times in different areas.
3. In Fig. 9, you can see a typical force deformation curve from the TPA penetration test.
4. We analyze the curve with "Exponent" software to obtain the following parameters: Hardness (N), Adhesiveness (N*s), Springiness (mm), Cohesiveness and Gumminess (N).
5. Finally, the result is calculated as the average of the six pieces.

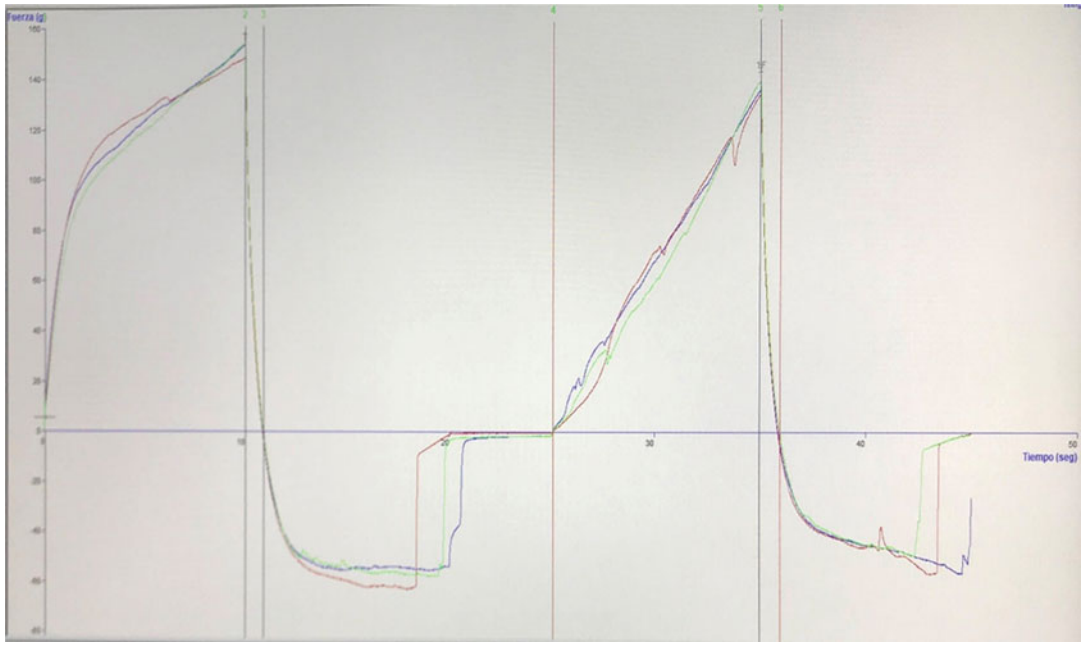

Fig. 9 Typical force deformation curve of the TPA (penetration test)

4 Notes

1. TA-XT Plus has 500 N of force capacity, 0.1 g of force resolution, a speed range between 0.01 and 40 mm/s, a maximum aperture of 370 mm, a distance resolution of 0.001 mm, and a data acquisition rate of 2000 pps.
2. The accessories are:
   (a) On the one hand, two interchangeable load cells of 30 kg and 50 kg. One or the other will be used depending on the expected hardness of the sample. Usually, a 30 kg load cell is used with fresh meat and a 50 kg load cell with drier samples such as dry-cured meat products.
   (b) On the other hand, three different probes. A Warner-Bratzler probe and two cylindrical TPA probes of 50 mm and 6 mm of diameter.
3. "Exponent" software allows us to take control of the texturometer, testing programming, automated curve analysis, statistical analysis, presentation of results, etc.
4. The temperature probe must be placed carefully on the fillet so as not to damage the sample to be used for texture analysis and to correctly control its internal temperature.
5. The edges of the steak are usually very irregular, have some fat and are dried. These facts could affect the results.

6. The pieces of steak should be cut parallel to the fibers.
7. These kinds of sample (dry-cured meat products) should not be cooked because, as a general rule, they are eaten raw. But in the case of fresh sausages, you have to cook them.
8. Texture analyzer should be turned on at least 30 min before analysis. In addition, the equipment must be calibrated. The calibration weight should be 5 kg for 30 kg and 50 kg load cells.
9. Note that the parameters of sausages are different from other dry-cured meat products.

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