

The impact of **tenderization** on increased slicing yield

Marta Xargayó, Josep Lagares, Eva Fernández, Daniel Borrell, Daniel Sanz



ABSTRACT

The yield obtained in slicing lines has quickly become a key of interest for manufacturers of meat products. Meat quality strongly influences yield, and though classification of the meat would be advisable, the increase of this type of products makes this practice difficult for most meat processors. This is why research is continually being conducted as to how to reduce slicing loss by means of the process, without affecting the appearance of the slice or the organoleptic characteristics of the product.

This article examines the impact of the type and intensity of tenderization on two products of differing qualities. The results demonstrate that greater yield is obtained in slicing lines when the degree of tenderization is intensified, but also that this may affect product slicing, so that an equilibrium must be found between yield and quality in each case.

These results attempt to demonstrate up to what point each type of tenderization can be applied and its impact on different aspects of the finished product.

INTRODUCTION

One of the major changes the meat industry has had to face in the past ten years has been the rapid development of sliced-packaged products. Changes in life style, greater product supply, improved quality, more attention to product presentation, increased channels of free service, etc have contributed to increasing market share with every passing year up to two-digit figures depending on the products and zones. While statistics show moderate increases or even decreases of some meat products, the only rapidly rising figures are those which refer to sliced-packaged products, so that nearly all meat processors have had to adapt their processes and machinery to meet this new demand.

In the case of whole muscle cooked products, the industrialization of slicing has given rise to a series

of problems, which although already existed in the past have now greatly increased. Areas with weak binding, air holes, muscles that break or crumble will result in slices unsuitable for packaging, reducing the percentages of yield of the lines. When this operation was carried out at the meat counter with manual equipment, these defects were partially counteracted by the person doing the slicing. But when this work is done by a machine that may produce up to 2,000 slices/minute, any defect in the product will result in the rejection of a large quantity of slices.

Yield in the slicing phase depends principally on two factors:

- Muscle cohesion
- Muscle firmness/consistency

Muscle cohesion

Cohesion of the muscles takes place thanks to the myofibrillar proteins which have been extracted during the manufacturing process and which are found on the surface of the muscle. These proteins form the exudate and, due to their gelling capacity, act as a glue between the muscles. It has been widely demonstrated in the pertinent literature that the greater number of proteins extracted, the greater the stability between muscles and therefore the better the sliceability.

Extraction of myofibrillar proteins is achieved through two actions:

- **Chemical action:** Brine composition. The presence of salt and phosphates increases the pH and the ionic strength of the medium, giving rise to the opening of the protein chains and facilitating their extraction.
- **Mechanical action:** Application of the mechanical process causes relaxation of the muscle structure and breaking up of the cells, making the membranes

more permeable and increasing mobilization of the proteins up toward the surface of the muscle. The degree to which the muscle structure is opened will determine the final quantity of proteins present in the exudate. This opening of the structure is done by means of tenderization, pre-massage and massage.

Tenderization is the mechanical action of producing multiple cuts in the meat muscle in order to increase the surface area and thereby facilitate extraction and solubilization during the massaging phase. Softening of the muscle is also obtained, making the meat more adaptable to the cooking moulds. A study carried out by Wieczorek and Jakubiec-Puka [1997] demonstrated that breakage along the fibers and myofibrils, both in the region of Z line and between A- I bands, caused by different types of tenderization, indicated a decomposition of the integrity of the contractile structure resulting in an increase in proteins available for muscle formation and cohesion.

Tenderization, pre-massage and massage are closely inter-related, and not all products require the same mechanical action. This will depend on the rest of the process and, above all, on the presentation and final quality of the product itself. The mechanical action applied to a whole muscle product to be sliced by hand will be less intense than that applied to a product destined for an automatic slicing line.

Chemical action and mechanical action are closely related and necessary in all products, but when the chemical action is weak due to legislative or market questions, the mechanical action must be intensified and adapted in order to compensate for some of the negative consequences that may result in the product's quality.

Muscle firmness and consistency

From a technological point of view, meat quality is usually measured in terms of meat that is PSE (pale

soft and exudative) or RSE (red soft exudative) and directly affects the yield in industrial slicing, since the lack of protein functionality gives rise to a soft texture of the fibers that present less resistance to the knives, causing breakage of the muscle and therefore resulting in slices that are unacceptable for the consumer. According to the data available from different slaughter houses, the percentage of PSE/RSE meat does not appear to be diminishing, although the statistics vary depending on their origin, with data from some slaughter houses of up to 16-20% occurrence in ham, resulting in high economic losses. The genetic makeup of the animals (presence of the halotane gene, predisposition to porcine stress syndrome), the treatment received before and after slaughter and seasonal factors will determine the presence of this defect. In the south of Europe, where summer temperatures can rise above 35°C, a considerable increase in the percentage of PSE has been detected during the hottest months. There also appears to be a direct relation with the leaner meat that is used for sliced products (Garcia-Rey et al. 2005; Oliver et al. 2001; Buege 1998).

The most advisable practice would be to analyze the meat and separate out the defective muscles, but due to the high incidence of PSE this is not a viable procedure, except for specific quality products. Therefore, processors have no choice but to use meat they know will cause problems, trying to find a way to minimize the negative effects. In low-injection products where meat content represents more than 80% of the final composition, meat quality is a determining factor in slicing yield, while in more highly injected products, this is not as important as the process and technology used.

By means of certain additives, aside from the above-mentioned salt and phosphates, such as carrageenan and vegetable gums, muscle texture can be slightly hardened and/or "plastified", however this alone will not be sufficient to compensate for the meat's lack of firmness. It has been observed that the mechanical action of

tenderization does have a positive effect on this type of meat, because the texture is less fragile due to an increased surface of contact between muscles.

The object of this work is to study which kind of tenderization is most effective for different products, with both slicing yield and appearance of the slice in mind, using commercial meat without muscle selection, in order to standardize the processes in the most real way possible.

EXPERIMENTAL DESIGN

In order to study the effect that tenderization has on slicing yield in whole muscle cooked products, two tests were designed with which to produce two commercial-type products with different types and degrees of tenderization.

Four different types of tenderization were used:

- **Blade head:** Consists of a head incorporated to the injector. It has 336 blades of 5 mm in diameter that deeply penetrate the meat, softening it without producing tearing or separation of muscles. This type of tenderization was used for all types of products for many years, but with the increasing growth of sliced products its use has been shifting to whole products, since cuts are produced only on one side of the muscle (Photo 1).
- **Dual-roller tenderizer:** consists of two counter-cutting rollers through which the meat is forced, producing cuts on both sides of the muscle, while



▲ Photo 2: Four-roller tenderizer, Filogrind Twin, Metalquimia, S.A.

piece. The shape of the rollers and the separation between them will determine the degree of tenderization. The machine used for the tests was a Filogrind model 360, manufactured by Metalquimia, S.A., with two types of rollers:

- **Rollers with prongs:** alternative to the blade head because deep cuts are produced without tearing the muscle, but with a sharper blade and making cuts on both sides. Used for low-injection sliced products in which the muscle should be kept as whole as possible (Photo 1).
- **Rollers with knives:** sharp serrated knives that produce quick multiple cuts and a certain degree of muscle tearing, depending on the separation between rollers. This type of tenderization is the one that results in greater protein extraction, but is also the one that may have greater impact on the appearance of the slice (Photo 1).

▼ Photo 1: Blades of 5 mm, roller prongs, detail of roller prongs and knives, and roller knives.



• **4-roller tenderizer:** similar to the tenderizer described in the above paragraph, but with a double set of rollers to increase the degree of cutting and to provide maximum compensation for the deficiencies in quality of the meat and also compensation for the lack of maturation time in processes of short duration. The model used was a Filgrind 360 Twin, manufactured by Metalquimia, S. A., with four rollers with knives (Photo 2).

In the two tests the only variable factor was tenderization, while all the other parameters of the process (injection, massage, stuffing, cooking...) were maintained as constants in each test. As mentioned above, no selection of meat was made in regard to its origin or the presence of PSE, to replicate the standard production within industry. Finally, all data were compiled, paying special attention to slicing yield, as well as texture and the physical appearance of the finished product.

Test 1: Impact of tenderization on low-injection products.

For this test an injection of 20% was selected, representing a quality product that can be found in many countries. The hams used were from pigs slaughtered in an industrial slaughter house. They were deboned, dividing each ham into the four major muscle groups and leaving a degree of trimming in accordance with sliced products. For each batch 55 hams were prepared, with an average weight after

trimming of 7.2 kg, and left for 48 hours in a chilling room until after rigor mortis.

The hams were injected with a Movistick spray injector, model 120/3000, Metalquimia, S.A. (Spain), before proceeding on to tenderization, which was carried out with three different systems that are usually applied by the industry:

- Batch 1 (T1): head with blades of 5 mm was used for the control batch (Photo 3).
- Batches 2 and 3: roller tenderizer, Filgrind model 360, Metalquimia, S.A. (Spain) with a set of roller prongs separated by 0 mm (T2a) and -10 mm (T2b- Photo 3).
- Batches 4 and 5: tenderizer with a set of roller knives separated by 0 mm (T3a- Photo 3) and -10 mm (T3b).

After injection and tenderization, the meat was massaged in a refrigerated vacuum reactor, Thermomat model PX 500, Metalquimia, S.A. (Spain). Because a low-injection product has a tendency to harden during the resting period, total massaging time was divided into two phases. The first one carried out after the injection and tenderization phases, and the second before stuffing in order to soften and facilitate adaptation of the muscles during automatic stuffing. The total massaging time was 180 minutes under vacuum, with a combination of tumbling and gentle action at different speeds. The resting period was 16 hours at 5°C.

▼ Photo 3: Batches T1 (Blades), T2b (Prongs, at -10 mm) T3a (Knives, at 0 mm).

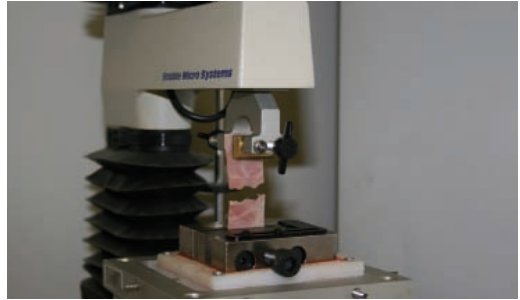
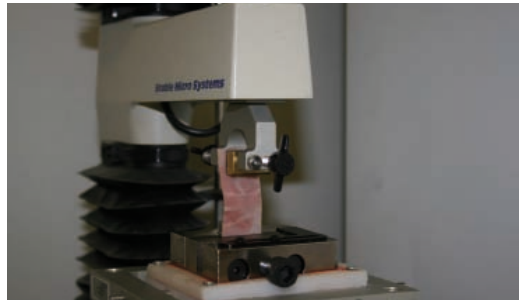


After the second massage, stuffing was carried out with a whole muscle automatic continuous vacuum stuffer, Twinvac model PC9, Metalquimia, S.A. (Spain), which allows for stuffing large pieces without destroying their morphology and obtaining the most natural cut possible. The pieces were placed in multi-mould baskets with a format of 190 x 120 x 1000 mm and cooked in a hot water cooker, following a step-by-step cycle with the first 2 hours at an exterior temperature of 60°C, which was then increased to 72°C until a temperature of 69°C was reached in the core.

Slicing yield: After two days of chilling and stabilization of the product, it was left for 2 hours in the freezer before proceeding on to slicing in a Weber 602 automatic slicer, at 500 rpm, at a thickness of 1,5 mm. The yield was calculated after completion of each piece. At the end of each batch, the average slicing yield of all the pieces was calculated.

Cohesion of the slices: Was evaluated by means of a Tensile Test undertaken in samples of 25 x 60 x 1.5 mm obtained from adjacent slices of cooked ham using a crosshead speed of 1 mm/seg. All the measurements were carried out using a Texture Analyser TA.TX2 (Stable Micro systems Ltd) with a 25 kg load cell. The analysis of the curve force-time leads to the extraction of maximum force [kg f] that is the tensile strength of the material. Five replications were carried out for each sample (kind) of cooked ham (Photo 4).

Analysis of slice appearance: 4 samples from each batch were sliced and visually analyzed by a panel made up of eight experts familiar with such products. For each sample, the following characteristics were evaluated: integrity of the pieces, color uniformity and general acceptability of the slice. A 10-point value scale was used (10 = maximum muscle integrity, natural and uniform color, etc). The evaluation is comparative between the samples, without indicating the degree of acceptability of product itself.



▲ Photo 4: Tensile test with the Texture Analyser TA.TX2 (Stable Micro System Ltd).

Results and discussion

The results obtained from the different combinations can be observed in Table 1. As was expected, slicing yield increased as more cuts were made in the meat to allow for more surface contact between muscles. In most of the options the results obtained were acceptable, except in the case of blade tenderization where the results are too far off the desired average for this type of products.

Given that the duration and type of massage was kept constant in order not to introduce other variables, in the cases of very similar batches, compensation could probably be obtained with one type of tenderization or another with more massaging time, which is the same as saying longer protein extraction time and greater softening of the meat. In contrast, in the case of batch T1, with tenderization applied to only one side of the muscle, it does not seem possible that a modification of the massage could give results similar to those of the other batches, since the meat was too

TABLE 1: TEST 1 PRODUCT ANALYSIS

TEST	SLICING YIELD	SLICE COHESION (tensile strength kg f)	VISUAL ANALYSIS OF THE SLICE
T1	90,2%	0,05	9,7
T2a	94,7%	0,07	9,4
T2b	95,3%	0,07	9,1
T3a	95,6%	0,08	8,9
T3b	96,5%	0,09	7,8

▲ **Table 1: Test 1 product analysis.**

tough to adapt itself correctly to the format of the mould, and protein extraction was quite inferior to the other products. Little difference is observed between the results from batches T2b and T3a, because although different rollers were used, the separation between them can compensate for the type of knife.

The Tensile Test reflects the same tendency as evidenced by the slicing yield, presenting values very far off the mark in the case of the blade tenderizer (T1), while little difference is observed between batches T2a, T2b and T3a.

In the visual analysis of the slice, it can be seen that a better slice is obtained with blade tenderization (T1) because it results in the least damage to muscle structure, but it is not convenient due to the low slicing yield obtained. On the other hand, very intense tenderization, with tightly closed roller knives (T3b), causes too much damage to the muscles for this type of products, in which a more natural appearance is desired. These samples also showed less uniformity of color due to the cuts produced, the presence of small muscles resulting from an excess of mechanical action, and the presence of small redder areas.

The other options gave very similar results and are considered totally acceptable for a high-quality product. But a slight preference for roller prongs (T2a, T2b) can be observed, because they leave no marks at all and the muscles remain in one piece, making them appear more natural. Tightly closed roller knives (T3b) could be useful when meat quality is below Standard or for high-yield products.

A preference for T2a, T2b or T3a may depend on many factors and will have to be studied in detail for each product, requiring statistical results of slicing yield in order to determine with exactitude which of the options is most suitable.

Test 2: Impact of tenderization on high-injection products

A product injected at 100% was chosen for this test. The pork shoulders used were obtained from the same slaughter house as in Test 1 and were deboned, keeping the piece whole, leaving a degree of trimming in accordance with a high-yield product destined for a slicing line. For each batch 84 shoulders were prepared, with an average weight after trimming of 2.9 kg, and left for 48 hours in a chilling room until after rigor mortis.

The same injector was used as in Test 1, and two batches were prepared with different tenderization systems:

- Batch 1 (T4): Roller tenderizer, Filogrind model 360, Metalquimia, S.A. (Spain) with a set of roller knives separated by -10 mm. After the results obtained in Test 1 and given the characteristics of the product, it was decided that no batch would be made with greater separation between rollers, because the main objective was a maximum increase in muscle cohesion (Photo 5).
- Batch 2 (T5): 4-roller tenderizer, Filogrind model 360 TWIN, Metalquimia, S.A. (Spain) with a double set of fixed roller knives, both with a separation of 0 mm. (Photo 5).

The massage was carried out in the same reactor as in Test 1, but since this was a high-injection product, the massage was with intense mechanical action. In order to obtain good sliceability, it is indispensable that the brine be absorbed as quickly as possible to prevent formation of inter-muscular paste, that would create areas with differing textures and more weakening of the muscle. Total massaging time

was 180 minutes and was done in a single cycle after injection-tenderization. In this case it was not deemed necessary to apply a second cycle after stuffing because the meat was sufficiently soft and mouldable. The resting time was 14 hours at 5°C.

Stuffing was carried out in the same whole muscle stuffer, Twinvac PC9. The mould used was square and of smaller format, 110 x 110 x 1000 mm, the most commonly used for this type of products. Cooking was done in a hot water cooker, at a constant exterior temperature of 75°C, until reaching 71°C in the core. The analyses conducted to determine quality of the slices were the same as in Test 1. Due to the texture and format of the product, the study of slice cohesion was carried out with a whole slice (see photo). Therefore, the samples and the scale of values will not be completely comparable between the two tests, but rather only within each individual test.

Results and discussion

As was the case in Test 1, it can be seen that an increase in mechanical action results in increased slicing yield, but in this case with less impact on the appearance of the slice. Tenderization with a double roller produces a multitude of cuts that result in greater contact between the muscles. It was initially thought that that two roller knives with a separation of -10 mm, crisscrossing each other, should give results similar to four rollers more widely separated.

It was observed in the batch T5 that the cuts produced were not as deep but much more numerous in all directions, which seems to result in a much more reliable cohesion. In this case, the depth of the cut is perhaps not as necessary as in Test 1, because at the time of stuffing the meat is much softer due to its higher water content and to having undergone a more intense massaging phase. In Test 1, one of the causes of reduction in yield is toughness of the meat, which if excessive will not permit the muscles to adapt to the mould. This is why cutting depth is just as important as the number of cuts produced.

TABLE 2: TEST 2 PRODUCT ANALYSIS

TEST	SLICING YIELD	SLICE COHESION (tensil strength kg f)	VISUAL ANALYSIS OF THE SLICE
T4	94,6%	0,16	9,1
T5	96,5%	0,18	8,7

▲ Table 2: Test 2 product analysis.

The slice cohesion test demonstrates a high degree of binding between the muscles. As was mentioned in a section above, in high-injection products there is less meat content and greater presence of some additives in the finished product. This allows meat defects to be minimized, so that the lack of meat consistency or the presence of PSE meat has much less repercussion than they do on low-injection products. But the high degree of tenderization and a more intense massage are key factors in hardening and cohesion of the pieces. The combination of

▼ Photo 5: Batch T4 [Two roller knives at -10 mm and T5 [four roller knives at 0 mm].



these factors results in much greater cohesion even when the product is softer.

The impact that the degree of tenderization has on slice acceptability is less than in low-injection products, where a visibly well-defined anatomical shape of the muscle is desired. In high-injection products it is also desirable for the muscles to appear whole, since this makes the product more attractive to the consumer, but the sector of the market to which this type of product is destined and the format of the mould (less viewing surface) allow the muscle size to be smaller. These data seem to indicate that as long as anatomical muscles are visible, and not ground to pieces, what is in the processor's best interest is for the yield to be as high as possible. Therefore, the best strategy would be to apply double tenderization and achieve the highest possible degree of cohesion.

CONCLUSIONS

The tenderization phase has a major impact on yield in the slicing process of whole muscle cooked meat products, regardless of the other characteristics of the process. The application of a multitude of cuts greatly increases the surface of contact between muscles, and facilitates the breakage of myofibrils, so that the possible weak areas with little resistance to the knives due to the presence of PSE/RSE meat, are distributed throughout the entire piece, thereby diminishing the formation of defective slices caused by lack of muscle cohesion or consistency. In contrast, blade tenderization, in which cuts are produced on only one side of the muscle, proves to be insufficient for acceptable in-line yield, but continues to be an optimum type of tenderization for whole pieces.

As the acceptance results demonstrate, various tests will be required for each product in order to determine the type and intensity of tenderization that is optimum for each product, depending on the desired quality of the product and the sector of the market to which it is destined. Rollers with prongs

appear to be the most suitable for low-injection products because they allow for keeping the natural appearance of the muscle intact. While rollers with knives, and above all with double tenderization, prove to be very effective in more highly injected products.

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