Effects of a pre-massaging stage (sequence of pressure impacts) in the manufacture of cooked whole muscle meat products

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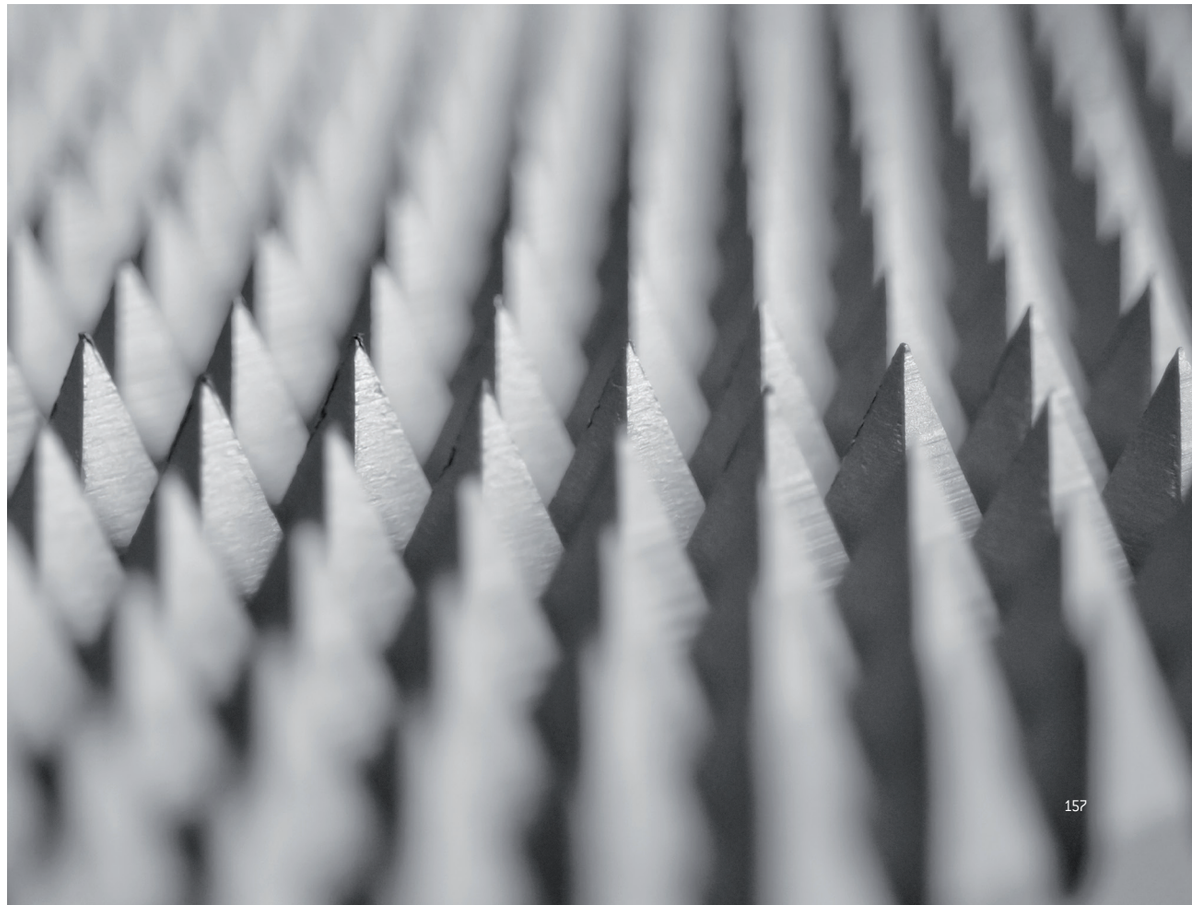


ABSTRACT

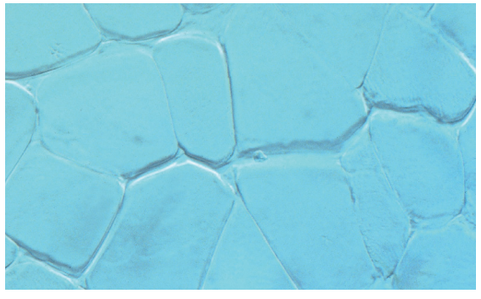
The application of a sequence of pressure impacts (pre-massaging) to the meat muscle has a notable and innovative effect on the way the meat responds during the course of the manufacturing process for cooked meat products. In order to quantify this effect and be able to apply it in a production line, a series of tests were conducted at the laboratory, pilot plant and industrial level. For the laboratory tests, samples of the *Biceps femoris* muscle, at different stages of the process, were taken and histological slices were prepared, in order to study the effect of pre-massaging at the cellular level. Subsequently, further testing was done in a pilot plant to define the system of pressure application to the meat. Finally, a series of tests were prepared in various industrial plants to study the effect of pressure applied sequentially to a number of commercial products. The following parameters were taken as reference: massaging time, yield, muscle binding and sliceability, since these are the factors that influence product quality and cost. The results obtained in the tests described in this article demonstrate that pre-massaging has a very positive and efficient effect on all the above-mentioned parameters and can be applied to most manufacturing processes for whole muscle meat products. The characteristics of muscle fibre vary from one kind of meat to another and from one product to another, so that the intensity of pressure must be adjusted in order to achieve the desired effect.

INTRODUCTION

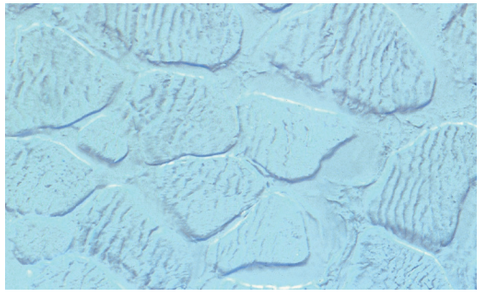
The objective of all manufacturers is to continually improve product quality and lower production costs. Thanks to the evolution of technology, these objectives have become more and more attainable. However, technological advances took place very quickly in the early days of industrialized processing lines for cooked meat products, and as processing techniques have been perfected, it is becoming increasingly difficult to improve upon them.

The manufacturing process for cooked meat products, in general terms, has consisted for some time now, of the same basic steps: **Injection, tenderization, massaging, stuffing, cooking and cooling**. The final objective of this process is to obtain increased water holding capacity and good binding of muscles. One of the key factors in reaching these objectives is to achieve proper extraction and solubilization of muscle proteins, in particular the myofibrillar proteins, which represent 50% of all meat proteins and are responsible for muscle structure. These proteins, once solubilized, form an exudate that acts as glue between the muscles and hold water, since they form a three-dimensional web of filaments.

▼ **Photo 1:** Unprocessed meat. Nomarsky Interferential Contrast Staining. 500X.



▼ **Photo 2:** Meat after injection, tenderization and pre-massaging. Nomarsky Interferential Contrast Staining. 500X.

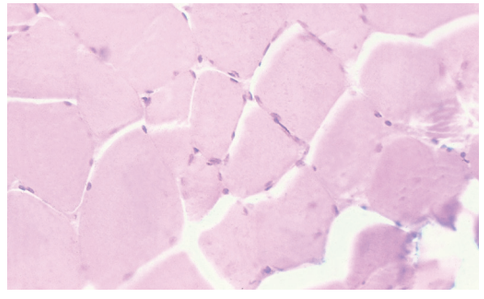


In addition to the chemical effect of brine ingredients (which increase the pH and ionic strength of the medium by facilitating the opening of chains and extraction), protein solubilization will depend on a mechanical effect carried out through tenderization and massaging. Tenderization is the mechanical action of producing multiple cuts in the muscle, thereby increasing the surface area for extraction. Massaging by means of pounding and/or rubbing action will help brine absorption and distribution, protein solubilization and extraction and, above all, the distribution of these proteins on the muscle surface. The degree of tenderization and the combination of massaging time and intensity will result in a determined yield and muscle binding.

PRE-MASSAGING UNIT

To increase product yield, or to reduce massaging time, simply increasing the degree of tenderization and/or intensity of massaging will not be enough to achieve said objective. There are a series of limitations imposed by product quality. Both tenderization and massaging, if applied in excess, can destroy the meat structure, with a resulting loss of visible muscle fiber in the slice. If the number of cuts is excessive, the muscles get torn and discoloured areas may appear in the product. An excess of massaging may cause a pasty substance to form between muscles, due to an excess of coagulated protein, as well as destroying the morphology of the piece.

▼ **Photo 3:** Unprocessed meat. Hematoxiline-Eosine Staining. 500X.



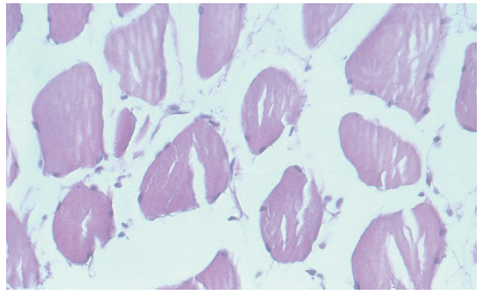
In order to achieve the objectives mentioned at the beginning of this article, a system was devised that would act on the myofibrillae but not be detected in the muscle fibre and, consequently, would not affect the appearance of the slice or product texture.

This process consists in sequentially applying impacts of pressure (60-100 kg/cm^2) to the meat muscle. This treatment process softens the meat, causing a stretching and separation of cells and increasing the interfibrillar free spaces, resulting in better and faster brine absorption, a reduction of effective massaging time and increased muscle binding.

EFFECT OF PRE-MASSAGING ON MUSCLE FIBERS AND MYOFIBRILLAE

The effect of pre-massaging, based on the application of pressure impacts to the meat mass, is the breaking up of muscle tissue at the cellular level, in particular the cell membrane, which facilitates the release of the cytoplasmic liquid containing myofibrillar proteins into the intercellular space.
It is widely accepted that an increase in the ionic strength of the medium, produced by the action of sodium chloride and phosphates, facilitates extraction of myofibrillar proteins. By applying pressure impacts to the cells, which breaks up the membranes, extraction is carried out more quickly and efficiently.

▼ **Photo 4:** Meat after injection, tenderization and pre-massaging. Hematoxiline-Eosine Staining. 500X.

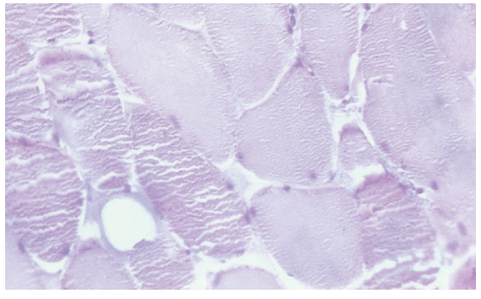


By comparing photographs 1-4, it can be observed the difference in the intercellular space and arrangement of cells in the unprocessed meat (Nº1 and 3) and in the meat after undergoing injection and a pre-massaging process (Nº 2 and 4). In the latter photograph the surface of the fibres appears cracked and the fibres have lost their polyhedral shape to become more rounded.

The massaging process has a similar function, the breaking up of muscle cells and the subsequent extraction and solubilization of proteins into the intercellular space. If the pre-massaging unit begins breaking up the cells right from the start of the process, the necessary massaging time is reduced, since a great part of the mechanical work has already been performed. Having this work carried out at the start of the process, rather than throughout the process, can reduce not only massaging time, but also maturation time.

In photographs 5 and 6 one can observe the difference in the final intercellular space in a meat muscle after having undergone injection, tenderization and massaging (photograph nº 5), as compared to meat that has undergone, in addition, a pre-massaging phase (photograph nº 6). One can also observe the change in the intercellular space in photograph nº 6 in relation to photographs 2 and 4, in which massaging has not yet been applied.

▼ **Photo 5:** Meat after the process of injection, tenderization and massaging. Hematoxiline-Eosine Staining.500X.



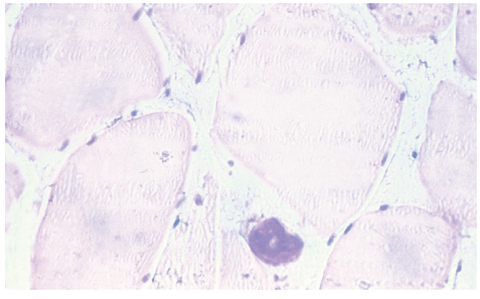
The initial intercellular liquid has been distributed by means of the massaging action, part of it having been reabsorbed into the cell and the rest distributed towards the meat muscle surface (exudate), where the solubilized proteins will be able to produce muscle binding. The reabsorbed liquid contains the myofibrillar proteins that have held the water present in the intercellular space. The liquid remaining between the cells will be in optimum conditions to hold the water that could otherwise be lost during the cooking process, thanks to coagulation of the proteins.
The difference in the intercellular space existing during the course of the cycle is what explains the differences in yield, effective massaging time and muscle binding that have been observed in the commercial tests. The muscle structure has not suffered any more aggression than in normal processing (no greater number of cuts or fissures) and the aggressive action of massaging has been diminished, so that product appearance and chewiness have been improved.

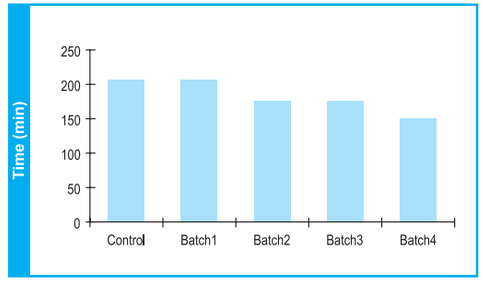
DESCRIPTION OF THE PROCESS AND ITS EFFECT ON THE MEAT MUSCLE

Material and Methods

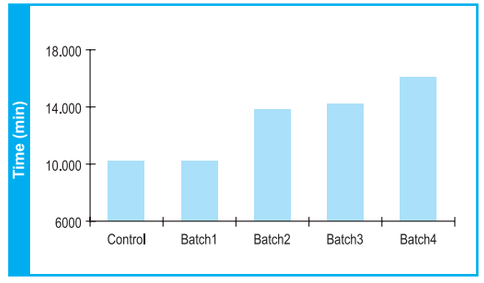
A series of pilot plant tests were designed to determine how a specific pressure should be

▼ **Photo 6:** Meat processed in the same way as photograph nº5, with the addition of the pre-massaging unit. Hematoxiline-Eosine Staining.500X.





▲ **Graphic 1:** Effective massaging time.



▲ **Graphic 2:** Compression measurement of muscle cohesion.

applied to the meat in order to achieve the most desirable effect.

A product of standard preparation was injected, with the meat of a post-rigor mortis pork leg (48 hours) quartered into 4 muscles. An appropriate brine for obtaining a cook-in product was injected at level of 50% with a spray injector. After injection, the sample underwent tenderization using star-shaped needles 12 mm in diameter. The standard massaging time for this product was three and a half hours of tumbling, carried out in a refrigerated reactor.

Before massaging, the meat was divided into 5 batches, to which a pressure of 85 kg/cm^2 (defined as standard in the histological laboratory tests) was applied in various sequences and application times. The processing of each batch was as follows:

- Batch Nº 1 - Control: Standard process (Injection + Tenderization) without pre-massaging.
- Batch Nº 2: Standard process + One pressure impact applied for 1 second.
- Batch Nº 3: Standard process + One pressure impact applied for 6 seconds.
- Batch Nº 4: Standard process + Four pressure impacts applied for 1 second.
- Batch Nº 5: Standard process + Eight pressure impacts applied for 1 seconds.

Subsequently, the massaging stage, divided into two cycles with a resting period of 16 hours between each cycle, was carried out. In order to determine the massaging time needed for each batch, pieces with various massaging times were stuffed.

Stuffing was done manually with impermeable thermo shrinkable bags before going on to a vacuum stage of 8 minutes and subsequent clipping in a vacuum chamber. Cooking took place in a wet steam oven, at a constant temperature of 72 ºC until reaching a core temperature of 69º.

For the determination of texture properties of the products, a texture analyser model TA-XT2 was used. Parameters measured were compression force and cohesion of the slices (defined as the quality of remaining compact, not breaking).

Results

As can be seen in the results shown in Table 1, the application of pressure has greater effectiveness when carried out on the basis of various applications (impacts) than when a single impact is applied, even if the single impact is of greater duration. If the number of applications or impacts is increased too much, the meat muscle gets torn and, although muscle binding is improved, quality is diminished in the appearance of the slice due to less visible definition and more separation of the muscles.

The total massaging time is reduced by different degrees according to the type of application, but

starting from batch Nº 2 it is significant in all cases, reaching 29% in batches 3 and 4. As was mentioned in the above section, this may be due to greater breaking up of the membranes and, consequently, increased protein extraction.

TABLE 1: TEST RESULTS FOR APPLICATION OF THE SYSTEM

TEST	MASSAGING TIME (min)	COHESION (kg)	SLICE APPEARANCE
Control	210	10.603	Normal
Batch 1	210	10.712	Normal
Batch 2	180	13.943	Better texture than Batch1
Batch 3	150	14.767	Better texture than Batch1
Batch 4	150	16.014	Excessively torn

An improvement in color uniformity was likewise detected starting from batch Nº 2, due to better brine distribution and, consequently, greater and faster contact of the nitrifying ingredients with the myoglobin.

With softening of the meat, the color appears more uniform throughout the entire piece, eliminating the problem that can sometimes be detected in areas near the nerves which, since they are tougher, hinder brine access.

As the results of table 1 demonstrate, the compression force, and therefore muscle binding, increase with the number of impacts applied to the meat, due to an increased breaking up of the cell membranes and, consequently, greater extraction of the myofibrillar proteins that form the exudate.

▼ **Photo 7:** Head with displaceable plate.

EFFECT OF THE PRE-MASSAGING UNIT IN INDUSTRIAL TESTS

In order to proceed to industrial testing, a pre-massaging unit was designed based on the results of the pilot plant tests, in such a way that the unit could be incorporated into a production line without interrupting the processing cycle or the meat flow.

The pre-massaging unit consists of four displaceable heads with a plate incorporating pointed members of various polyhedral shapes (Photograph nº 7). The heads, each with adjustable stroke time, are operated by hydraulic cylinders. A conveyor feeds the meat between the plates at the lower part of the unit.

The pressure applied at each impact is adjustable, to allow for adaptation to varying degrees of toughness in different meats (pork, beef and turkey) as well as varying sizes of the meat to be processed.

The pre-massaging unit is incorporated into a processing line, at the output end of the injector-tenderiser, with the meat going directly from one machine to the other.

Since the effect of the pressure impacts is at a cellular level, the unit is applicable to all kinds of products, with preference given to one or another studied parameter according to the product's characteristics and requirements. In order to demonstrate that the effect of the pre-massaging unit would be universal, tests were conducted in a variety of countries, each with their own particular conditions and demands. The studied parameters were the same as in the pilot plant testing: reduction of massaging time, improved muscle binding and sliceability and increased yield.

Reduction of effective massaging time

Effective massaging time depends on the characteristics of the machine used, and so varies from one to another. Reduction in massaging time is beneficial in all cases, since the same machine can be used for more production batches, thereby increasing profitability of the unit. Also, fewer units are needed, which lowers the investment cost and reduces the amount of space needed for the equipment.

Material and Methods

In order to evaluate effectiveness of the pre-massaging unit, four products with varying characteristics were selected as a basis for testing:

- Product Nº 1: Extra Cooked Ham in Spain, injected at 15% using cook-in system (115% yield). Process similar to the standard one described in the pilot plant tests: Whole skin-on ham, injection with a constant pressure spray injector, tenderization with needles 12 mm in diameter and massaging in a refrigerated pulmonary reactor. Stuffing in thermo shrinkable bag and steam cooking at a constant temperature of 72ºC until reaching a core temperature of 69ºC. Effective massaging time is 200 minutes, divided into two cycles with a resting period of 20 hours in between.

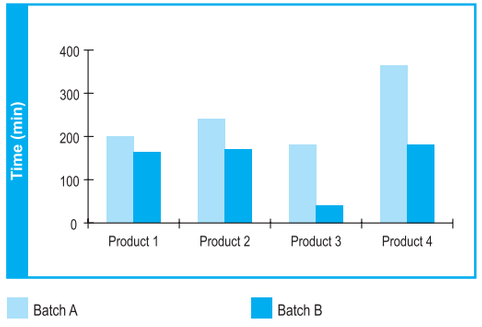
- Product Nº 2: Premium Cooked Shoulder in Spain, injected at 35% using cook-in system (135% yield). The normal process is as follows: Whole shoulder, injection with a constant pressure spray injector, tenderization with roller knives and massaging in a refrigerated pulmonary reactor. Stuffing and cooking the same as product Nº 1. Effective massaging time is 235 minutes, divided into two cycles with a resting period of 20 hours in between.

Product Nº 3 and 4: Turkey breast in the United States, a product very typical of this market, whose consumption is on the rise in most other countries.

Although injection of this product type varies from 15 % to 60%, injections considered to be most representative were used, 23% (Product Nº 3) and 54% (Product Nº 4). The process is the same for both products and is similar to that of pork ham: injection with a spray injector, tenderization with needles 3 mm in diameter, vacuum massaging (unlike the model used in products Nº 1 and 2, and much less effective), stuffing in thermo shrinkable bag and steam cooking. Effective massaging time in Product Nº 3 is 180 minutes and in Nº 4, 360 minutes. In both cases the product undergoes a single cycle, and the resting period before cooking is from 5 to 8 hours.

TABLE 2: REDUCTION OF MASSAGING TIME

PRODUCT	PRE-MASSAGING TREATMENT		MASSAGING TIME (min)	MASSAGE TIME REDUCTION
	PRESSURE (kg/cm2)	TIME		
Product Nº 1 - Batch A	-	-	200	-
Product Nº 1 - Batch B	80	0,75	160	20%
Product Nº 2 - Batch A	-	-	235	-
Product Nº 2 - Batch B	85	0,75	165	29,8%
Product Nº 3 - Batch A	-	-	180	-
Product Nº 3 - Batch B	70	0,65	45	72,7%
Product Nº 4 - Batch A	-	-	360	-
Product Nº 4 - Batch B	70	0,65	180	50%



▲ **Graphic 3:** Reduction in massaging time.

Each of the tests was divided into two batches (A and B). Batches A of each product served as controls and were manufactured according to the standard process for each product. Batches B underwent processing in the pre-massaging unit (pressure and time parameters were adjusted as shown in Table Nº 2) and, as was done in the pilot

plant tests, the effective massaging time needed to obtain a cook-in product was calculated.

Results

It can be observed in the results, a significant reduction in effective massaging time in Batches B of all products, the percentages varying according to the type of meat and injection.

The time reduction is much more notable in the turkey breast products, since they contain a higher protein percentage and the proteins are more easily extracted from this meat type, and also because the massaging unit used was less effective than that used for the first two products.

These test results demonstrate that the increase in intercellular space observed in the histological slices gives rise to greater water holding on the part of the myofibrillar proteins. In batches B of products Nº 1 and 2, an improvement in meat texture was observed, being classified by the panellists as a more meaty texture, undoubtedly due to the reduction in massaging time. The softening of the muscle mass and, above all, of the connective tissue allows the meat to lose rigidity and reduces the retraction produced during cooking, resulting in a lower percentage of pieces with areas of cooking loss. This phenomenon was not observed in the turkey breast products, since this is a softer meat with little connective tissue.

Increased muscle binding and yield in sliced products

The market demand for sliced products is increasing all the time, and more and more processors are opting for production of this product type. Products destined for slicing in high-speed machines (400-800 slices/minute) must have a special design that facilitates, among other aspects, the binding between muscles, which must be strongly reinforced in order to withstand the intensity of high-speed slicing and prevent the product from getting torn.

▲ **Photo 8:** Pre massage Unit.

Since an increase in muscle binding was observed in pilot plant testing, the results of the cohesion tests conducted in a texture analyser were compared with the percentage of defective slices obtained from a high-speed processing line.

Material and Methods

Product Nº2 of the previous test, Premium Cooked Shoulder, was chosen to be used as a sample. After cooking, pieces from each batch were taken and kept separate in preparation for the testing. Slicing was done in an automatic slicer at a speed of 500 slices per minute. All slices obtained from the two ends of the pieces were eliminated, so that the rejected slices recorded in Table 3 refer only to the slices torn in the machine due to insufficient muscle binding.

Cohesion in the cooked ham slices was determined, as in the pilot plant tests, by means of a TA-XT2 texture analyser equipped with a 50 mm cylindrical probe with a 25 kg load cell. Testing was conducted on 200 homogeneous rectangular slices from each batch, in order to determine the compression force needed to compact the sample by 40%.

Results

In Table 3, the influence of the pre-massaging unit on reducing the percentage of defective slices can be observed. The pilot plant tests had already demonstrated that, thanks to increased protein extraction, muscle binding was improved, and this fact was confirmed by the automatic slicing test in an industrial processing line. It is also likely that, with the disappearance of tough areas due to greater softening of the connective tissue, and with a greater degree of homogeneous compactedness obtained throughout the entire piece, less product tearing occurs during the slicing process, thereby reducing the % of defective slices.

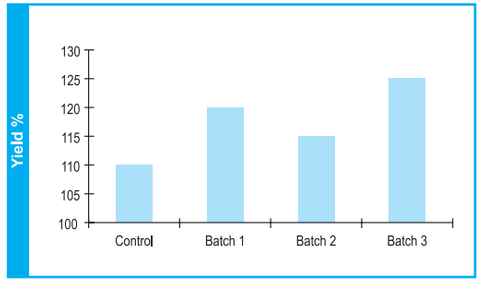
Increased yield in the final product

This parameter was evaluated with products different from the ones used in the tests described above, because of the limitations on yield imposed by legislation in most cases. In order to obtain more information regarding the pre-massaging unit's effect on all types of meat, testing was conducted with beef meat, since it responds to processing very differently than pork meat does. In general, beef is tougher, with less brine absorption power and less water holding capacity. These tests were carried out in a processing plant in the United States, since this country has high consumption of beef products.

TABLE 3: INCREASED MUSCLE BINDING

PRODUCT	COHESION (kg)	% DEFECTIVE SLICES
Product Nº 2 - Batch A	11.430	2.5%
Product Nº 2 - Batch B	14.560	0.5%

▼ **Graphic 4:** Yield variation on 100 Kg green meat.



Material and Methods

The product prepared was made from hindquarter muscles, trimmed of fat and connective tissue, and underwent the following process. 35% injection with a spray injector, a single massaging cycle of 90 minutes with tumbling in a refrigerated reactor, and cooking with the classic cook-in method demanded by the manufacturer. The final yield obtained in standard productions, after cooking and cooling, is from 108-112% on 100 Kg of green meat.

In this test, the effect of the pre-massaging unit on the meat was also evaluated before injection, because the meat type being processed is very tough and composed of larger muscles. For the same reason, the testing was conducted with greater pressure intensities than those that can be applied to pork or turkey meat. The meat sample was divided into four groups with the following characteristics:

- Control: Injection + Massaging
- Batch 1: Pre-Massaging Unit (Pressure = 70 Kg/cm^2 and head down stroke time of 0.8 seconds) + Injection + Massaging
- Batch 2: Injection + Pre-Massaging Unit (Pressure = 70 Kg/cm^2 and head down stroke time of 0.8 seconds) + Massaging
- Batch 3: Injection + Pre-Massaging Unit (Pressure = 100 Kg/cm^2 and head down stroke time of 1.5 seconds) + Massaging

Results

The results obtained are shown in Graphic 4, in which it can be observed how the final product yield

increases greatly as the pressure of the impacts applied to the meat is increased. As regards effective massaging time, it was left the same as in the control, since there was no evidence of increased brine absorption speed. While with pork meat the pressure intensity used does not usually exceed 90 kg/cm^2, since that would damage the meat structure, with beef it was possible to reach an intensity of 100 Kg/cm^2 without affecting the product, resulting in a greater increase in final product yield. Another interesting aspect of these test results is that, at equal pressure, the meat processed with the pre-massaging unit before injection gave a better yield than the meat processed with the unit after injection. This fact does not affect the production line, since the unit can be installed before or after the injector without interrupting the continuity of the line.

CONCLUSIONS

In all the industrial tests carried out with the pre-massaging unit, which consists in the application of pressure impacts by means of plates driven by hydraulic cylinders, an improvement in product quality and yield was observed. Effective massaging time can be reduced, in most cases, by 20 to 30% when working with products based on pork meat. With products made from turkey breast this reduction can reach 73%. The increase in muscle binding, due to greater protein extraction, results in a reduction in defective slices in high-speed slicing lines. Finally, the tests demonstrated that with products in which water holding is difficult (beef products) the increase in final yield can reach up to 16 points in comparison with products processed without the pre-massaging unit.

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