Whole muscle **stuffing** of meat

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ABSTRACT

This article describes a series of tests conducted in order to compare the results of an automatic vacuum stuffing-dosing machine, specially designed for the stuffing of whole muscle meat products, with other stuffers on the market used for the same purpose but not specifically designed for this type of product.
First the stuffing system's impact on product yield was studied in terms of sliceability, verifying that the stuffer analyzed attains a significant reduction in the number of slices rejected due to poor intermuscular binding. This difference in yield was found to be a result of the stuffer's capacity to greatly reduce the appearance of occluded air and the formation of intermuscular meat emulsion.
Then the stuffing system's reliability was tested by comparing the dosing precision of various machines, confirming the qualitative and economic advantages of vacuum stuffing-volumetric dosing systems as compared to conventional systems.
Finally, a comparative study was done to determine the stuffing system's influence on bacterial contamination of the meat. A significant reduction in the bacterial count was observed when an automatic vacuum stuffing-dosing system was used, thereby eliminating human contact with the products, as opposed to the manual stuffing system.

INTRODUCTION

The stuffing phase has been one of the most neglected parts of the production process for cooked ham. A look at the references existing up to the present reveals that most of the meat industry's research has been aimed at perfecting the phases related to greater technological and scientific development, such as brine compositions, injection systems, types of massaging, etc. in which knowledge of the meat's composition and characteristics is of prime importance. In contrast, the stuffing phase, that is, introducing a determined volume of meat mass into a bag, fibrous casing, or directly into a mould, has been a basically mechanical operation carried out manually, requiring a great deal of manpower and with the possibility of human errors. Rarely has any emphasis been placed on the importance this phase has in the finished product's appearance and presentation or its impact on a production plant's economy, except in terms of cutting down on manual labor. It is also evident from the industry's references that most of the innovations in stuffing machines have been aimed at ground or emulsified products, with a clear evolution and improvement in these machines over time.

In the field of cooked ham and similar products, where one of the most important factors is maintaining the whole muscle intact, these same machines began to be used, making it necessary to grind meat that, up until this phase, had been kept whole. Little by little, these machines were adapted to be able to work with larger meat pieces, eliminating the need to cut the muscle, but in all cases severe tearing was produced in the meat muscle as it passed through the stuffing system, with a clearly negative impact on the finished product's appearance, especially when compared to cooked ham stuffed manually. In addition, these types of stuffers, which are still being used, are not capable of efficiently eliminating intermuscular air, despite the adaptations that have been made towards that end, and do not satisfy the requirements of precision dosing. These machines have been used primarily for the manufacture of low-cost products, where the significant savings in manpower takes priority over the finished product's appearance.

In recent years, the evolution and globalization of markets, with products of ever-increasing quality at a lower cost and the general rise in demand for sliced products, has created the need for stuffing machines capable of obtaining products with an appearance similar to those molded by hand, with equal or better sliceability behavior when working with high-speed slicing machines and providing the reduction in manpower necessary to be able to offer a good cost-quality ratio in today's meat markets, which are becoming more competitive all the time.

This article documents, in a comparative way, the advantages offered by one of these new generation stuffer-dosers, analysing which design and process variables are responsible for the improvement it provides in the stuffing phase and, essentially, in the finished product's appearance

INFLUENCE OF THE STUFFING SYSTEM ON INTERMUSCULAR BINDING AND ON THE FINISHED PRODUCT'S APPEARANCE. AIR OCCLUSION.

It is a well-known fact that in manufacturing cooked products to be sliced in high-speed slicing machines (400 to 800 slices per minute) a special product design is necessary to affect, among other aspects, the binding between muscles, which must be strongly reinforced in order to withstand the force of high-speed cutting without damage to the product.

A problem that strongly affects intermuscular binding is the incorporation of air into the protein exudate film which forms during massaging. This incorporation of air tends to occur in the unloading of massaging reactors if it is done very slowly (with many revolutions of the reactor at atmospheric pressure) as well as in stuffing machines, when two factors converge:

- Insufficient air elimination in the stuffing zone.
- Aggressive movement of the meat in this zone.

The existence of air in this zone, combined with the strong agitation of the meat, causes a microemulsion to form which, once coagulated in the finished product, creates an area of less consistency between the muscles, forming a weak spot where tearing occurs during high-speed slicing.

In order to verify the influence of the stuffing system used on sliced product yield, the following test was designed:

In a pilot plant, 2 batches of 250 kg were produced, each batch of the following products:

Cook-in ham with a final yield of 125 % (100 kg of ham + 25 kg. of brine) in rectangular loaves of 19.5 x12 x27 cm, with a weight of 7 kg.

Cook-in shoulder with a final yield of 150 % (100 Kg of shoulder + 50 kg.19.5 x12 of brine) in rectangular loaves of x27 cm, with a weight of 7 kg.

Both products contain carrageenan, in addition to the usual ingredients and additives. Both were injected with a spray injector and tenderized with a needle head, the tenderizing needles being 5 mm. in diameter in the case of the ham, and 12 mm. in diameter in the case of the shoulder. After this process, the products were massaged in a refrigerated vacuum pulmonary reactor, with a maturation period between injection and cooking cycle of approximately 20 hours and a maturation temperature of 5º C, with total massaging times of 2 hours, 10 minutes (ham, final yield 125 %) and 2 hours, 45 minutes (shoulder, final yield 150 %). Then each batch was subdivided into four parts, which were stuffed in four different machines in multilayer Cook-in bags, then vacuum-clipped and molded in stainless-steel moulds suitable for obtaining loaves of the dimensions described above.

The following machines were used:

1. Multi-baffle stuffer with impulser worm in open hopper and air drive in the stuffing chamber. This stuffer uses 6 baffles in order to handle relatively large muscles. Outlet-stuffing tube of 60 mm.
2. Double-worm screw stuffer with impulser worm in open hopper with air drive through the screw and outlet-stuffing tube of 60 mm.
3. Single-baffle stuffer with impulser worm in closed vacuum hopper and volumetric dosing accessory, with outlet-stuffing tube of 80 mm.
4. Volumetric stuffer for whole muscle meat with impulser piston in vacuum hopper (object of this study) with outlet-stuffing tube of 125 mm.

The pieces obtained from the different stuffing procedures were cooked in a water cabinet at a temperature of 74º C until reaching a core temperature of 69º C. After cooking cycle, they underwent a pre-cooling process for 24 hours, reaching a core temperature of approximately 6º C, then were de-molded and cooled for another 24 hours until reaching a core temperature of -1º C in order to strengthen the pieces and facilitate the slicing process.

After this cooling process, the pieces (8 pieces for each stuffer and product) were sliced in an automatic slicer at a speed of 500 slices per minute, with 1 mm width slices. Of the slices obtained, all those corresponding to the two opposite ends of the pieces were eliminated, so that all the data of defective slices that appear in the chart below refer to slices torn in the machine due to insufficient muscular binding.

▲ **Stuffer 4:** Whole muscle vacuum stuffer.

Results

The results obtained cannot be considered as absolute parameters, since there are a multitude of processing factors that perceptibly affect intermuscular binding in the finished product, but they do have an important comparative value, despite the few pieces tested, given that the only processing variable was the stuffing system used.

TABLE 1

STUFFER	% DEFECTIVES SLICES	
	HAM 125 %	SHOULDER 150 %
1	13,2	22.5
2	8,1	11.4
3	0,8	1.2
4	0,3	0.2

As can be observed in the chart above, the factors outlined in the introduction of this section have a very important influence on the final result obtained. The determining factors in the different results observed above can be analyzed machine by machine.

• Stuffer N 1: Because this machine is not specially designed for the stuffing of cooked ham or whole muscle products, it presented many difficulties during the stuffing process, despite having reduced the number of baffles in the stuffing chamber. In this machine, with an open hopper, a first mixing with air is produced by the action of the worm that pushes the meat to the dosing chamber. Being a low-speed worm, the air is not emulsified but it mixes with the meat and moves with it into the stuffing chamber, where an intense friction with the baffles and walls produces air emulsification, as well as generating a greater amount of intermuscular meat emulsion due to the smear produced by the baffles. The vacuum applied in this chamber is clearly insufficient since the slices obtained have abundant micro-holes in the intermuscular meat emulsion, directly responsible for the poor binding reflected in the data of defective slices, as well as many spherical holes 2-3 mm in diameter due to unemulsified air bubbles that, because of the inadequate vacuum effected in the stuffing chamber, were unable to be eliminated. The appearance of the slice is the worst of the four, with a very poor muscular definition and, in the case of the shoulder slices, intermuscular strings of a very visible yellowish color, due to the high nitrite consumption caused by the emulsified air.

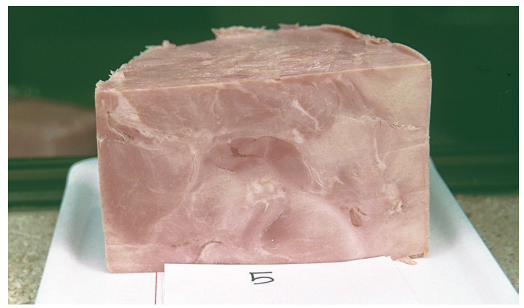
• Stuffer N 2: The design of this machine, open hopper with meat impulser worm,results in the same defects observed in the first stuffer. However, much less smear is produced in the double-worm stuffing zone, and the finished product has less intermuscular meat emulsion. Although air extraction is somewhat more efficient, producing slices with much fewer spherical holes 2-3 mm in diameter, it is still insufficient to prevent air from being occluded in the meat by the hopper's worm action and being emulsified by the strong friction produced in the stuffing chamber. In the shoulder slices a slightly yellowish intermuscular color is still visible, even though the amount of intermuscular meat emulsion is less than in the first stuffer, and the slice is cleaner but made up of many small pieces, resulting from the cutting effect of the double-worm stuffer.

• Stuffer N 3: In this stuffer a significant difference is observed in slice yield, essentially due to the presence of vacuum in the hopper, obtaining products free of emulsified air in the intermuscular meat emulsion, a fact which confirms the premise set forth in this section regarding the strong influence the condition of intermuscular protein film has on final slice yield. However, when the product obtained with this machine is compared to that obtained with stuffer n 4, a slightly greater amount of intermuscular meat emulsion can be observed, and this is verified by the difference in slice yield results. This additional intermuscular emulsion produced in the third stuffer can be attributed to the friction the meat is subjected to by the hopper's worm impulser, by the baffle's movement in the stuffing chamber, and throughout the length of the tube that takes the meat to the dosing accessory.

• Stuffer N 4: Like the above machine, this stuffer's hopper operates in a closed vacuum so that, with a normal average load of about 200 kg and stuffing pieces with a weight of 7 kg, the average vacuum time is about 5 minutes, constituting a genuine pre-vacuum phase that eliminates any air that may have become occluded during unloading after the massage or during loading of the stuffer. Impulsion in this machine is effected by a piston, so that there is a minimal formation of meat emulsion in this stage. As the meat goes to the dosing chamber, it follows a minimally rectilinear path, through tubing never narrower than 100 mm, producing much less friction and practically no addition to the intermuscular emulsion as the product comes from the massaging phase. A significant difference between these 2 machines is also obvious in the appearance of the slice, especially in the cooked ham with 25 % injection. The stuffing tube's diameter of 100 mm in this stuffer allows the finished product's large muscles to remain intact in the slice, without structural deformation of the raw material's muscle. The difference is particularly evident in the ham's large muscles, which in stuffer n 3 are forced through a circuit 80 mm. in diameter, resulting in slices

▼ **Stuffer 4:** Product stuffed with a vacuum stuffer-doser.

▼ **Stuffer 3:** Product stuffed with a single baffle stuffer.



with tears and little definition, whereas the slices produced in stuffer nº 4 appear whole and, above all, with well-defined contours. The overall appearance of the slice is cleaner, with a more pronounced muscular definition, essentially because of the smaller amount of intermuscular meat emulsion.

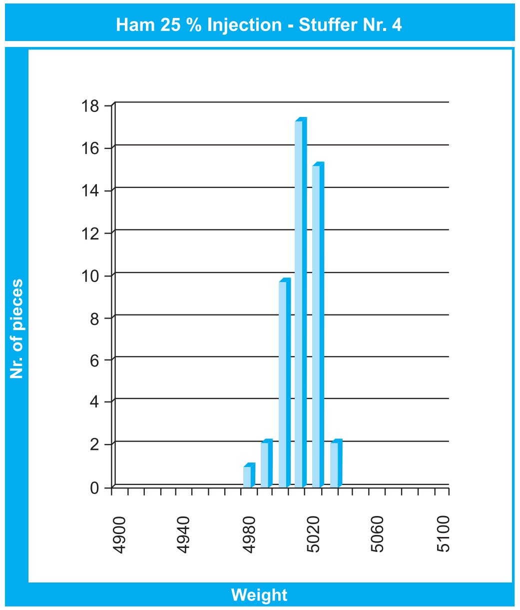
DOSING PRECISION

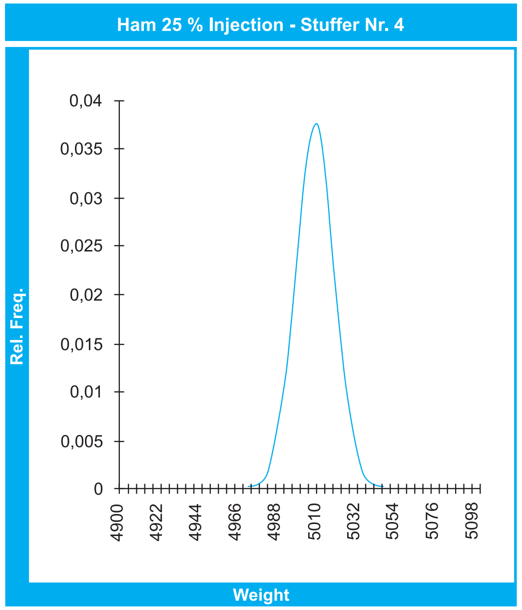
In order to statistically define the dosing precision of the stuffers in the study, the parameter used is the standard deviation obtained in a series of pieces stuffed in the different machines described above. This value can be interpreted as a statistical measure of the weight dispersion in the pieces with respect to the average weight, so that a lower deviation represents greater reliability of the machine as regards precision of weights obtained. This value is represented graphically by a curve known as the Gauss bell.

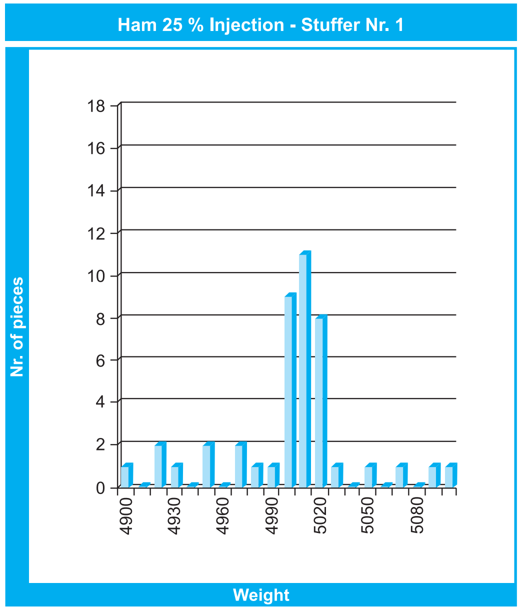
A narrow and pointed Gauss bell means a lower standard deviation, that is, a greater probability that the weight of each piece is within a zone very near the average.

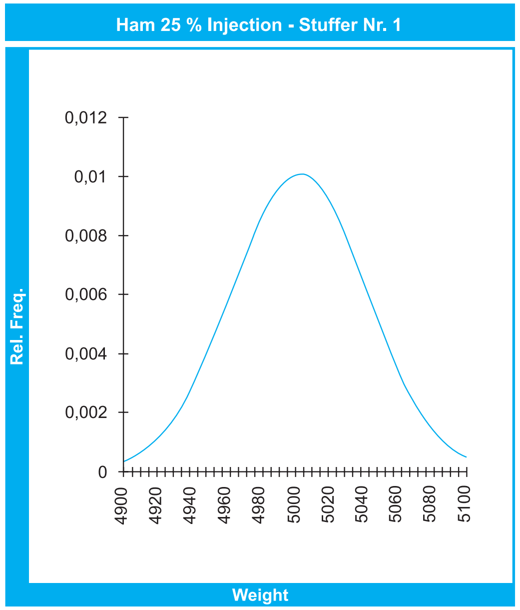
A low standard deviation is especially important for products to be sold as whole units, a minimum weight difference among the units being of utmost importance to the manufacturer, since the legislation in force in each country usually establishes a limit for such variation, especially as regards the package's minimum weight in relation to the net weight on its label. In order to guarantee this minimum weight, it is always necessary to set a somewhat higher average weight value. A stuffer that guarantees a low standard deviation among pieces will allow this average weight value to be set much closer to the net weight on the product's label, since it guarantees that no pieces will be below the minimum.

Furthermore, from a technological point of view, it is extremely important for the product moulds to be uniformly filled. Overfilling can result in undercooked finished products or breakage in the plastic packaging during cooking cycle, while underfilling can prevent full muscular binding and/or cause exudation of juices during cooking.









Stuffer Nr. 4

WEIGHT	Nr. PIECES
4980	1
4990	2
5000	9
5010	16
5020	14
5030	2
TOTAL	44

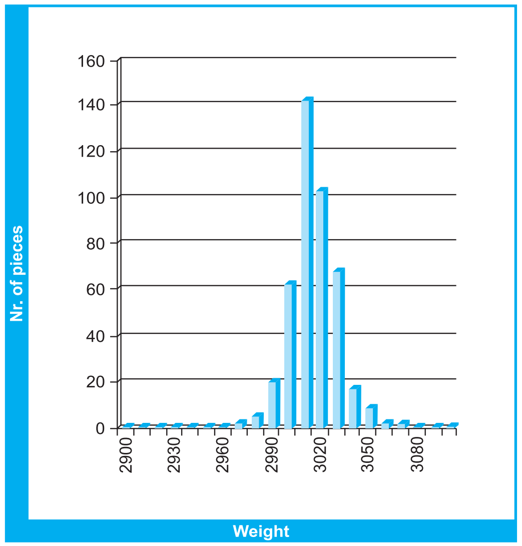
DESIRED WEIGHT	5000 g
AVERAGE WEIGHT	5010 g
STANDARD DEVIATION	10.6 g
MAXIMUM WEIGHT	5030 g
MINIMUM WEIGHT	4980 g

Stuffer Nr. 1

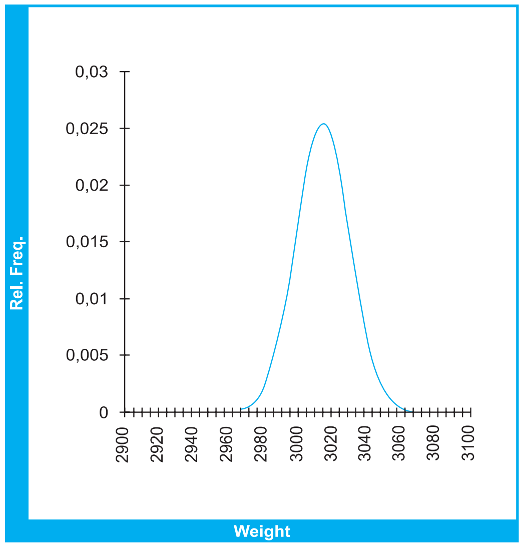
WEIGHT	Nr. PIECES
4900	1
4920	2
4930	1
4950	2
4970	2
4980	1
4990	1
5000	9
5010	11
5020	8
5030	1
5050	1
5070	1
5090	1
5100	1

DESIRED WEIGHT	5000 g
AVERAGE WEIGHT	5003 g
STANDARD DEVIATION	39.7 g
MAXIMUM WEIGHT	5100 g
MINIMUM WEIGHT	4900 g

Lean trimmings 90 % Injection - Stuffer Nr. 4



Lean trimmings 90 % Injection - Stuffer Nr. 4



Stuffer Nr. 4

WEIGHT	Nr. PIECES
2960	0
2970	2
2980	5
2990	20
3000	62
3010	142
3020	103
3030	68
3040	17
3050	9
3060	3
3070	2
3080	1
3090	0
3100	1
TOTAL	**435**

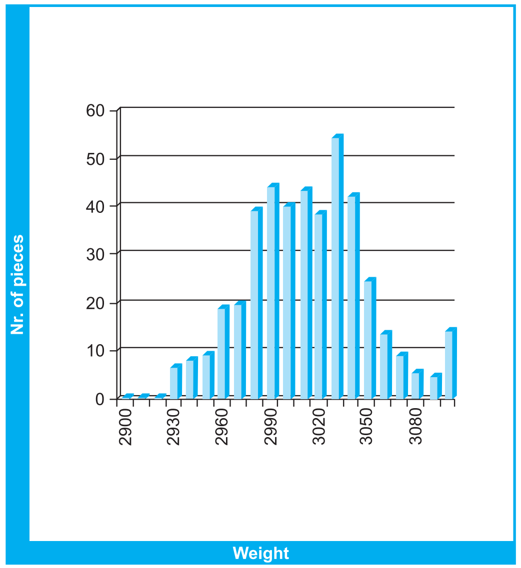
DESIRED WEIGHT	3000 g
AVERAGE WEIGHT	3015 g
STANDARD DEVIATION	15.70 g
MAXIMUM WEIGHT	3100 g
MINIMUM WEIGHT	2970 g

Stuffer Nr. 1

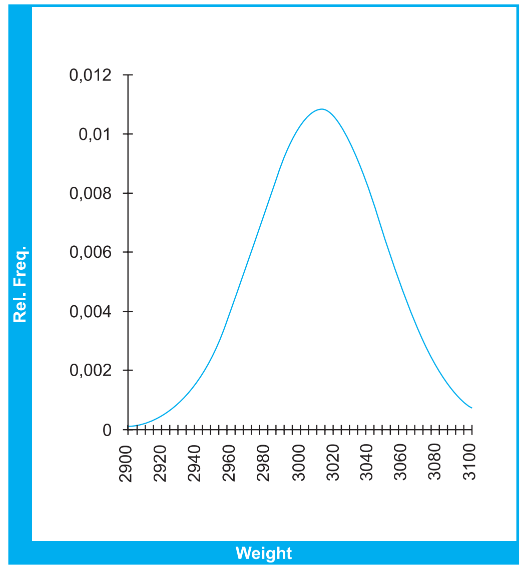
WEIGHT	Nr. PIECES
2930	6
2940	8
2950	9
2960	19
2970	20
2980	39
2990	44
3000	40
3010	43
3020	38
3030	54
3040	42
3050	25
3060	14
3070	9
3080	5
3090	4
3100	14
3110	1

DESIRED WEIGHT	3000 g
AVERAGE WEIGHT	3013 g
STANDARD DEVIATION	37.05 g
MAXIMUM WEIGHT	3110 g
MINIMUM WEIGHT	2930 g

Lean trimmings 90 % Injection - Stuffer Nr. 1



Lean trimmings 90 % Injection - Stuffer Nr. 1



To guarantee a good dosing precision, it was assumed as premise in this article that the best dosing system is the use of volumetric pistons. In order to verify this hypothesis, a comparative test was designed between two of the machines in the above section, stuffers n 1 and n 4. The products used in the test were the same ham with 25 % injection and a shoulder injected at 90 %, with a more liquid consistency and more likely to produce weight differences during the stuffing process. In the preparation of the shoulder, the same machines were used as in the case of the ham, following a similar procedure. These two products were selected in order to study the two extremes, with respect to injection percentage and final yield, that are commonly found in many meat markets.

Results

As can be observed in the results illustrated above, in the volumetric stuffer there is a greater and better compacting of the meat before it is introduced into the bag or moulds, since the volume to be stuffed is made up exclusively of meat free of any mixing with air, resulting in a much greater number of pieces that are very close to the desired weight.

A higher product quality was also detected since the weight of all pieces is very uniform, providing a perfect adaptation when the meat mass or the bag is placed in the mould guaranteeing that no time is lost in this stage. This results in a better and more uniform presentation of the cooked meat product, in terms of its external appearance, and therefore fewer pieces rejected for their substandard presentation.

MICROBIOLOGICAL ASPECTS OF MANUAL AND AUTOMATIC STUFFING

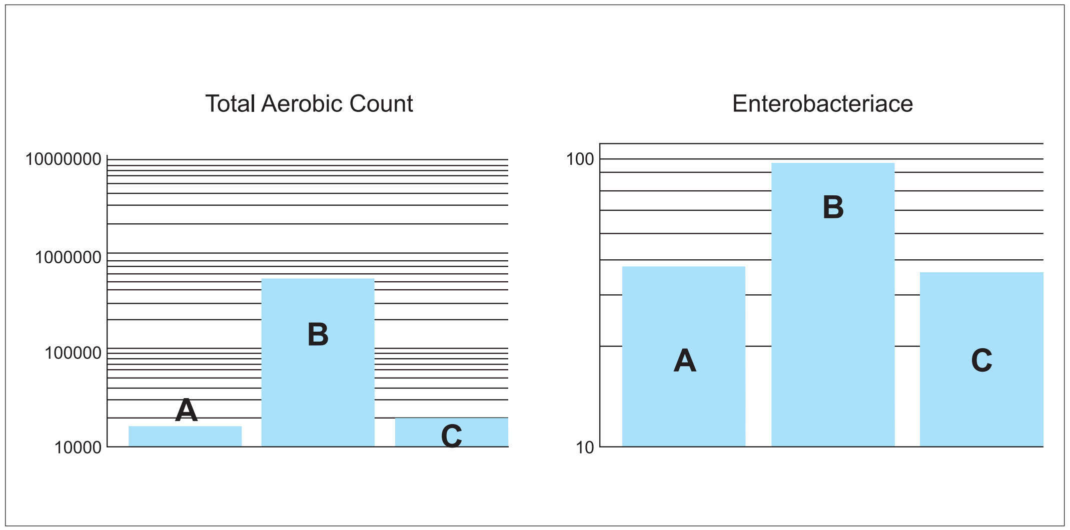
A fundamental aspect in quality control of meat products is determining their microbiological load. A low microbiological load will provide a longer shelf-life, as well as a guarantee against risk of food poisoning. For this reason, it is essential to exercise a strict microbiological control during the entire technological process, from raw material quality to obtaining the finished product, and during all the intermediate manufacturing stages.

Meat contamination begins with slaughter of the animal and continues in other sections of the slaughterhouse, where frequent human contact with the product usually takes place. Contamination continues during shipping, storage and subsequent handling in processing plants, so that by the time the technological process for manufacturing cooked meat products begins, Total Aerobic Count of 105-106 cfu/g can be achieved on the meat surface. Starting with the injection phase, when sodium chloride and sodium nitrite are added, and with proper maturation temperatures (5º C) maintained, bacterial growth is minimal, since most of the species are mesophilic bacteria and have a minimum growth temperature of 15º C. With modern manufacturing technologies, human contact with meat products has been reduced considerably, resulting in better hygiene and thereby greatly reducing the risk of microbiological growth. At present, the only contact point between hands and meat takes place in the stuffing and molding phase, when this process is not fully automated, constituting a genuine risk and Critical Control Point.

In order to determine what influence this phase has on the superficial microbiological load of meat masses prior to cooking, a comparative study was conducted, using the same meat product, between a manual stuffing system and an automatic volumetric vacuum stuffing system.

The tests were carried out in a meat processing plant, during the normal course of production. The sample product chosen was pork leg (divided into 4 cuts) injected at 30 % with a spray injector, then immediately tenderized with a tenderizer head with 3 mm diameter needles. Following this phase, the meat received a massaging treatment in a refrigerated vacuum pulmonary reactor, with a maturation cycle between injection and cooking cycle of approximately 20 hours, at a maturation temperature of 5º C, and a total massaging time of 2 hours, 20 minutes. From the same batch, after massaging cycle and previous to the stuffing cycle, 25 samples (Samples A) were selected at random. The meat temperature at the time of taking the samples was 7-8º C. Subsequently, the meat was divided into 2 sub-batches, one to be molded manually (samples B) and the other to be stuffed in an automatic volumetric vacuum stuffing machine (samples C). The 25 samples taken from these two sub-batches were also selected at random.

▼ Figure 1.



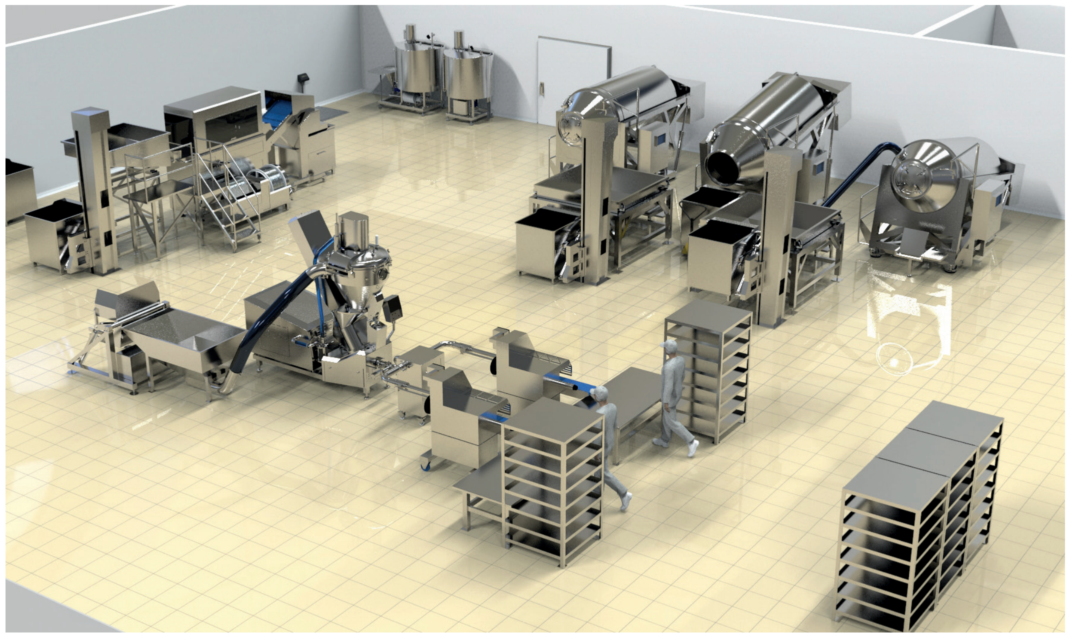
Sample selection, preparation and analysis: The samples were taken aseptically from the surface of the meat muscles and put into containers under sterile conditions. They were transported in containers refrigerated at 0-2º C to the microbiological laboratory, where they were homogenized by means of a Stomacher lab blender in order to obtain homogeneous suspensions without risk of subsequent contamination. Because the focus of the comparative study was the general contamination level, the media of analysis used were the Total Aerobic Count (PCA) and the Enterobacteriaceae Count (VRBG agar). The different Petri dishes (each sample in duplicate) were incubated at 36º C for 48 hours.

Results

Of the results obtained, the average was calculated for each set of samples, as illustrated in the table below (Figure 1).

As can be observed in the tables above, there is no significant variation in the contamination levels of samples A (samples before stuffing) and samples C (automatic volumetric vacuum stuffing), in either of the counts, Total Aerobic Count or Enterobacteriaceae Count. But in Samples B a contamination increase of close to 2 decimal logarithmic units can be observed. Since the same product was used, and since the only variable was human handling during the manual stuffing process, it can be concluded that, from a hygienic point of view, automatic stuffing provides the process with a greater degree of safety and a minimization of risk.

In addition, the space of time that elapses between the stuffing process and cooking can, in some cases, allow Fermentative bacteria to form gas. Even though most of the microbiological flora is eliminated by heat during the cooking process, the gas formation may already have caused small fermentation holes to appear, deteriorating the physical appearance of the finished product's slice. This is why it is essential to reduce to an absolute minimum all risk factors that influence the total bacterial count in meat masses, and manual stuffing is one of these critical factors.



CONCLUSIONS

The increase in slicing yield between conventional stuffers (adaptation of stuffers for emulsified products) and automatic volumetric vacuum stuffers, specially designed to handle large meat pieces while maintaining the muscles intact, has been proved from the data obtained in this study. It has been demonstrated that the stuffer analyzed obtains a significant reduction in the number of slices rejected for poor intermuscular binding, due to a lesser amount of occluded air and intermuscular meat emulsion, thereby minimizing zones with less intermuscular consistency that weaken the slice and cause them to tear when sliced in high-speed slicers and, simultaneously, obtaining a cleaner slice with better muscular definition.

The study has also shown that automatic volumetric vacuum stuffing-dosing machines produce a better compacting of meat muscles as compared to conventional stuffing machines, resulting in fewer weight variations among the pieces with respect to the average, and therefore a better dosing precision in the meat mass and higher quality finished product. These systems also offer significant advantages in terms of production costs since they allow the meat manufacturer to greatly reduce manpower and, consequently, reduce the product's cost.
Finally, the stuffing process has been analyzed as a Critical Control Point, verifying that automatic vacuum stuffing systems clearly reduce the risk of microbiological contamination in meat masses, while increasing the finished product's shelf-life.

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