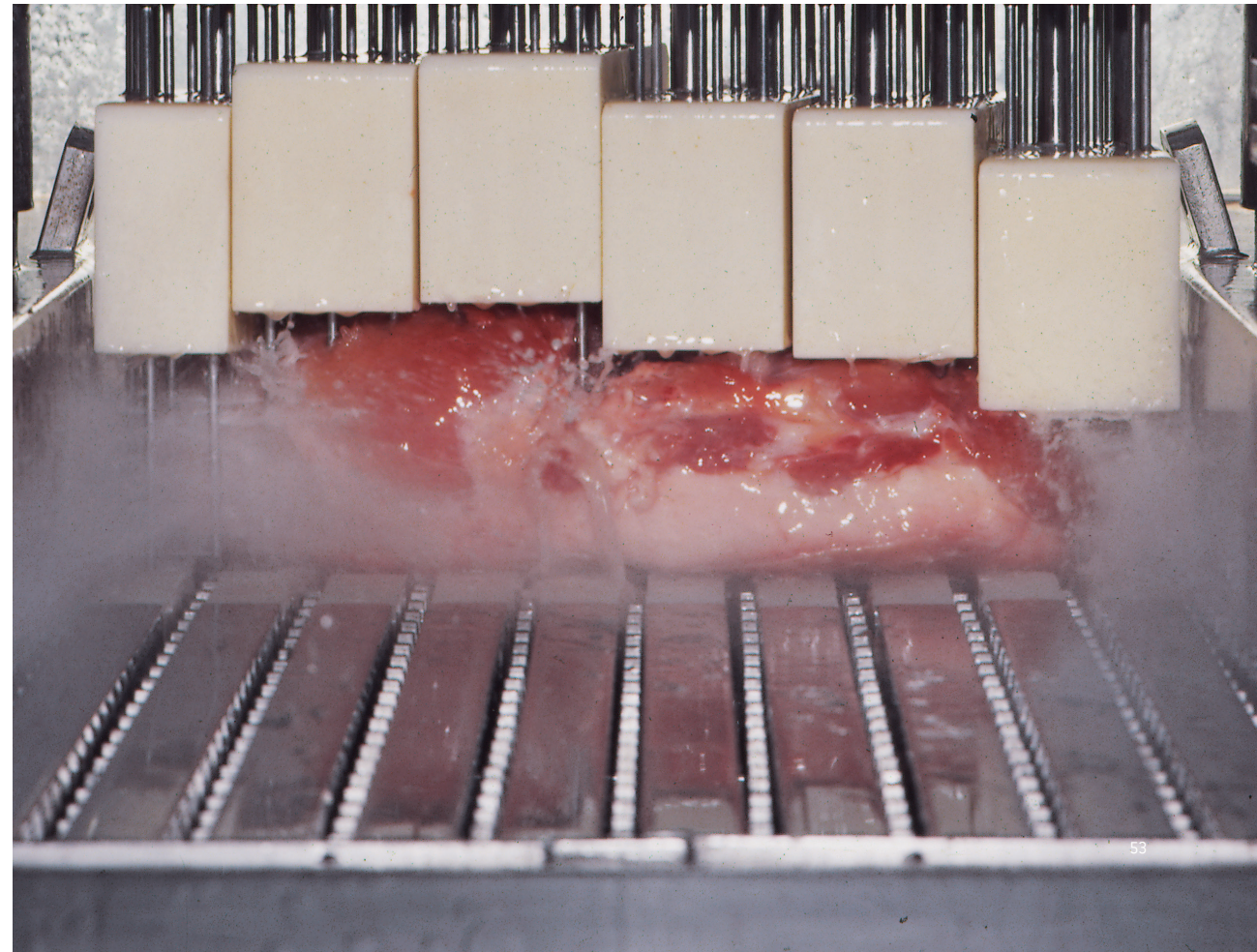


Spray injection of meat. Influence of the **brine pressure** in the quality of injected products

Llorenç Freixanet



ABSTRACT

A meat injecting machine based on a spraying injection concept is tested. Since the size and speed of the micro drops formed during the injection phase are strongly conditioned by the pressure applied to the brine, this parameter can be expected to exert a major influence on the injection quality. In the present work, series of tests are described showing the effect produced by different spraying pressures in three aspects which determine the injection quality such as deviation of injection among pieces of meat, brine dripping loss and distribution of the brine. From these tests it can be concluded that spraying pressures over 6 kg/cm² substantially improve the regularity of injection and the distribution of the brine and dramatically reduce the dripping losses without causing any damage in the meat structure. The regularity of injection percentages from piece to piece, is specially improved with the use of volumetric piston propellers instead of continuous pumps for brine impulsion. Also, the influence of the brine pressure on the injection percentage achieved is tested. Series of muscles of similar sizes and weights are injected with water [In order to avoid the influence of the rheological characteristics of the brine] at pressures growing from 2 to 8 kg/cm².

The results confirm a spectacular increase of the percentage of water injected. A maximum of 74% is injected at a pressure of 8 kg/cm².

INTRODUCTION

The injection process is of decisive importance in the manufacture of whole muscle meat products, specially on those which are not submitted to ulterior phases of massaging, such as Wiltshire style products, bacon, backs and bellies brined for home cooking.

The following parameters will determine the quality of the injection process and have a direct impact on the quality of the finished product obtained:

Accuracy of injection piece by piece. It can be evaluated calculating the standard deviation in the injection rate values of a series of pieces. This factor will determine the regularity in the sensory characteristics of the product and also affect the yield obtained, as accurate injection makes it possible to get closer to the analytical limits established by legislation, reducing the risks of finding pieces over these limits and avoiding miscuring defects.

Brine dripping loss after injection. Two aspects have to be evaluated in this point: the amount of brine lost and the time required to lose it. Low dripping losses indicate a good retention of the brine, avoiding additional losses once the piece is vacuum packed.

Also, a short dripping time will permit the pieces to be packed under vacuum only a few hours after injection, providing a more fluid process, "without bottlenecks or downtime".

Brine distribution. Although the injected brine is thereafter naturally diffused throughout the meat structure, this process requires very long times if not aided by a mechanical treatment such as massaging. In order to avoid the characteristic red injection bands often observed in unmassaged products processed in 24 hour cycles and other curing defects, it is very important that the injection process distributes the brine as uniformly as possible among the meat fibres in order to reduce to a minimum the time required for the brine to migrate to the uninjected areas, always present in products with low injection levels. Series of tests were conducted in order to determine the effect of the injection pressure on these three aspects. The tests were run in an injecting machine using a particular injection concept known as spray injection.

WHAT IS SPRAY INJECTION?

Most of the multineedle injecting machines existing in the market use continuous pumps which propel the brine through needles with 2 to 4 holes of

1 mm or more in diameter, depositing the brine during the needle stroke through the meat. Due to the holes' diameter, the brine flows through them as a continuous jet. These machines usually work at a variable pressure inside the brine circuit which normally does not exceed 4 kg/cm². With the concept used in this type of equipment, higher pressures damage the meat structure, as the jet causes the separation and even the breakage of the meat fibres and forms brine pouches in the bottom of the hole created by the needle stroke, so the brine must be gently deposited in the meat. These injection defects result in curing anomalies affecting the appearance of the product producing coloured spots. Regulation of the injection percentage often includes in these machines the modification of the speed of the brine pump [Altering the pressure of injection].

In contrast, spraying injectors introduce a volumetrically measured dose of brine only after the needles have completely penetrated the meat, and are stopped at the end of their downstroke.

The needles are designed with 11 to 14 holes of 0.6 mm. in diameter distributed at different heights, depending on the product to be injected.

The spraying effect is achieved by means of a volumetric piston pump, which compresses the brine to an internal pressure of 6 to 12 kg/cm² [Depending on the machine], forcing it to pass through the holes at a very high speed, causing the dispersion of the brine jet into thousands of micro drops [Spray]. The small size of these drops and their high speed [See Picture 1] allow them to be introduced deeply between the meat fibres without causing any damage in the meat structure. The brine which is incorporated into the meat framework in such a way is subject to minimum drip losses, since the principal cause of dripping is the free brine which remains inside the needle holes. As the brine penetrates deeply between the meat fibres, more muscular volume will be covered with brine, so the distribution can be expected to be more perfect.

Another important feature of spraying injectors is derived from the volumetric dosing system they use. As the piston always propels the brine at the same speed, the same brine pressure is always achieved, independently of the injection percentage desired, so the benefits of the spraying system are applicable to the full range of products of any manufacturer with only one machine.

The injector used in the trials is a fully hydraulically operated machine, provided with a Singer type conveyor belt, with advancements adjustable from 2 to 12 cm by means of a hydraulic volumetric device. The machine is equipped with a 3 litres volumetric pump, adjusting the amount of brine to be sent to the injecting head in each stroke by means also of a hydraulic volumetric device.

INFLUENCE OF INJECTION PRESSURE ON INJECTION ACCURACY

4 series of 15 cuts of «*longissimus dorsi*» of approx. 15 cm in length were injected around 20% with the annexed brine in the spraying injector at brine pressures of 2, 4, 6 and 8 kg/cm². At the same time 3 more series were run in different machines

▼ Spray Injector: MOVISTICK 5500 CR.



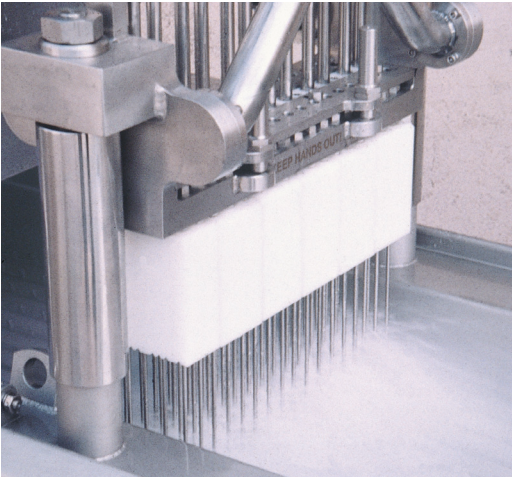
using the low pressure technology described in paragraph 2. With slightly different working pressures [from 1,5 to 2 kg/cm²], the 3 injectors have in common that the brine is propelled by continuous pumps. Each piece was weighed before and immediately after injection, calculating the injection percentages. Each series of data was statistically studied and the standard deviations calculated.

BRINE COMPOSITION	
ADDITIVE	%
Salt	12
Sugar	2.4
Sodium Triphosphate	0.3
Sodium Nitrite	0.12
Sodium Nitrate	0.12
Sodium Ascorbate	0.36
Water	84.7

Results

As can be observed in Table 1 in the standard deviation values of the four series injected with the spraying injector, injection accuracy seems to be affected only by pressures under 6 kg/cm², while between 6 and 8 kg/cm² no significant differences are detected, with values of standard deviation of around 0.6. This fact can probably be explained by

Picture 1: Spray Injector.



the poor spraying effect produced at pressures of 2 and 4 kg/cm² when the drops formed have a big size and a low speed.

Under these conditions the different resistances generated by the meat structure's natural variations can affect the flow through the needles, producing local differences in the brine pressure which can be responsible for the increase in the standard deviations detected. We can conclude that injection accuracy (Understood as difference of injection percentages among pieces) is affected by the spraying pressure used only under 6 kg/cm², when a poor spray effect is produced. (Table 1)

At the same time, an important difference of accuracy was detected between these 3 series (Brine propelled with a volumetric piston pump) and the ones injected by means of the machines using continuous brine propellers, the latter obtaining much higher standard deviation values (From 1.4 to 2.7).

From these data, it can be concluded that volumetric dosing of brine gives much more accurate injection results than continuous pumps, obtaining products more regular in their sensory characteristics, avoiding miscuring defects and reducing the security margin required in the final yield in order to ensure that all the pieces manufactured are within the analytical limits established by legislation.

This loss of precision in the machines using continuous pumps can probably be attributed to the valves they have in the injecting head which do not permit injection in the needles or groups of needles (depending on the machine) which are not inside the meat. As injection is performed in equal times in each stroke, the brine injecting pressure suffers continuous variations depending on the quantity of opened needles. Since the brine flow is determined by the inner brine pressure, the quantity of brine introduced in the meat is also continuously varying, producing the differences in the injection percentages of different pieces

TABLE 1			
MACHINE TYPE	BRINE PRESSURE	AVG. INJECTION %	STANDARD DEVIATION
Spray Injector	2	20.21	1.21
Spray Injector	4	20.40	0.93
Spray Injector	6	20.18	0.61
Spray Injector	8	20.13	0.62
Injector A	2	20.13	1.42
Injector B	1,5	20.37	1.63
Injector C	1,5	20.90	2.74

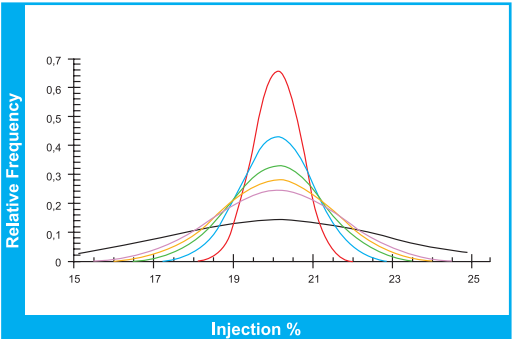
described in Table 1. Also, we can attribute part of this lack of accuracy to the fact that with low injection pressures (big size of the injection holes), the different resistances offered by the pieces of meat produce local variations in the pressure of injection, causing important variations in the percentages injected. None of these phenomena were observed in the spray injector for pressures over the 6 kg/cm².

The Normal Gauss distribution bells representing the probabilities of finding different injection percentages for each series are shown in Graphic 1.

INFLUENCE OF INJECTION PRESSURE ON BRINE DRIPPING LOSS

Samples of «longissimus dorsi» were injected in the spraying injector with the same brine used the previous paragraph. An approximate injection rate of 20% was kept for each sample, regulating the volume of brine sent to the head in each case.

TABLE 2									
INJECTING PRESSURE (KG/CM²)	INJECTION % AFTER					DRIP LOSS % AFTER			
	INJECTION	10 MIN.	1 HOUR	2 HOURS	24 HOURS	10 MIN.	1 HOUR	2 HOURS	24 HOURS
2	20.3	17.9	17.3	17.2	16.9	11.82	14.78	15.27	16.75
3	19.9	18.0	17.6	17.5	17.3	9.55	11.56	12.06	13.07
4	20.5	18.8	18.3	18.2	17.9	8.29	10.73	11.22	12.68
5	20.3	18.9	18.5	18.4	18.3	6.90	8.87	9.36	9.85
6	20.5	19.2	18.9	18.9	18.9	6.34	7.80	7.80	7.80
7	20.2	19.3	19.2	19.2	19.2	4.46	4.95	4.95	4.95
8	20.0	19.2	19.1	19.1	19.1	4.00	4.50	4.50	4.50

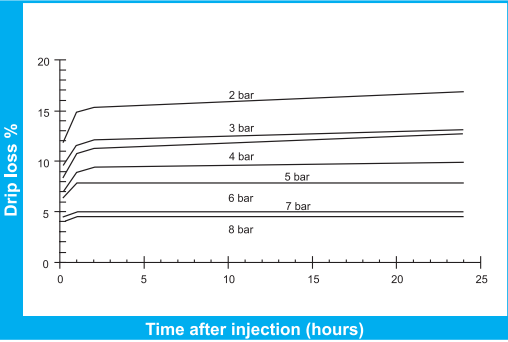


Graphic 1: Normal Gauss Distribution Bells.

The brine pressure was varied from 2 to 8 kg/cm² regulating the maximum pressure of the hydraulic circuit. After injecting the pieces were kept in separate containers and weighed immediately after injection, after 10 min., 1 hour, 2 hours and 24 hours discarding each time the free brine. The results were tabulated for analysis (Table 2). A sample at each pressure was placed in a multi-layer plastic bag and thermosealed under vacuum one hour after injection.

Results:

The values tabulated in Table 2 are represented in Graphic 2. Two distinct influences of the brine pressure on the dripping loss percentage can be extracted from these data:



▲ Graphic 2: Drip loss % [Dependence on the brine pressure].

First, high injection pressures drastically reduce the total dripping loss and, second, an important reduction of the dripping time is observed for high brine pressures.

The vacuum packed pieces were opened and checked after 24 hours. In accordance with the results obtained under atmospheric conditions, only the pieces injected with pressures lower than 6 kg/cm² presented free juices in the bag, the lower the injection pressure, the greater the amount of juice found in the bag.

Both facts are of capital importance in the manufacture of meat products. The reduction of dripping time [From 6 kg/cm² on no dripping loss is produced after one hour] permits products which are marketed only cured such as bacon, backs and bellies to be packed under vacuum within the same day of injection without further brine exudation in the package. At the same time, the reduction of the total amount of dripped off brine [From 16.75% of the amount injected at 2 kg/ cm² to 4.5 % at 8 kg/ cm²] permits a significant adjustment in the production costs of these unmassaged products and an important reduction in the massaging times required for products such as cooked hams, shoulders and loins.



▲ Picture 2. Injection bands with Methylene blue.

The results obtained are consistent with the idea expressed in the introduction that the brine which is dripped off the injected meat is basically the brine which remains in the hole made by needle in its passage through the meat. This brine is not fixed to the meat structure, being easily dripped off.

High spraying pressures introduce the brine deeply inside the meat structure, fixing it and, consequently, reducing the dripping loss percentage.

INFLUENCE OF THE INJECTION PRESSURE ON BRINE DISTRIBUTION

Samples of «*longissimus dorsi*» were injected in the spraying injector with a coloured brine (0,004% of Methylene blue added). An approximate injection rate of 20% was kept for each sample, regulating in each case the volume of brine sent to the head. The brine pressure was varied from 2 to 8 kg/cm² regulating the maximum pressure of the hydraulic circuit. All samples were passed through the injector with conveyor belt advancements of 12 cm, in such a way that each one of the parts of the piece received only one stroke of the head. After injecting, the pieces were cut transversally in 2 parts. The first one was sliced transversally following the needle lines and the other half was sliced longitudinally in order to map the brine Distribution Index.

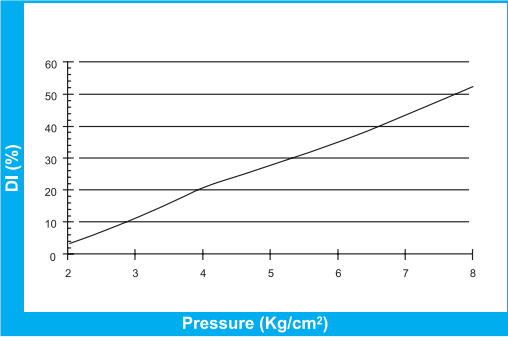
TABLE 3		
INJECTING PRESSURE (KG/CM ²)	BANG AVG. WIDTH (MM.)	DISTRIBUTION INDEX
2	5	3 %
3	10	11 %
4	14	21 %
5	16	28 %
6	18	35 %
7	20	44 %
8	22	53 %

Results

The longitudinal cuts of half of the sample provide a map of the distribution of the brine in the piece. The injection holes are geometrically distributed around the needle at a height of 60 mm. When injection takes place, the brine is sprayed through the hole forming a coloured irregular shape which, once the needle is removed can be easily assimilated to a sphere. The longitudinal cuts show a distribution of nearly circular shapes whose diameters can be measured and averaged.

The results of these measures are described in Table III as average band widths which can be taken as brine penetration indexes. These bands can be seen in the transversal slices photographed in Picture 2. As can be observed, there is an important correlation between the band widths and the pressure of injection.

As the above-mentioned diameters are averaged throughout the whole volume of the piece, we can use them to create theoretical distribution maps. These maps are used to define a Distribution Index, representing the percentage of the meat volume which is coloured by the methylene blue present in the brine. In Table 3 these indexes are evaluated. We observe that with a pressure of 2 kg/cm² the amount of brine injected (20% of the green weight ~17% of the total injected weight) is concentrated in only 3% of the total volume. Increasing the pressure, the Distribution Index grows in a nearly linear way, at least in this range of pressures, in



▲ Graphic 3: Distribution Index [Dependence of the Pressure].

such a way that at 8 kg/ cm² 53% of the volume is embedded with brine [See Graphic 3].

Obviously, the Distribution Index can be improved reducing the rate of advancement of the conveyor belt, in such a way that the needle strokes are overlapped on the meat. For example, the Distribution Index at 8 kg/cm² for a conveyor belt advancement of 8 cm reaches a value of 80% and at 4 cm the brine is distributed in 99% of the meat volume.

INFLUENCE OF THE INJECTION PRESSURE ON THE INJECTION PERCENTAGE ACHIEVED

Samples of «*longissimus dorsi*» were injected in the spraying injector regulated in order to obtain the maximum injection percentage [minimum belt advancement and maximum volume sent to the head in each stroke] with pure water. The brine pressure was varied from 2 to 8 kg/cm² regulating the maximum pressure of the hydraulic circuit. The pieces were weight before and after injection and the injection percentage calculated.

Results

As can be seen in table 4 the injection percentage shows a nearly linear progression between 2 and 6 kg /cm², and, though it is still increasing, the increment is lower from 6 to 7 and from 7 to 8 kg /

TABLE 4	
INJECTING PRESSURE (KG/CM ²)	INJECTION PERCENTAGE
2	20.30
3	29.40
4	38.60
5	49.30
6	62.50
7	71.50
8	74.20

cm², obtaining a maximum of 74.2%. Keeping in mind that the machine used in the test is a single head machine, the spray injection concept shows an evident superiority to the standard low pressure injectors which in most of the cases are not able to exceed the limit of a 40 % of injection percentage. The maximum obtained in this test 74% can be increased to nearly 100 % using high viscosity brines, and double head injectors using the same spray injection concept can achieve values of injection percentage close to the 100 % with water, and around 120% with heavy brines in one only pass through them.

The hydraulic construction of this type of injectors makes them capable of working with very high viscosity brines, so these percentages can be obtained without difficulties. Anyway, it has to be kept in mind that these limits of injection percentage are referred to the loins used in the test, but they can be applied to whole muscles of ham and, with a very small reduction, to whole shoulders. Obviously, with small pieces of meat, the maximum percentages obtained are strongly reduced, especially if the height of distribution of the needle holes is not adapted to the thickness of the muscles.

OTHER FACTORS INFLUENCING THE QUALITY OF INJECTION

From the previous tests we can conclude that spraying pressure is a determining factor in the quality of injection, finding that pressures over

6 kg/ cm² substantially improve the regularity of injection and the distribution of brine and dramatically reduce the dripping losses without causing any damage in the meat structure but, obviously, this is not the only factor affecting the quality of the injection process.

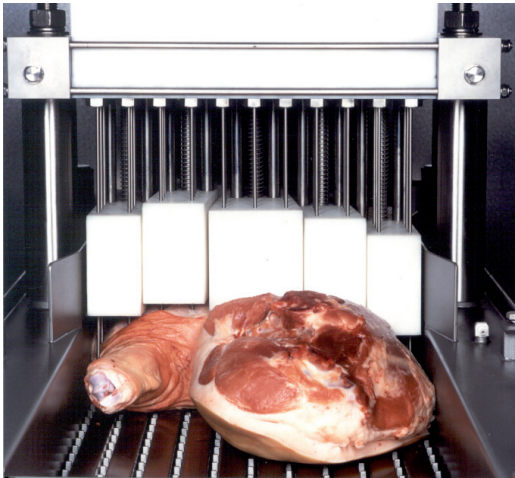
There are a few concepts related to the design of the injecting machines which are of decisive importance in the accuracy of the injection process:

Type of motion of the head: If the stroke of the head is generated by means of an excentrical connecting rod, a movement of sinusoidal characteristics is produced, in such a way that the head spends longer in the upper and lower parts of its course, passing faster through the central part of the stroke. This type of movement produces important accumulations of brine in the lower parts of the piece, which are easily detectable by immediate analysis of the salt content in lower and upper fractions of the muscles. The brine pouches formed are reflected in the cooked products as deeply coloured spots due to the curing irregularities produced by the different brine concentrations.

Conveying of the meat through the injector: It is very important for the meat pieces to be transported through the injector gently enough to keep their relative positions between the different strokes of the head in order to avoid irregular shapes in the holes produced by the needles and consequently irregularities in the brine distribution.

Different solutions have been adopted by the injector manufacturers:

• **Continuous conveyor belts with continuous movement:** They have the problem that the injection takes place while the piece of meat is moving, with the risk that the head may produce variations in the relative position of the pieces and it does not allow the needles to go completely through the piece,



▲ Bone-in Ham Injection.

often leaving an uninjected band in the lower part of the meat.

• **Continuous conveyor belts with discontinuous movement:** As with the above conveyor type, the needles cannot go completely through the meat and, if constructed of plastic materials, the meat pieces do not adhere well to the conveyor and are therefore displaced with each stroke. The adherence can be improved constructing the belts with metallic mesh, but it has the important disadvantage that the interstices of the mesh easily become clogged with small pieces of meat, being very difficult to clean.

• **The use of a Singer type conveyor** is probably the best solution, but the design of the conveyor has to take into account that the pieces must be well fixed during the movement in order to avoid irregular advancements and that they must also be retained during the downstroke of the head, minimizing the displacements produced when the head catches in its movement the beginning or end of a meat piece.

Design of the meat retainers: Injecting machines are always equipped with plastic retainers which take the pieces out of the needles once injected. There are two concepts in its design which are of capital importance in order to obtain a good

injection accuracy. First of all, they need to be equipped with a spring system which produce enough pressure on the piece to take it out of the needle without lifting it from the conveyor. If the meat is elevated, then the compression of the spring usually results in a violent fall of the piece which alters its relative position causing distribution irregularities. Further, the pressure exerted by the plastic retainers has to be uniformly distributed among all the pieces, since the compression of the muscles causes a slight reduction in the percentage of brine retained. This means that, as the meat pieces have naturally irregular heights, a single plastic retainer covering the entire injection head will contribute to create differences in the injection percentages. The multiple plastic retainers covering small surfaces are the best designing solution for this purpose.

System of dosage: As has been shown in the tests described above, a constant pressure volumetric dosage has proved to be the most suitable system concerning injection accuracy.

In addition to these constructive concepts of injecting machines, injection regularity is also conditioned by many other factors related to the uniformity of the raw materials used in the process [Meat and brine]:

Regularity of meat quality: As a live material, the properties of meat muscles present important variations due to the different characteristics of the animals. A simple experience consisting in the spray injection (around 20%) of a series of hams of similar weight (within a range of 500 gr.) in which the legs coming from the same animal were conveniently identified have shown that the difference of injection between the more and the less injected pieces of the series was of 2.1 points of injection (10% of the amount of injected brine), while the maximum difference between left and right legs coming from the same pig was only of 0.8 points (4% of the amount of injected brine). Though

it is impossible to have muscles of exactly the same characteristics a good recommendation in order to optimise the accuracy of injection and the quality of the finished product is to perform a selection in the raw materials based on weight, colour and pH criteria. Unfortunately, these operations represent an additional cost in the production line which is only acceptable in highly priced products.

Regularity in the manufacturing process: The accuracy of injection also depends on the regularity in the brine characteristics [Viscosity, temperature, etc...] and in the meat process prior to injection. Differences in brine temperature affect its viscosity, modifying the dripping loss rate. Changes in meat temperature alter the rigidity of the muscular tissue, also causing injection variations. Since meat continues to undergo important changes in its characteristics after slaughter, differences in the interval elapsed between slaughtering of the animal and injection of raw material will cause variations in the quality of the finished products. In conclusion, the keyword to obtain a quality product is regularity in the conditions of all steps of the process, before injection, during injection and, in those products

which require further processing, after injection, since most of the irregularities of the process will be reflected in different ways in the finished products obtained.

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▼ Movistick Plus 4500.

