Marination of fresh meats by means of spray effect: influence of spray injection on the quality of marinated products

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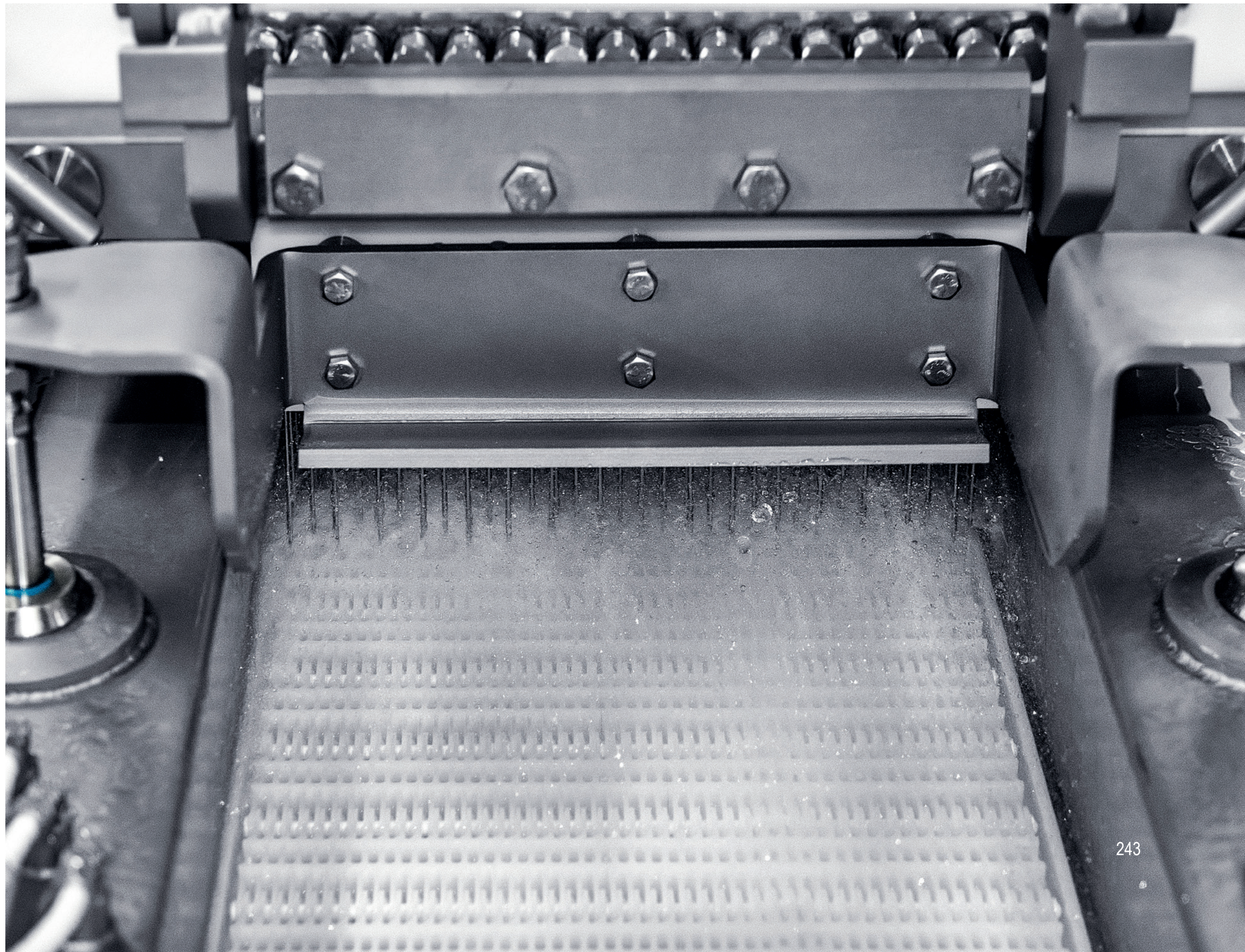


ABSTRACT

A recent study was carried out in order to evaluate the influence of spray injection on various types of marinated meat products, in comparison with a conventional injector without spray effect. The evaluation was accomplished by quantifying the parameters that most influence the quality of this type of products, such as: regularity and precision of injection (piece-by-piece calculation of the standard deviation in the injection), distribution of the ingredients inside the muscle (analysis of the sodium chloride content in the product) and marinade retention capacity inside the meat muscle (rate of marinade dripping loss). In each of the trials three types of meat were used: whole chicken, pork and beef, in order to determine whether said spray effect exerted an appreciable influence to substantially improve the above-mentioned parameters, and whether, as a result, regularity of flavor and texture in the finished product was improved.

INTRODUCTION

Traditionally meat has been marinated to obtain better and different flavors, increase tenderness of the toughest muscles, and prolong product shelf-life through salting. But due to lifestyle changes in today's society, which has less time to spend in the kitchen, these practices have fallen into disuse, resulting in a loss of the quality benefits that were obtained with such traditional methods.

The existing literature on the subject contains numerous references to the beneficial effects of marination on meat texture, which show that the incorporation of a certain quantity of water with various ingredients, such as salt, phosphates and proteins, gives the meat a juicier texture and reduce the loss of juiciness during cooking. There are also references to the increase and enhancement of palatability by means of a wide range of products that vary according to different cultures, such as: spices, fruit extracts, aromatic liquors (wine, cognac), oils, Oriental sauces, etc.

Another important aspect of marination is the increase of yield of the raw material, which, when well controlled, can provide benefits to the producer and the consumer, giving rise to the creation of products with a high added value.

But in order for this type of products to be accepted, it is very important to maintain product constancy in time, and for this to transmit to the consumer a regularity in taste and texture. To achieve this requires equipment and technology capable of assuring the attainment of this regularity.

Currently, the design of more efficient and precise equipment, together with the development of technology, allows for "marinating" products at an industrial level, reducing costs and preparation time.

MARINATING METHODS

There are three methods for producing marinated products: immersion, injection and massage. Immersion, the oldest method, consists in submerging the meat in the marinade and letting the ingredients penetrate the meat through diffusion with the passage of time. This method is quite unreliable in the meat industry because it does not provide regularity in distribution of the ingredients and because it increases the risk of bacterial contamination. Also, it is not practical because it requires long processing times and limits the quantity of marinade to be absorbed. In regard to massage marinating, this has greater application to small boneless meat pieces, as it is difficult to maintain good regularity and uniformity of marinade ingredients in large pieces when the brine is distributed by diffusion alone, and when dealing with bone-in meat, the bones can get damaged or separate from the meat.
Injection marinating is perhaps the most widely used method because it allows for dosing an exact quantity of brine, guaranteeing regularity in the products and without the time losses involved in immersion. But to obtain this regularity the equipment used must be able to inject the desired quantity of marinade with precision; moreover marinade distribution must be uniform throughout the entire piece, without affecting the integrity of the meat. Another important factor to be kept in mind is the dripping that takes place subsequent to injection, which must be the minimum possible, in order not to affect the appearance of the finished product.

Spray injection has been used for some time with optimum results in cooked meat products, which gave rise to the idea of carrying out a comparative study between an injector with spray effect and a conventional injector without this effect, in order to determine the influence of spray effect on the quality of marinated products. To quantify said effect, the parameters that most influence quality of the finished product were selected, namely: precision of injection percentage, retention of marinade with the passage of time and marinade distribution inside the meat muscle.

Spray Effect

Most of the injectors existing on the market use pumps that propel the brine or marinade through needles with holes of 1 mm or more in diameter, depositing the marinade during their downward stroke through the meat, forming a deposit of brine in the needle's zone of penetration.
In contrast, spray injectors do not form brine or marinade pockets around the needle, but rather force the marinade through needles of lesser diameter (0.6 mm) at high speed, causing dispersion of the marinade into thousands of atomized micro-drops during the needles downward stroke through the meat muscle. The tiny dimensions and high speed of these drops, produced by the constructive characteristics of the injector itself, cause them to be introduced deeply between the meat fibers without damaging the muscle structure. The marinade incorporated into the muscle in this way is subject to minimum dripping loss, and by penetrating deeply inside the muscle, greater muscle volume is covered with said marinade, so that improvements in distribution of same can be expected.

For the comparative trials two types of injectors were used:

- Injector A: Conventional injector without spray effect for marinated products, having needles with holes of 1 mm.
- Injector B: Spray injector, having needles with holes of 0.6 mm for atomized distribution of marinade inside the meat.

In all the trials a basic brine was used composed of: Water (89.3%), Sodium chloride (7.7%), Sodium tripolyphosphate (1.5%), and various flavorings depending on the type of meat used (1.5%).

Influence of Spray Effect on injection regularity

Injection regularity is understood as the minimum variability between the values of injection percentage obtained in the different pieces injected. Evaluation of said variability can be carried out by calculating the standard deviation of injection percentage values in different series of pieces, injected one by one, which will reflect the precision of the injector in question.

The factor that most influences injection regularity is the injector itself, but there are other factors to be kept in mind, such as conditions of the meat to be processed (temperature, pre-maturation time, regularity of weight and shape) and brine characteristics (viscosity, temperature), so that in order to eliminate variations due to external causes, these factors must be maintained as constant as possible.

With the objective of comparing the influence of spray effect on injection regularity, with respect to a conventional injector without this effect, a series of trials were carried out with the following meat products:

- Bone-in pork loin (*longissimus dorsi*)
- Whole chicken
- Whole muscle beef: Eye of Round (*semitendinosus*)

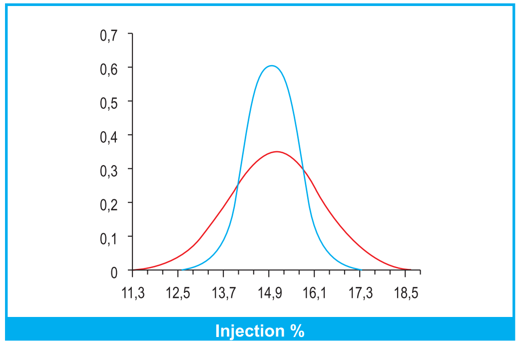
Three series of 20 pieces of each of said products were injected, at standard levels for marinated products (15% injection percentage), with Injector A and three series more of each product with Injector B. All the pieces were weighed separately before and immediately after injection, calculating the corresponding injection percentages. Each series of data was evaluated statistically and the respective standard deviations were calculated.

Results

As can be observed in Table 1, the standard deviation values for the nine series injected with Injector B (spray effect) are significantly lower than the values for the series injected with Injector A. Therefore, it can be said that injection precision (regularity) is improved by spray injection.

In Injector B, thanks to the spray effect, the brine is sprayed through the needles in the form of micro-drops, at higher speed, and so penetrates the meat more deeply. For the same reason, better brine distribution is obtained, since its atomized exit from the needles prevents the formation of brine pockets in the piece and allows for good dispersion of the micro-drops. These two aspects are responsible for obtaining great injection regularity and homogeneity of sensory characteristics among the products and throughout each individual piece. In this way, the safety margins required in the final yield, to assure that products comply with the legislation in force, are also reduced.

In Graphic 1, the Normal Gauss Distribution Bell for the *longissimus dorsi* injection trial can be observed, representing the probabilities of finding pieces with differing injection percentages for the two types of injectors. This graphic shows a curve for Injector B that is narrower than the curve for Injector A, which makes it possible to assure a constant quality in many more pieces and also to increase the average injection percentage (and consequently the final yield) maintaining the same assurance of precision in the analytical results of the pieces.



Injector A (without spray effect)   Injector B (spray)

▲ **Graphic 1:** Injection Regularity Distribution.

TABLE 1: COMPARISON OF STANDARD DEVIATION RESULTS OBTAINED IN INJECTOR A AND INJECTOR B

SERIES	INJECTOR A		INJECTOR B	
	INJECTION %	STANDARD DEVIATION	INJECTION %	STANDARD DEVIATION
	Pork Loin (longissimus dorsi) bone-in			
1	14,98	1,22	15,05	0,73
2	14,93	1,34	14,90	0,65
3	15,07	1,16	14,95	0,81
	Whole Chicken (broiler)			
1	14,80	1,32	14,90	0,67
2	14,83	1,30	14,95	0,74
3	14,94	1,08	14,95	0,66
	Beef-Eye of Round (semitendinosus)			
1	14,91	1,25	14,80	0,74
2	14,96	1,18	14,98	0,69
3	15,00	1,22	15,15	0,77

Influence of spray effect on marinade retention in the meat

Retention can be defined as the water-binding capacity of the meat's natural proteins. The stronger this union, the better the meat's water-holding capacity and the less the subsequent dripping loss. The meat's proteins, and specifically the muscular myofibrillae, are responsible for retention of water. These proteins possess electrically-charged reactive groups and can therefore be associated with the water molecules' polar groups.

The water molecules that remain strongly bound to the meat proteins are those that are located nearest them. Other water molecules can be

TABLE 2: MARINADE RETENTION IN TERMS OF TIME

	SAMPLE	t=0 (0 min)		t=1 (10 min)		t=2 (30 min)		t=3 (1 h)		t=4 (24 h)		TOTAL Drip %
		Inj %	Drip %	Inj %	Drip %	Inj %	Drip %	Inj %	Drip %	Inj %	Drip %	
		Pork Loin (longissimus dorsi) bone-in										
INJECTOR A	1	15,0	-	12,5	2,5	11,1	1,4	10,0	1,1	9,3	0,7	5,7
	2	15,5	-	13,8	1,7	12,8	1,0	12,1	0,7	11,1	1,0	4,4
	3	15,3	-	12,9	2,4	11,5	1,4	10,4	1,1	9,7	0,7	5,6
	4	14,2	-	12,0	2,2	10,7	1,3	10,1	0,6	9,2	0,9	5,0
	5	14,7	-	12,4	2,3	10,8	1,6	9,7	1,1	8,9	0,8	5,8
INJECTOR B	1	15,0	-	13,4	1,5	12,5	0,9	12,1	0,4	12,1	0,1	2,8
	2	15,5	-	14,0	1,3	13,3	0,7	13,1	0,2	13,0	0,1	2,3
	3	15,3	-	14,2	0,8	13,7	0,5	13,6	0,1	13,3	0,3	1,7
	4	14,2	-	14,1	1,0	13,4	0,7	13,1	0,3	13,1	0,0	2,0
	5	14,7	-	14,0	0,9	13,6	0,4	13,4	0,2	13,3	0,1	1,6
		Whole Chicken (Boiler)										
INJECTOR A	1	14,5	-	11,9	2,6	10,4	1,5	9,7	0,7	9,2	0,5	5,3
	2	15,3	-	12,8	2,5	10,9	1,9	9,7	1,2	9,0	0,7	6,3
	3	16,0	-	13,7	2,3	12,0	1,7	11,0	1,0	10,3	0,7	5,7
	4	14,7	-	12,3	2,4	10,4	1,9	9,2	1,2	8,3	0,9	6,4
	5	14,0	-	12,1	1,9	10,6	1,5	9,8	0,8	9,1	0,7	4,9
INJECTOR B	1	15,2	-	13,2	2,0	12,2	1,0	11,9	0,3	11,6	0,3	3,6
	2	14,8	-	13,2	1,6	12,5	0,7	12,1	0,4	12,0	0,1	2,8
	3	14,7	-	12,8	1,9	11,8	1,0	11,5	0,3	11,1	0,4	3,6
	4	15,1	-	13,1	2,0	12,0	1,1	11,5	0,5	11,2	0,3	3,9
	5	15,4	-	13,7	1,7	12,9	0,8	12,5	0,4	12,3	0,2	3,1
		Beef-Eye of Round (Semitendinosus)										
INJECTOR A	1	15,4	-	13,0	2,4	11,4	1,6	10,5	0,9	9,9	0,6	5,5
	2	14,5	-	12,6	1,9	11,4	1,2	10,5	0,9	10,0	0,5	4,5
	3	14,8	-	12,9	1,9	11,5	1,4	10,7	0,8	10,2	0,5	4,6
	4	15,1	-	12,8	2,3	11,4	1,4	10,4	1,0	9,8	0,6	5,3
	5	15,5	-	13,3	2,2	12,0	1,3	10,9	1,1	10,1	0,8	5,4
INJECTOR B	1	15,1	-	13,9	1,2	13,2	0,7	13,0	0,2	13,0	0,0	2,1
	2	14,6	-	13,8	0,8	13,4	0,4	13,3	0,1	13,2	0,1	1,4
	3	15,0	-	14,1	0,9	13,5	0,6	13,1	0,4	12,9	0,2	2,1
	4	14,9	-	14,1	0,8	13,7	0,4	13,3	0,4	13,1	0,2	1,8
	5	15,1	-	14,4	0,7	14,0	0,4	13,5	0,5	13,2	0,3	1,9

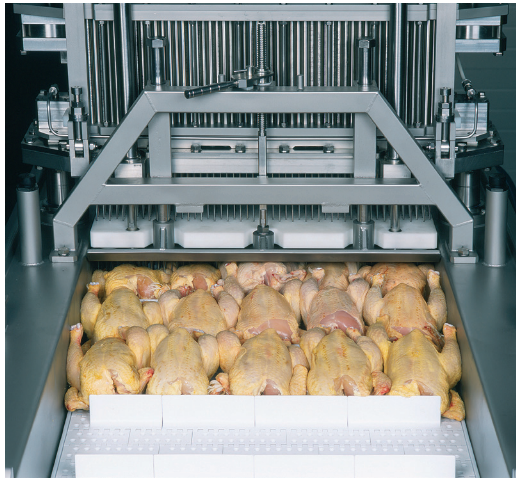
successively attracted by the molecules bound in layers, which are weaker the further away they are from the protein's reactive group. This water can be called immobilized, but the quantity so immobilized depends on the amount of force physically exerted on the muscle. The water that stays bound only by superficial forces is called free water and it is this water which can be most easily lost through dripping.
To carry out the trials on retention of marinade in the meat, five samples were taken from the batches injected in the above-mentioned trials, and the weight of the samples was controlled at different times: t0 (immediately after injection), t1 (5 min after injection), t2 (30 min), t3 (60 min) and t4 (24 hr after injection). The meat was kept in a cooling chamber (2º C) but without packaging so as not to interfere with the natural dripping.

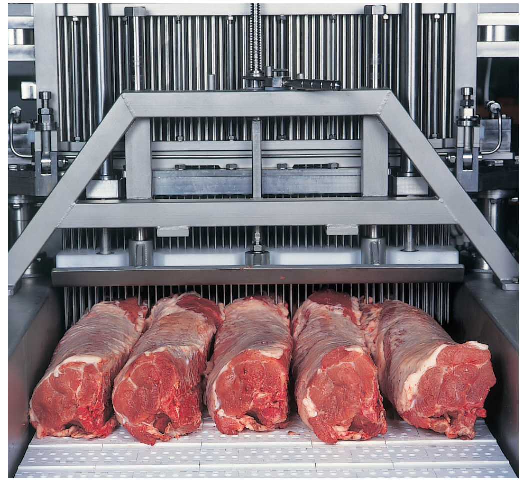
Results

The values of the different percentages of marinade retained for the time period, as well as the dripping percentage at each stage, are shown in Table 2, where it can be observed that with spray effect the loss of marinade is reduced by up to 63% depending on the meat type. The time that must pass before dripping can be considered finished (<1%) is also reduced, which guarantees conditions for quick packaging without subsequent problems of liquid being present in the final packaging. Another positive consequence of reduction of the total dripping loss is an increase in meat yield, without the necessity of increasing the injection level.

In the products marinated with the spray injector, the marinade is distributed in the form of micro-drops, and therefore in a totally uniform manner,

▼ Spray Marinating Injector: AUVISTICK PLUS.





so that the space between the micro-drops and the proteins is minimum. In this way, there are many more water molecules bound directly to the proteins, resulting in a much stronger union between them and consequently less dripping loss during storage of the product. Dripping is also reduced because the micro-drops occupy minimum space between the muscle fibers and, consequently, the pressure exerted upon them is also reduced.

In contrast, in the marinated products injected with a conventional machine without spray effect, due to the design and size of the holes in its injection needles, the marinade comes out of the needles and forms deposits, leaving channels of marinade around the needle, with the result that many water molecules are far from the points of binding with the meat proteins, so that the binding which takes place between them is very weak. Since the space occupied is much greater, the pressure exerted on the muscle also increases, resulting in greater dripping loss.

Reduction of dripping loss is fundamental in marinated products, since in-line packaging can take place the same day as injection without subsequent exudations being produced inside the packaging and, in addition, work in the production plant is made easier by the creation of a more continuous process. It must also be taken into consideration that the presence of exudate in the packaging bag means the product's shelf-life will be shortened, since any juice or free substance inside the package is highly susceptible to suffering microbiological contamination, negatively affecting consumer safety in the finished product.

Influence of spray effect on marinade distribution in the muscle

One of the principal challenges in the injection marinating process consists in obtaining a finished product of great regularity throughout its entire volume without affecting muscle structure or the product's external appearance. The process of marinade distribution must be carried out with maximum uniformity, minimizing the presence of marinade-free zones, very difficult to compensate for by means of simple diffusion. This point is particularly important in products with low injection levels and/or products where no type of mechanical work can be applied to enhance said diffusion.

For these trials a single type of muscle was used, having chosen boneless pork loin (*longissimus* *dorsi*) for its regularity in shape, and the trials were performed in the same injectors (A and B) as the above-mentioned trials, using the same marinade and injection percentage (15%).

The working conditions were prepared for maximum production, that is to say, with both injectors configured with maximum belt feed and maximum injection speed, so that each part of a muscle would receive only a single stroke of the injection head. The percentage of brine injected was regulated in each case by means of the brine pump's speed.

In order to evaluate brine distribution, two types of trials were carried out:

a) DI (Distribution Index) analysis: DI is defined as the percentage of meat volume injected with marinade in relation to the total meat volume. The distribution trial consists in a visual analysis of the distribution of one of the brine components throughout the meat's entire volume, from which the brine content distributed in each zone of the muscle can be extrapolated. To achieve this, 0.004% Methylene Blue was added to the brine used in the previous trials.

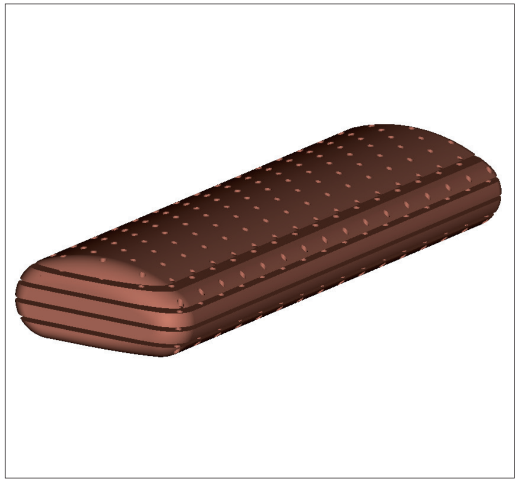
After injection, and with the objective of being able to evaluate the entire volume of the injected muscle, the pieces were frozen to facilitate subsequent slicing in layers or horizontal slices (1 cm thick). In this way, it was possible to obtain the distribution map of needle penetration and brine expansion around the needle's path in the various slices. Figure 1 shows a digitalized image of a piece of meat, of which a model rendered in 3D was obtained through the Pro Engineer software program, in which the injection points and the slices made can be observed.

Results

Figures 2 and 3 show photographs of the slices made. As can be seen in Figures 2 and 3, the marinade was distributed in a fairly regular manner in both cases (circles of Methylene Blue), but it can be detected visually that the area of coloring is greater in the samples corresponding to Injector B.

Figures 2 (Injector A) and 3 (Injector B): Brine distribution during injection (circles of Methylene Blue).

▼ **Figure 1.** Digitalized image of injection points through slices.



▼ **Figure 2 and 3.** Brine distribution during injection (circles of Methylene Blue).

The visual results were confirmed by the DI calculations, which are shown in Graphic 2, where the ratio between the surface containing Methylene Blue, and therefore marinade, and the surface without this component can be observed. In the case of spray injection (Injector B) this ratio is higher, and therefore the marinade distribution is more homogeneous.

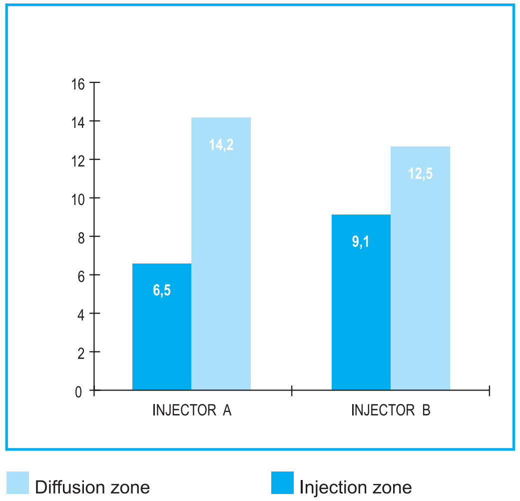
b) Injection % ratio between injection zones and diffusion zones: In terms of the injection distribution map, the diagram of the muscle can be divided into injection zones (corresponding to the colored areas of the previous trial) and diffusion zones (areas without coloring and where the marinade can arrive only by means of diffusion).

To quantify the marinade distribution in injection zones and diffusion zones, the meat pieces were frozen and subsequently cut along the profile of the different zones. Then the NaCl content was analyzed in each of the injection and diffusion zones, averaging the results for each piece.

Results

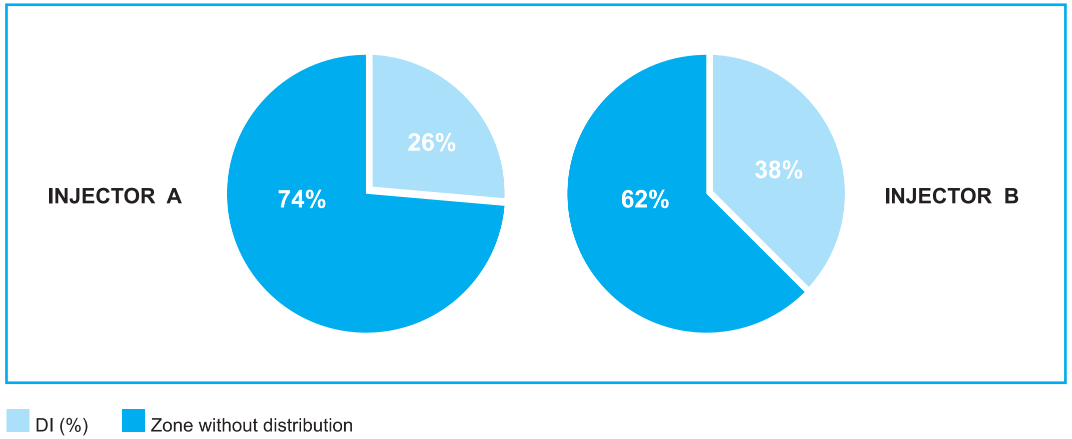
The results obtained from the analysis of NaCl content can be observed in Graphic 3.

As can be seen in Graphic 3, the distribution of NaCl, and therefore of the rest of the marinade components, is more regular in the case of Injector B with spray system, given that in the same working conditions the difference in content between injection zones and diffusion zones is less. The introduction of marinade in the form of micro-drops facilitates its dispersion, making it possible to cover a wider area than in the case of introduction by means of liquid jet.



▲ **Graphic 3:** NaCl Distribution (g/Kg).

▼ **Graphic 2:** Distribution Index.



CONCLUSIONS

In all the trials carried out comparing spray injection (Injector B) to injection without this effect (Injector A), it was observed that the spray effect improved results in the parameters indicative of injection process quality in marinated meat products. Standard deviation of the various injection percentages is reduced by almost 50%, which increases injection percentage regularity in a given batch of meat. Dripping loss is reduced by levels of over 60%, obtaining greater product yield and an increase in packaging safety. The regularity of salt content throughout the entire piece is increased, assuring greater consistency in product flavor and texture. It can be concluded that atomization of the marinade in micro-drops improves the quality and added value of this type of meat products.

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