

Spray marinating: a definitive solution for improving meat texture

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ABSTRACT

Meat “marinating” is a method that has been used for a very long time to obtain better and different flavors, increase tenderness of the tougher muscles and prolong shelf life of the product by means of salting. At an industrial level, this practice has been absent until recently because no need had previously been found to investigate and invest in this type of processing. But in recent years, due to the growing demand for quality added-value products, a major change has been observed in many markets and “marinating” is beginning to become a part of industrial processing.

This article examines the influence of spray injection on the organoleptic and sensory characteristics of various types of meat. The results demonstrate that controlled spray brine injection contributes to improving meat quality and directly influences the consumer’s acceptance of these products.

INTRODUCTION

Current market trends and demands have led to the acceptance of three concepts of quality: hygienic and sanitary quality or food safety, organoleptic or sensory quality and nutritional quality, dictated by nutritional value. In any case, food safety and palatability are the properties on which today’s consumers place most emphasis when defining their preferences in the purchasing of meat.

As regards palatability, texture, characterized by the attributes of tenderness and juiciness, is the sensory quality that most influences product acceptability on the part of the consumer. Inconsistency and variation in texture has been identified as one of the most important problems and one of the principal areas of improvement that the meat industry must face in the 21st century.

Therefore, tenderness is a characteristic of great economic importance, since it affects repetition

of the consumer’s meat purchasing. This characteristic is very difficult to homogenize, that is, to guarantee the consumer a constant degree of tenderness, mainly because it depends on so many factors (environmental, handling, genetic) which act alone and/or in combination with others. An effort to compensate for these factors has given rise to “marinated products”, which offer an improvement and a standardization of meat tenderness. These products have been very well received in certain markets, both because of the meat’s increased sensory and organoleptic quality, and because of the ease of purchasing and use (case-ready convenience). In addition, this type of product not only provides the consumer with added value, but generates value for the processor, offering him more competitive costs and a greater presence of his meat products in the display cases of sales outlets.

What is organoleptic and sensory quality?

Organoleptic properties of meat, or any food in general, are defined by the attributes perceived by the consumer when the product is eaten. Among the attributes that most influence consumer satisfaction are those related to texture and consistency, characterized by impressions of tenderness and juiciness, and the flavor that results from a combination of olfactory and gustative sensations, which is what we call taste.

- **Tenderness:** Meat tenderness is defined as the difficulty or ease with which the meat can be cut or chewed. The impression of tenderness is directly related to four main factors: degradation of the muscle fiber, the contractile state of the muscle, the quantity and distribution of connective tissue, and the quantity of intramuscular fat. These factors are susceptible to genetic or environmental variation.
- **Juiciness:** Juiciness plays a very important role in the general impression of palatability perceived by the consumer. It could be defined as the impression

that results from chewing, caused by the juices that are released from the meat during the process. Meat juices contain many aromatic, volatile components responsible for flavor, and also help to soften and fragment the meat during chewing. In addition, they stimulate the production of saliva, which provides a sustained impression of juiciness. The lack of juiciness in meat limits its acceptability and destroys its unique sensory virtues.

- **Flavor:** Many of the psychological and physiological reactions that meat awakens derive from a complex impression resulting from the perception of its flavor and aroma. Flavor involves the perception of four basic sensations (salty, sweet, acidic and bitter) by the gustative papillae on the tongue. The aroma is detected thanks to the existence of numerous volatile and soluble substances that stimulate the nerve endings in the nasal fossae. The overall sensation is a combination of gustative and olfactory stimulation. The meat components responsible for flavor and aroma have not yet been fully identified.

What is a marinated product?

The term “marinating” refers to the process by which an aqueous solution, which may contain different ingredients and/or additives (salt, phosphates, flavoring, etc.) is added to or injected in the meat with the goal of improving its texture and flavor, and thereby reducing variability in its sensory quality. It is the same method used in traditional cooking, where the meat is pickled and left for a time in the refrigerator, but at the industrial level employing the most advanced technologies and equipment designed specifically for this purpose. Recent studies have shown that marinating meat in the phase prior to rigor mortis can, in addition, reduce the negative effects caused by PSE meat and greatly improve quality of the end product [Alvarado et al. 2003]. Thus, the effect marinating has on meat can be summarized in 4 key points:

- Increased water-holding capacity during cooking, including when overcooking occurs due

▼ Spray Marinating Injector: AUVISTICK 360 PT.



to carelessness, and therefore greater juiciness [McGee et al. 2003].

- Relaxation of muscle fibers, giving rise to a product that is more tender and more easily chewed [Smith et al. 2002, Genho et al. 2002, Zheng et al. 2000].
- Uniform addition of salt and specific flavorings throughout the entire piece.
- Improved quality of PSE meat [Alvarado et al. 2003].

Marinating can be applied to any type of meat muscle, such as pork, beef, chicken, turkey, lamb, etc. The effect will be more noticeable the drier and tougher the muscle to begin with, such as, for example, pork loin, chicken or turkey breasts and most bovine hindquarter muscles for roasting.

How is marinating done?

Traditionally, three methods have been used to produce marinated products: immersion, injection and massage. Immersion is the oldest method and consists in submerging the meat in the marinade, allowing the ingredients to penetrate the meat through diffusion with the passing of time. This method is quite unreliable in the meat industry, because it does not provide regularity in the distribution of ingredients and it increases the risk of bacterial contamination. In addition, it is not practical, as it requires lengthy process times and limits the quantity of marinade to be absorbed. In regard to massage marinating, its principal application is to small, boneless meat pieces, since it is difficult to obtain proper diffusion of the ingredients in large pieces, which hinders homogeneity and uniformity in the end product. Further, massaging can damage bone-in products, causing separation of meat from bone and a loss in the product's morphology.

Therefore, the most reliable, safe and modern marinating method is injection by means of a multi-needle spray injector, with which a homogeneous distribution of marinade ingredients throughout

the entire piece is obtained [Xargayó et al. 2001]. It should be kept in mind that the marinating solution must be incorporated effectively and retained in the muscle in order to impart the desired 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 brine deposit in the needle's penetration zone.

In contrast to the above, spray injectors do not form brine or marinade pockets around the needle, but rather force the marinade to penetrate at high speed through needles of lesser diameter (0.6 mm), causing its dispersion into the meat muscle in thousands of sprayed micro-drops during the needle's downward stroke. The tiny dimensions of these drops, and the high speed produced by said injector's constructive characteristics, result in the drops penetrating deeply between the meat fibers without causing damage to the muscle structure. Marinade incorporated into the muscle in such a way is subject to minimum dripping loss and, due to its deep penetration in the muscle, greater muscle volume will be covered by said marinade, so that better marinade distribution is to be expected.

Given that the injector is the key element or brain of the entire process, it is indispensable that the machine be reliable, technologically advanced and designed specifically for this purpose.

Meat quality's influence on the marinated end product

The meat should be as fresh as possible and in proper hygienic-sanitary condition. It must be kept in mind that marinating is not a method for improving low-quality meat, or for making acceptable meat which is not, but rather for improving meat quality generally speaking. Otherwise, a lack of confidence would be created among consumers and the product would disappear from the sales outlets.

The meat factors and parameters that will most influence the marinated end product's characteristics are the following:

- **Age of the animal.** A young animal has a greater ratio of lean meat to fat, and therefore, having more protein, a greater number of reagent groups capable of associating with water molecules. On the other hand, an adult animal has more fat and, therefore, a lesser proportion of protein.

In addition, in an adult animal, the muscle fibers are more rigid due to the lesser solubility of collagen, giving rise to a lesser penetration of the marinade solution.

- **Breed.** Significant effects have been described in different breeds in regard to intramuscular fat, water-holding capacity, color and tenderness. In some breeds, a very rapid descent of the pH is observed after slaughter, resulting in a pale, exudative and less tender meat [PSE]. This effect can be explained by the high frequency of a single gene called the halothane gene. Other breeds have very low pH as a general rule, which results in meat with poor water-holding capacity and subject to great cooking loss. This fact is related to a gene called the RN gene.

- **Meat Maturation.** When the muscle is in the rigor mortis phase, the meat fibers are contracted, increasing the number of bridges between muscle filaments and forming a muscular lattice that hides the reagent groups of proteins susceptible to binding with water molecules. After a maturation period and with the passing of time [ageing], protein degradation eliminates structural connections between the muscle filaments and between the cellular membranes and the structural filaments. The result of this process is that the groups of electrically-charged proteins are exposed so that they can unite with the marinade's water molecules.

- **pH.** The descent of pH in meat after slaughter to values of 5.4-5.8 causes the disappearance of

electric charges and shrinkage of the network of polypeptide chains, resulting in a reduction of the meat's water-holding capacity. With maturation, the pH is recovered and the number of electric charges increases. Water-holding capacity is closely related to the final pH value, and will increase as the pH value rises. When the drop in pH occurs more rapidly, the alterations suffered by the myofibrillar and sarcoplasmatic proteins will result in a reduction in water-holding capacity.

Variables and Parameters to be controlled during the marinating process

During the marinating process there is a series of parameters that must be taken into consideration in order to obtain the desired increase in quality. These parameters are as follows:

- **Raw material and process temperatures:** Given that fresh meat is being dealt with, rigorous temperature control must be maintained to reduce the risk of bacterial contamination. The temperature of the meat should be between 1 and 4° C and the marinade below 6° C. For processing plants, it is best not to exceed 10° C and the refrigerating chain must not be interrupted at any time during shipping and distribution.

- **Maintenance and care of equipment:** As mentioned above, the injector is the key element of the process, and therefore it should be in the best possible condition and able to prevent injection percentage deviations or poor marinade distribution. A mechanically reliable and easily maintained machine will ensure a standardization of the process.

- **Hygiene and sanitation:** In fresh products, hygiene and sanitation of the plant, equipment and personnel must be very rigorous. In addition to the routine cleaning of machinery at the end of a production day, application of a disinfecting solution before and after use of the machine is recommended.

- **Injection percentage:** The percentages recommended for increasing meat's organoleptic quality are between 5 and 20%, depending on the type of animal and muscle. Excessive injection may produce the opposite effect, that is, a reduction in quality. These negative effects may include: gummy or too soft texture, dripping in the trays and excessive muscle contraction during cooking.

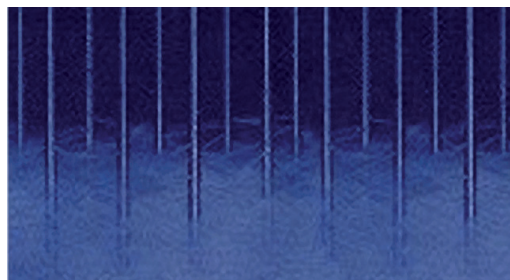
Marinade composition

The additives and/or ingredients to be used in the composition of marinade will depend on the objective defined for each product. Functionality of the non-meat additives and/or ingredients is principally based on their contribution to increasing water-holding capacity and, therefore, their effect on the meat's juiciness and texture (Miller et al. 1998). Increased product yield may be an economic factor taken into consideration, but if the products are to be accepted by a demanding market, they must be subject to an end product with higher organoleptic quality than that of the fresh meat. Otherwise, they will be viewed as profitable only for the producer. In addition to water, which must be of optimum quality as regards contamination and hardness, there are other ingredients that may have a determined functionality in the marinating process, such as:

- **Salt.** Salt has always been used to increase a product's flavor and shelf-life. But it also plays a basic role in increasing water-holding capacity, reducing dripping and cooking loss. Salt reduces the isoelectric point of proteins, thereby increasing the separation between chains, allowing the chloride ions (negatively charged) to bind with the positively-charged proteinic chains, increasing the repulsive force between them. In this way, the protein's three-dimensional matrix opens, giving rise to a greater number of charges being exposed to bind with water molecules. It is known that meat proteins can swell up to double their size in the presence of salt concentrations used in meat processing.

- **Phosphates.** Phosphates are used primarily for their ability to increase meat's water-holding capacity, since they act as agents to capture Ca^{2+} ions, which are responsible for keeping the proteinic chains together to form a three-dimensional network. This produces a relaxing of the muscle, increasing the space available for the incorporation of water. In addition, phosphates have an alkaline pH, and their addition causes a displacement of the meat's pH to values above the isoelectric point of proteins (between 5.2 and 5.3), increasing the negative charges able to bind with water. There are various scientific studies demonstrating that the addition of water containing up to 0.5% phosphates in the end product results in lower Warner-Bratzler shear force values, better water-holding capacity and, consequently, more tender and juicier meat (Smith et al. 1984, Dettienne et al. 1999).

▼ Brine sprayed in thousands of micro-drops by Metalquimia, S.A.U., spray injectors.



▼ Poultry parts spray marination.



- **Proteins.** Added proteins have a gelling capacity, but alone do not have an impact on the water-holding capacity of meat proteins, as is the case with phosphates. Water-holding of added proteins is due to their gelling capacity, generally induced by heat. When cold, they have little gelling capacity, which can be observed when the brine or marinade becomes more viscose. This viscosity can have a positive influence on dripping, since a marinade more viscose than the water will tend to be retained between the meat fibers and, therefore, produce less dripping. During cooking, added proteins contribute to diminishing cooking loss, thanks to their gelling capacity, but this effect will not be visible while the meat is being packaged.

- **Carrageenan.** Hydrochlorides possess a great gelling capacity and, therefore contribute to increasing water-holding capacity during cooking. There exists a new generation of carrageenans that have a gelling property in cold conditions, therefore increasing brine viscosity, providing special tixotropic characteristics that allow them to pass through the injector. This type of ingredient helps to retain marinade in fresh meat.

- **Aromas or flavoring.** Flavoring agents are added to fresh meat to generate a wide range of alternative products for the consumer. The flavoring agents that may be used in marinade solutions include a variety of different kinds, but they must always be totally water-soluble in order to prevent damage to the needles.

EXPERIMENTAL DESIGN

Samples

In order to determine both objectively and subjectively the influence marinade has on meat products, a series of experiments were carried out with the following products: boneless pork loin (*longissimus dorsi*), eye of round (*semitendinosus*) and boneless chicken breast (*superficial pectoral*).

The meat samples were supplied by a local distributor and were stored in refrigeration at 2-4°C until their use.

Marinating process

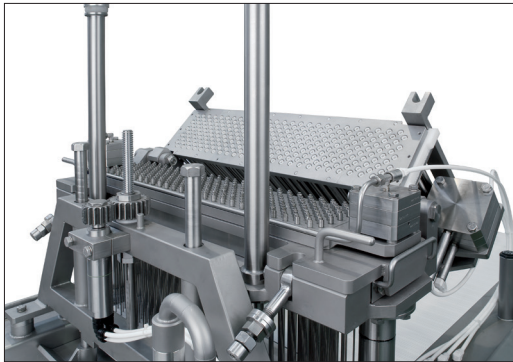
After completion of the *rigor mortis* phase, each of the meat pieces was assigned randomly to one of the three processing groups: control or 0%, 15% and 25%. The samples were injected using an Auvistick spray injector, model 130, manufactured by Metalquimia, S.A.U. (Spain). The brine for the marinade, containing 6.0 g/kg sodium chloride and 2.5 g/kg tripolyphosphate based on the end product, was prepared using decalcified water at a temperature of 4°C. For proper dissolution of the ingredients, a Molistick crushing mill, model 550, manufactured by Metalquimia, S.A.U. (Spain), was used. After injection, the samples were stored in refrigeration at $2 \pm 1^\circ \text{C}$ during the following 24 hours, before proceeding with the qualitative and quantitative determinations.

Cooking process

The pieces were cooked using an industrial oven, Spider model 5. The eye of round was cooked whole at an exterior temperature of 200° C until reaching a temperature of 63° C in core. The pork loin, cut into fillets 1.5 cm thick, was cooked in the same oven at 110° C until reaching an internal temperature of 70° C, and the chicken breasts were cooked at 180° C until reaching an internal temperature of 80° C. The samples were weighed before and immediately after cooking to determine the degree of cooking loss that took place during the process.

Texture analysis

For the quantification of texture properties, dual compression and shearing tests were carried out using a Texture Analyzer manufactured by Stable Micro Systems, model TA-XT2. The samples (2 x 2 x 1.5 cm) were compressed twice until reaching



▲ Detail of AUVISTICK PLUS marination head.

50% their original height before determining the parameters of hardness [Kg], springiness [Kg], cohesiveness, adhesiveness [Kg·s], gumminess [Kg] and chewiness [Kg]. The shearing strength of the samples (2 x 1 x 1.5 cm) was measured using a Warner-Bratzler attachment, by means of which a shear measures the maximum force [Kg] necessary to cut the sample and the work needed [Kg·s] to displace the probe through the sample.

Sensory analysis

The various slices were analyzed by a panel made up of 12 tasters familiar with this type of meat. Salt was added externally to the control samples to minimize differences in flavor. The panelists evaluated the samples according to the following attributes: flavor, smell, juiciness, tenderness and overall acceptability, using a scale of values with 8 points (8 = extremely juicy, extremely tender, extremely good, etc.; 1 = extremely dry, extremely tough, extremely bad, etc.).

RESULTS

Texture

The results obtained from the dual compression and shearing tests are shown respectively in table 1. The data corresponding to each of the products are the averages of the tests carried out with 5 pieces from different animals.



▲ Detail of AUVISTICK PLUS marination head.



▲ Detail of automatic injection regulation.

In regard to the hardness parameter, it was observed that the marinated products corresponding to the three types of meat (pork, chicken and beef) were not as hard as the unmarinated products, with hardness being understood as the force necessary to compress the meat and cause a certain degree of deformation. However, both products behaved in the same way with regard to springiness (speed at which a deformed sample returned to its original condition). Significant differences were not

TABLE 1: EFFECT OF MARINATING ON TEXTURE PROPERTIES IN DIFFERENT TYPES OF MEAT						
PRODUCT	HARDNESS - kg	SPRINGINESS	COHESIVENESS	ADHESIVENESS - kg · s	GUMMINESS - kg	CHEWINESS - kg
Control Chicken	4,87 ± 0,67	0,69 ± 0,02	0,50 ± 0,03	-0,002 ± 0,004	2,42 ± 0,34	1,67 ± 0,26
Chicken 15 %	3,94 ± 0,49	0,70 ± 0,04	0,46 ± 0,01	-0,006 ± 0,004	1,79 ± 0,22	1,24 ± 0,15
Chicken 25%	3,15 ± 0,51	0,69 ± 0,04	0,44 ± 0,02	-0,004 ± 0,002	1,41 ± 0,12	1,07 ± 0,19
Control Loin	8,48 ± 1,99	0,62 ± 0,04	0,63 ± 0,04	-0,008 ± 0,005	5,36 ± 1,4	3,35 ± 0,99
Loin 15%	7,24 ± 1,39	0,57 ± 0,03	0,62 ± 0,02	-0,007 ± 0,004	4,48 ± 0,93	2,56 ± 0,60
Loin 25%	5,80 ± 0,89	0,60 ± 0,02	0,61 ± 0,02	-0,007 ± 0,003	3,53 ± 0,89	2,21 ± 0,61
Control Beef	6,95 ± 1,05	0,66 ± 0,03	0,65 ± 0,02	-0,004 ± 0,004	4,51 ± 0,74	2,94 ± 0,50
Beef 15%	3,94 ± 0,49	0,74 ± 0,05	0,60 ± 0,04	-0,002 ± 0,003	3,52 ± 0,47	2,57 ± 0,40
Beef 25%	4,68 ± 1,01	0,79 ± 0,04	0,58 ± 0,05	-0,002 ± 0,002	2,77 ± 0,79	2,21 ± 0,75

observed either in the parameters of cohesiveness or adhesiveness, which means that the two products both had the same quality of remaining compact, not breaking nor sticking to the surface of other materials with which they came into contact. The parameters of gumminess and chewiness are ones that depend on all the above parameters and reflect the energy required to disintegrate a food product to a state in which it can be swallowed. It was observed that for all the meat types the marinated products showed less gumminess and less chewiness compared to the unmarinated products, which is directly related to greater chewing ease and, therefore, greater tenderness.

The results of force and work done obtained with the Warner-Bratzler shear are shown in table 2. The data indicate that the addition of a marinade to the meat causes an important descent both in the

shear force and the work done, the products with 25% injections being numerically the most tender. It must be taken into account that a greater content of water/humidity in marinated products results in them being less hard and easier to chew and cut.

Sensory analysis

Table 3 shows the results obtained from the sensory analysis carried out by the panelists. As can be observed, the products with a 25% injection were the ones that obtained the highest points in tenderness and juiciness, compared with the control samples and with the products with a lesser injection percentage. On the other hand, the products numerically higher in overall acceptability were those with a lesser injection, 15%. The fact that the products with greater injection did not receive a high valuation in overall acceptability is because some of the panelists defined the products as “meat products” and not as meat, pointing out their gummy texture.

The higher scores in flavor obtained by the marinated products indicate a better distribution of ingredients (above all, salt) inside the meat, resulting in a more homogeneous product. In smell there were not significant differences among the samples, indicating that there is no reason why marinating should necessarily affect the meat’s natural aroma. Another matter entirely would be the creation of alternative products using spices

TABLE 2: EFFECT OF MARINATING ON SHEARING PROPERTIES IN DIFFERENT TYPES OF MEAT		
PRODUCT	SHEAR FORCE - kg	WORK DONE - kg · s
Control Chicken	1,52 ± 0,48	3,52 ± 0,16
Chicken 15%	0,96 ± 0,37	2,48 ± 0,56
Chicken 25%	0,44 ± 0,23	2,21 ± 0,49
Control Loin	4,22 ± 0,60	8,27 ± 1,34
Loin 15%	2,79 ± 0,50	6,36 ± 1,04
Loin 25%	1,56 ± 0,43	5,68 ± 0,95
Control Beef	4,69 ± 1,54	9,53 ± 3,10
Beef 15%	2,12 ± 0,45	5,27 ± 1,01
Beef 25%	1,97 ± 0,36	4,70 ± 0,73

TABLE 3: EFFECT OF MARINATING ON SENSORY CHARACTERISTICS IN DIFFERENT TYPES OF MEAT					
PRODUCT	FLAVOR	SMELL	JUICINESS	TENDERNESS	OVERALL ACCEPTABILITY
Control Chicken	5,5	5,3	6,0	6,0	6,2
Chicken 15%	6,2	5,5	6,6	6,5	7,0
Chicken 25%	5,6	5,4	7,0	6,7	6,0
Control Loin	5,9	5,4	6,1	6,2	6,4
Loin 15%	6,4	5,2	6,6	6,8	6,9
Loin 25%	6,1	5,6	7,1	7,0	6,5
Control Beef	5,3	5,1	6,1	6,2	6,1
Beef 15%	6,1	5,2	6,8	6,8	7,0
Beef 25%	5,7	5,1	7,2	7,1	6,1

and specific flavorings, which directly influence the gustative and olfactory sensations.

Cooking loss

Table 4 shows the cooking loss values obtained for the three types of meat as well as the final yield, both for the injected and uninjected products. In both cases, it can be observed that the cooking loss in injected products is slightly higher than in fresh meat, due to the amount of water added, but the final yield of an injected product is always much higher than an uninjected product. In this way, the water held inside the meat fibers is released during the chewing process, providing greater juiciness, tenderness and general palatability.

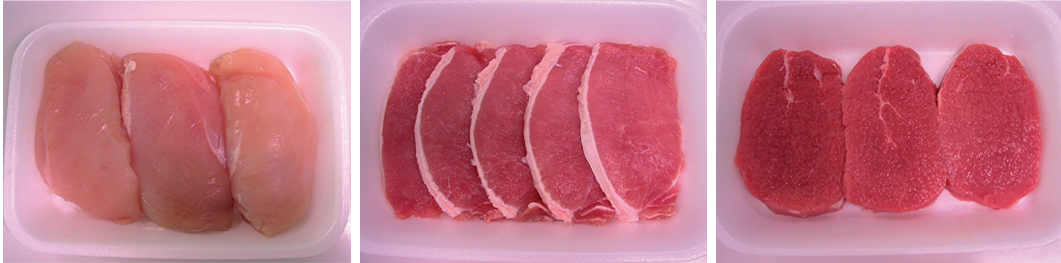
CONCLUSIONS

The process of marinating by means of controlled spray injection of a properly formulated brine satisfies perfectly the established objective of improving the meat’s organoleptic characteristics. It has also been observed that meat quality in the marinated pieces is more constant than in the unmarinated pieces, and therefore the variability presented by meat due to genetic factors or production, and originating from defects (PSE), can be compensated for by spray marinating. Thanks to marinating, a more tender, juicier and, in general, more palatable product is obtained. This is due to greater water-holding capacity in the

meat after cooking, water which is then released during chewing, causing the consumer to detect a juicier and, therefore, more appetizing product. It is important to emphasize that injection percentage is one of the factors that most influences a marinated product’s degree of acceptability by the consumer. Excessive injection can have a negative impact on meat quality, producing a less acceptable product that may even be rejected.

All the marketing polls detect a consumer who is avid for new products and, above all, for case-ready products. But, at the same time, the consumer is becoming more and more critical and demanding in regard to quality. The introduction of new products must insure that the product fulfills a series of requirements and maintains consistency in quality. To achieve this, it is essential to make sure that processing is carried out in the best conditions and with the most appropriate equipment. In this way, advantages will be created for the consumer with products of better quality and for the processor,

TABLE 4: PERCENTAGE OF DRIPPING LOSS AND FINAL YIELD AFTER COOKING				
TYPE OF MEAT	UNMARINATED PRODUCT - 0%		MARINATED PRODUCT - 15%	
	COOK LOSS %	FINAL YIELD	COOK LOSS %	FINAL YIELD
Boneless chicken breast	15,3 ± 2,5	84,7 ± 2,5	14,5 ± 0,8	98,4 ± 2,1
Pork Loin	15 ± 3,3	85,0 ± 3,3	16,2 ± 3,9	96,6 ± 4,5
Eye of round	19 ± 2,9	81,0 ± 2,9	21,2 ± 3,0	89,8 ± 3,5



▲ Case-ready marinated products.

since he will obtain better yields and will be able to offer a wider range and more attractive products.

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ACKNOWLEDGMENTS

We would like to thank the engineers Mr. Narcís Lagares and Mr. Josep Mª Brugué of METALQUIMIA S.A.U.'s Engineering Department for their help and collaboration in the preparation of this article. Thanks also to Mr. Brian Dowd of Nu-Meat Technology, Inc. [USA] for his collaboration in the search for technical information in the United States, and to the IRTA Sensory Analysis Laboratory [Spain] for its help in the determination of meat texture.