QDS Process® technology as an exponential accelerator of R+D in cured meats

Daniel Sanz, Francesc Castells, Llorenç Freixanet, Josep Lagares

INTRODUCTION

The development of new products is nowadays practically the only possible way a food company can differentiate itself on the supermarket shelves, and this is especially true for the meat industry that competes primarily against distribution labels. These new products contribute to building a label, or branding, together with fresh marketing and positioning campaigns.

Cured meat products are no exception, although the nature of their process limits both the development of new references (due to required curing and drying time) and the characteristics thereof (the slow stabilization by drying implies restrictions on the formulation and process).

These limitations in the drying process have forced processors of cured meats to innovate primarily in the presentation and format of their products: from imaginative multi-product formats to packaging with a more natural or functional look.

Recently Quick Dry Slice process (QDS process®) technology has revolutionized the drying process for cured sliced products by means of drying the fermented product's slices instead of the unsliced bar, which speeds up the manufacturing process while maintaining all organoleptic characteristics and food safety of the traditional curing process. This method not only accelerates the production process itself – going from weeks to days – but also facilitates the development of new products due to a reduction in the time required for evaluating results of each test.

In addition to the obvious advantages of the QDS process® for the development of new products due to the reduction in drying times, the study of its application has revealed an unusual synergy with the prior step of fermentation in the development of new cured product concepts, by introducing an intermediate freezing phase that becomes an exponential catalyzing element in both steps.

Hurdle technology

In fermented and dried cured meat products produced by the traditional industry, food safety is ensured through the use of multiple hurdles (Leistner, 2000), which in the particular case of fermented and dried products are applied sequentially due to the lengthy duration of the processes and the following of a specific order of steps (curing-fermentation-drying). The main safety hurdles applied to these products are:

- Addition of curing salts to the mixture of lean and fat (salt, nitrite and/or nitrate for conversion into nitrite by means of Micrococcus with nitrate-reductase capability).
- Reduction of potential RedOx through the application of vacuum during stuffing and the use of antioxidants such as ascorbate.
- Acidification through the fermentation of sugars by starter cultures that generate acids, principally lactic acid.
- Reduction of water activity through progressive drying (sometimes with initial acidification overlap), done gradually to avoid the typical defect of case hardening due to excessive dehydration of the surface (Arnau, 2011).

These are the main hurdles used in the production of cured meat products, the final pH and Aw being what defines the food safety of the finished product, although in some markets and with some types of cured products thermal treatments are increasingly applied to the product following fermentation and prior to drying to meet the standards for reducing pathogens in the finished product outlined by the FSIS of the US Department of Agriculture (FSIS, 1999).

But the limitation lies in the sequential application, as stabilization of the initial meat mass is required through the use of salts or their substitutes, as well as the use of nitrite as a preservative (or nitrate for its subsequent conversion into nitrite by Micrococcus during fermentation). With this initial step taken, the product can enter into the fermentation step, in which current industrial production conditions require that the product be stabilized by means of sharp drops in pH in order to accelerate subsequent drying.

It is thus evident that entering into the industrial drying process requires a certain lowering of the Aw as well as preliminary acidification in order to make sure there are not excessive deviations during this step in which multiple defects can easily occur due to a multitude of converging factors (Arnau, 2011).

This lack of continuity between the different steps of the traditional process means they are bound together and that both the formulation as well as the fermentation and drying processes are so interdependent that they influence one another in such a way that leaves no real possibility for changing them to generate new concepts without having an effect on subsequent steps.

In the case of a product processed by QDS process® technology, this paradigm changes completely since between the previous step of fermentation and the subsequent drying step, a freezing step is applied. The introduction of freezing breaks the interdependence of the other two steps and provides an overall solution for process continuity that allows you to explore and maximize the technological possibilities of the prior and subsequent steps without the typical restrictions imposed by the hurdle theory. In this way, the processes are freed to realize the full potential of their applications, since the intermediate freezing step eliminates any risk of undesirable product evolution that could pose a limit to the possibilities of each particular step and the overall process as a whole.

▲ **Image 1.** QDS process® drying technology.

Different steps of the process and their interrelation

This section discusses more fully the implications and applications of each step of the process and their common synergy thanks to the intermediate freezing step that is performed between fermentation and drying with QDS process® technology.

Fermentation

It is during the fermentation step that development of most of the organoleptic parameters of uncooked cured products, such as color, texture, flavor, acidity and most of the aroma, take place. This process is currently carried out with the addition of lyophilized starter cultures specially selected and dosed for specific uses, of which there exists today a wide variety from which to choose depending on the use and product to be developed.

In recent years products made with traditional technology have tended to be increasingly more acidified during fermentation in order to more easily control drying, and to reduce drying time since a lower pH, below the isoelectric point of meat protein, facilitates product dehydration due to a reduction in water holding capacity of the meat mass.

And though these points have an obvious positive effect on control and optimization of the subsequent fermentation and drying process of the industrially-produced product, they have a negative impact on the sensory characteristics of the finished product.

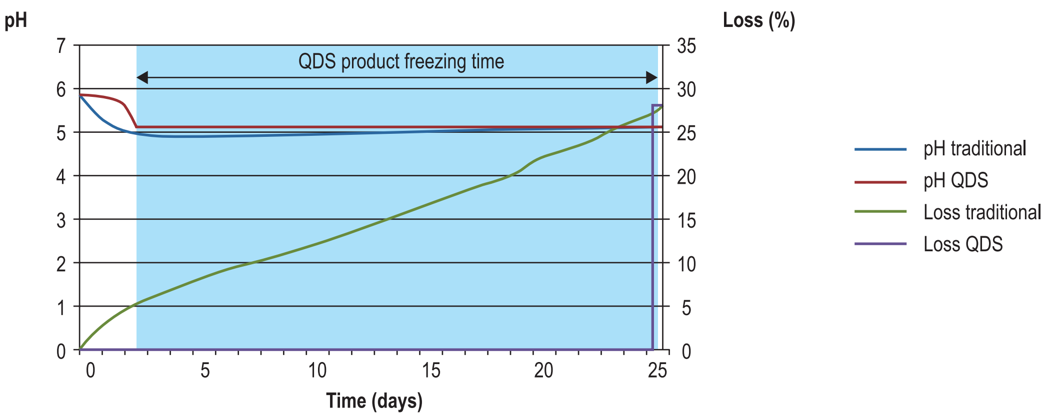
This method of applying biotechnology by means of starter cultures in fermentation and drying systems currently used in industrial processes greatly restricts the functional possibilities and results that could otherwise be attained.

In contrast, when QDS process® technology is applied, the product can be stuffed and fermented in plastic and this is a key factor for absolute control in the fermentation step, since the stuffed product has a stable composition throughout the entire fermentation process (no moisture loss) and is not exposed to any external environmental factor except temperature. This situation allows you to control and systematically reproduce the behavior of the starter culture to perfection and, by adjusting the types and level of sugars, as well as the temperature, activate more or less the desired microorganism at the desired moment, so that the product is obtained with a fermentation of a few days and drying of a few minutes with QDS process® technology, and new products can even be developed thanks to the possibility of developing the full potential of the microorganisms added to the mass with the starter culture.

In order to obtain development of texture and all organoleptic characteristics during fermentation in only a few days, prior to drying with QDS process® technology, fermentation conditions are manipulated to provide the optimal environment for the culture, which in turn implies that the evolution of the pH be regulated in such a way that no sudden drop occurs to inhibit its activity. This evolution can be observed in Graphic 1, and you can also see how the final pH of fermentation will be that contained by the product dried with QDS process® technology, making it possible to standardize a final pH without the need for excessive acidification during fermentation.

Freezing

Once the fermentation step is completed and before drying with QDS process® technology, an intermediate freezing step is required to provide the product with the sufficient firmness so that it can be sliced more easily, since its high water content gives it a lax consistency that makes slicing at refrigeration temperatures difficult. And it is this intermediate freezing step that provides the QDS process® system with its important innovative capability of developing new products, since it frees the previous curing and fermentation step from the subsequent step of drying, while linking them together synergistically to enable the exponential development of new concepts. What at first glance may seem to be an anecdotal fact, upon closer examination proves to have a number of extremely useful technological implications:



▲ **Graphic 1.** Evolution of the pH and loss in a Spanish-type salami made with traditional and QDS drying.

- The ability to stuff in plastic allows for the use of any size or format without altering the result of fermentation or subsequent drying and even allows for using all types of molds to experiment with the presentation of the finished product.
- The final pH level has a much wider range (belowr 5.3) because freezing the product puts an immediate stop to any microbiological evolution of the fermented product.
- Production planning is simplified by a virtually continuous process, since once the bars are made they can be processed for drying immediately and at any time with QDS process® technology, with the resulting benefits for launching promotional campaigns.
- With QDS process® technology, the separation between fermentation and drying is not only in time but also in space, which allows you to generate new business models based on the possibility of separating or concentrating the different operations depending on the product or market (Flores, 2013).

Graphic 1 shows an example of how the freezing step becomes a point of suspension in which the product does not evolve as regards its main physio-chemical parameters and composition, although analytically a drop in Aw is produced due to the change from a liquid to solid state that occurs mainly in the fraction of free and available water. This is why freezing is a common method of preservation, since the water in frozen foods is in the form of solid ice crystals, which precludes their availability for microorganisms.

This temporary suspension of the process caused by freezing will not affect the texture of the finished product provided that freezing is done quickly and immediately at the end of fermentation, so that the ice crystals formed are smaller in size and cause the least possible damage to the product's structure (Hui, 2004), both in the binding interfaces through the muscle protein soluble in saline solution extracted during the steps prior to stuffing (mainly actin-myosin complex) and coagulated by acidification during fermentation, as in the muscle fibers present in coarsely ground or whole-muscle type products.

On the other hand, while it is well documented in scientific literature that freezing prevents the growth of microorganisms and maintains many physiochemical characteristics intact, there are certain enzymatic and chemical processes that, although slowed down, continue to take place and gradually reduce the sensory and organoleptic properties of the product, one of the most significant being lipid oxidation rancidity by means of enzymatic and non-enzymatic pathways.

To determine the impact of this freezing step on the finished product produced by the QDS process®, a study was developed using a Danish-type salami from an industrial producer to evaluate the impact of the different aspects of the process and of freezing (table 1) such as the stuffing material (high-barrier plastic material or permeable cellulose), the method of freezing after fermentation (rapid tunnel ultra freezing down to -18ºC or slow chamber freezing to -18ºC) and the storage temperature of the product before drying (-18ºC or -8ºC, ±1ºC):

Sample types studied during freezing	
A.	High-barrier plastic casing + rapid tunnel ultra freezing to -18ºC + storage at -18ºC
B.	High-barrier plastic casing + rapid tunnel ultra freezing to -18ºC + storage at -8ºC
C.	High-barrier plastic casing + slow chamber ultra freezing to -18ºC + storage at -18ºC
D.	High-barrier plastic casing + slow chamber ultra freezing to -18ºC + storage at -8ºC
E.	Permeable cellulose casing + rapid tunnel ultra freezing to -18ºC + storage at -18ºC
F.	Permeable cellulose casing + rapid tunnel ultra freezing to -18ºC + storage at -8ºC
G.	Permeable cellulose casing + slow chamber ultra freezing to -18ºC + storage at -18ºC
H.	Permeable cellulose casing + slow chamber ultra freezing to -18ºC + storage at -8ºC

▲ **Table 1.** Processing combinations of the different Danish-type salami samples studied.

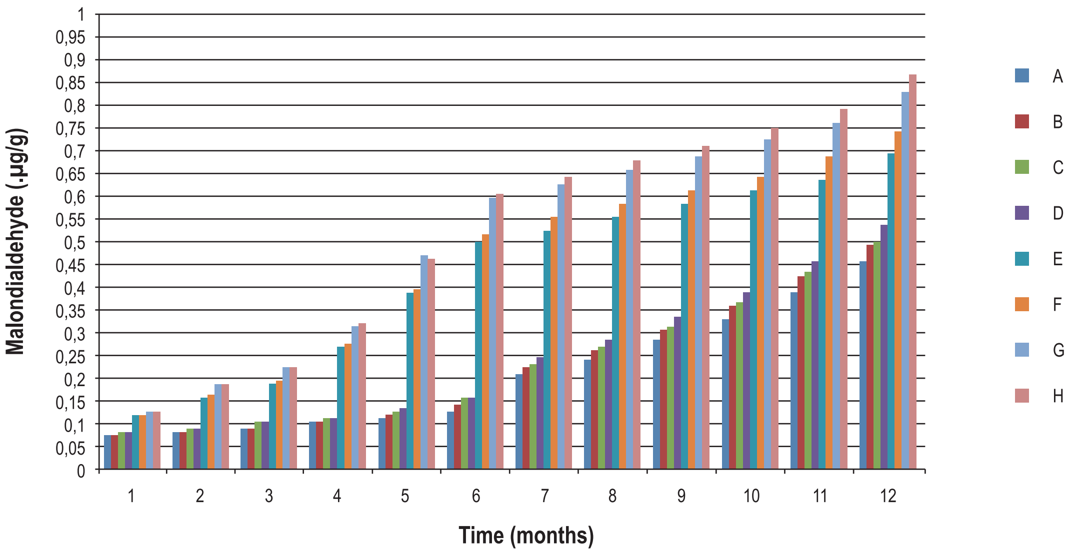
A sufficient amount of samples of each combination was saved in order to carry out, for a period of one year, monthly evaluations throughout the duration of the study (a total of 24 samples of each type). The preserved samples with the different freezing temperatures were vacuum packaged: those in plastic casing packaged simultaneously with vacuum stuffing, and those in fibrous casing peeled and repackaged in high-barrier bags before freezing.

All samples analyzed were sliced and dried to a final loss of 22±0.5%; in the case of the samples stuffed in fibrous casing, the loss was slightly less with the QDS process ®system to compensate for the initial fermentation loss (5±0'21%). The air conditions of the process were the same in all cases, varying only the overall time to adjust the level of loss to the specific composition for the product (Table 1). Vacuum-packaging took place immediately afterwards and the Thiobarbituric Acid (TBA) test was conducted to determine the level of Malondialdehyde (MDA) in accordance with the method adapted by Botsoglou et al. (1994). Since MDA is the main byproduct of oxidation of polyunsaturated fatty acids, the result is expressed in μg of malondialdehyde per gram of tissue.

In Graphic 2 you can see how the values of MDA remained more stable when the product was stuffed in plastic and frozen quickly compared with the other combinations. The difference between maintaining a higher or lower temperature (always below freezing) only had an impact on the total time it took to reach significantly higher levels of MDA. In in-house tasting sessions conducted at the same time as the analyses, no noticeable oxidation was detected in the samples for the first six months. From this point onward, some of the panelists perceived slight traces of rancidity in the samples stuffed and fermented in fibrous casing, although in no case did this imply classification of the sample as unacceptable. For this product, and arbitrarily, it was determined that a level of MDA greater

Product	Fat	Protein	Moisture	Salt
Danish Salami	**45 - 47%**	**>12%**	**<35%**	**4%**

▲ **Table 2.** Analytical specifications of the Danish Salami studied.



▲ **Graphic 2.** Evolution of the TBARS (MDA) results of the different samples.

than 0.5 μg per gram of product could give oxidation ratings to the product once dried.

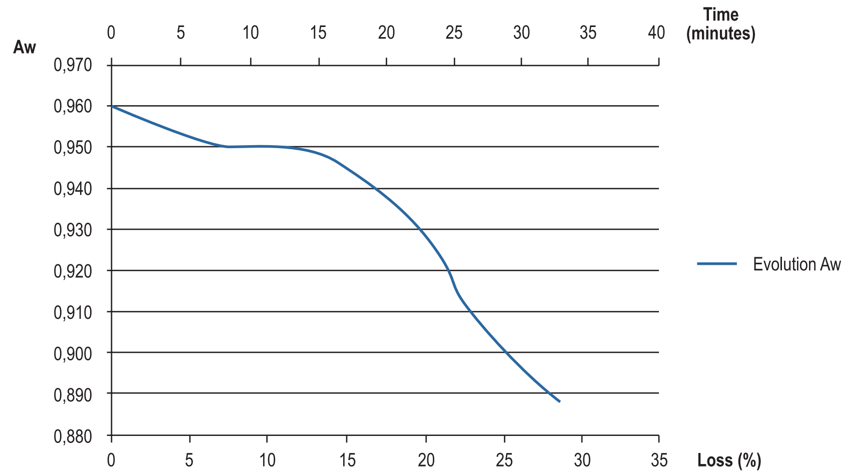
It can be assumed that exposure of the product to air (and therefore oxygen) due to stuffing in permeable fibrous casing facilitated non-enzymatic reactions of lipid oxidation, with the formation of peroxides, and hence the results observed, although this process depends on many other factors such as processing temperatures, fat quality (level of unsaturation), level of salt and pro-oxidant ingredients and others, so while it cannot be established as the sole determining cause, if did have an effect in this particular study. In fact it should be noted that the choice of this product was not random, rather it was chosen for being a very economical product with a high percentage of fatty trimmings and soft tissues, which are highly unsaturated, in addition to a high degree of mechanical processing.

Thus the freezing step provides for stopping the evolution of the product at the desired point, and in the proper conditions, keeping it frozen and unaltered for the required period of time. If we combine this with vacuum fermentation in plastic casing, we can achieve total control of drying loss (equal to zero in the step prior to QDS drying), organoleptic quality of the product (avoiding possible deviations during fermentation such as case hardening , generation of silt or undesirable fungi) and we generate a more homogeneous environment for additional starter cultures since the composition remains stable throughout fermentation.

Drying with QDS process® technology

As explained above, with QDS process® technology the product is processed in slices, allowing for exponential acceleration of the drying process, which goes from days to minutes because the slices are exposed to a convective treatment with accelerated and controlled circulation conditions to optimize total processing time, drying the previously fermented and frozen product to the desired level of loss and obtaining a stuffed product with pre-designed, constant and uniform organoleptic and physio-chemical characteristics.

This third element of the process, together with fermentation and freezing, is what finally defines the product's characteristics and ensures its stability; for this, you can set the level of drying loss necessary without any detriment to the safety or quality of the final result, since the time it takes to reach an Aw low enough to prevent the growth of the main pathogens associated with meat products is less than the lag phase of any such products (Rolfe, 2012), as can be seen in Graphic 3 for an example of Pepperoni stuffed in plastic and with a final loss of 28%. after 33 minutes of drying time with QDS technology.



▲ **Graphic 3.** Evolution of the Aw of Pepperoni during drying with QDS process® technology.

Thus, drying with QDS process® technology is what closes the circle and generates the exponential capacity for innovation, because it is not just a faster way to achieve the desired drying loss of the finished product but also a way to obtain the maximum technological potential from the previous steps of fermentation and freezing, since the product can be stabilized in a few minutes to ensure its safety, regardless of the formulation or ingredients used, or even the level of the initial pH or Aw parameters.

Application lines: case studies of development

So far in this article we have discussed the technological and scientific basis of the application of QDS process® technology as a catalyst for innovation in cured fermented products, as well as its interrelation with the other steps of the process to achieve a common synergy between the different steps of fermentation and freezing.

We will now take a look at a series of practical applications developed for the industry that graphically illustrate the possibilities in developing new products for the meat sector. These are real cases of development in which the parameters of composition and cost were defined, as well as the organoleptic characteristics and format, which were subsequently evaluated by consumer testing or tasting panels defined by the parameters of each processor or market.

Italian-type Salami

In this case the goal was to develop an Italian-type product of highly proteolyzed texture, well-defined grain and low acidity, with a clean but intense flavor and natural aroma, and composed only of pork lean and fat.

No colorants were used and the only nitrifying agent added was potassium nitrate, so that to obtain the color commercial starter cultures were combined, specially selected for color development together with lactic acid cultures of low acidification. The product was then stuffed in plastic casing and fermented for 72 hours until reaching a pH of 5.22. It was then immediately frozen and, once a texture firm enough for slicing was reached, cut and dried with QDS process® technology until obtaining an Aw of under 0.91.

The absolute control of fermentation conditions and of the microorganisms used allowed for acidification of the product without abnormal fermentations to the desired pH, and the drying process carried out was so fast that there was not material time for any subsequent negative evolution of the product since, although the pH is basically reduced by the generation of lactic acid by means of the lactic acid bacteria added to the industrial starter cultures during fermentation, secondary acidifications may be generated, producing other organic acids, such as acetic or butyric, that result in bitterness in the finished product. This defect is quite common in the industrial production of cured products and while a touch of bitterness may be desirable, such as in some Spanish-type chorizos, generally speaking this bitterness is rejected by the consumer (Stolz, 2011) and reduces the overall score of such products in tasting panels.

The finished product had a preference higher than the standard, especially among younger sectors (young adults), the most appreciated characteristic being the absence of bitter traces, as well as a soft texture and mild flavor.

Poultry products

This time the aim was to develop a complete line of uncooked cured products from different cuts of poultry, in order to obtain products of only chicken and only turkey that covered the range of products existing on the market.

The two main quality factors to consider were that the products developed not present the two most common problems of this type of stuffed product, namely the tendency to bitterness due to the high Aw and bacterial load of these meats, as well as a total absence of rancidity despite the use of only fatty tissue of chicken or turkey.

To develop the different types of poultry products, we started with stuffing fermentation in plastic casing to prevent possible oxidation through contact with air, and the temperatures used were low enough to prevent fusions of fat that lead to subsequent oxidations. It should be noted that poultry fat is highly unsaturated, which confers on it a strong predisposition to oxidation, especially turkey fat (table 2), which has a higher percentage of polyunsaturated fatty acids compared to chicken fat (USDA, 2012). The proper selection of starter cultures was ensured

▼ **Table 2.** Relative composition of the main types of animal fat used in food.

Type of fat	Beef tallow	Pork bacon	Chicken fat	Turkey fat
Saturated fatty acids	**49,80%**	**32,21%**	**29,80%**	**29,4%**
Monounsaturated fatty acids	**41,80%**	**41,95%**	**44,70%**	**23,10%**
Polyunsaturated fatty acids	**4,00%**	**10,35%**	**20,90%**	**42,90%**

▼ **Image 2.** Italian-type salami produced with QDS process® technology.

▼ **Image 3.** Turkey sausage developed with QDS process® technology.

to guarantee their implantation and subsequent acidification action in the stuffed meat mass, thereby avoiding deviations that could lead to abnormal fermentations with bitterness in the finished product.

Finally the product was dried by means of QDS process® technology with full control of the processing temperature to prevent a fusion of fat that could free unsaturated fatty acids that could result in oxidation processes during the product's shelf life.

The complete line for chicken and turkey was successfully developed, including salamis y pepperonis and similar products with a natural appearance, the turkey products being especially valued by the consumer because this meat is of greater consistency and more flavorful, especially in the more lean products, although the chicken product with a higher fat content was considered to be more succulent since, despite being highly unsaturated, this fat has more consistency and a greater fatty sensation in the mouth than other poultry fats.

"Clean label" products

Another development project consisted in the formulation and elaboration of clean label products, without allergens or E numbers in their composition, but without sacrificing a natural flavor and texture. While you can find such products on the market, most of them use naturally derived antioxidants and preservatives, even though added through vegetable extracts that contain the natural precursors of the functional ingredient, such as the use of natural extracts rich in nitrate for subsequent conversion to nitrite by the micrococci present in the starter cultures.

A Spanish-type salami, composed of pork lean meats and bacon, was developed in which the main ingredients used were salt, sugar beet extract, sugar, spices and flavoring. The sugar beet extract used did not contain nitrates or residual nitrites and its use was justified by the absence of nitrification of the myoglobin that, despite not being associated with a rancid or unusual flavor to the taste, generated a brown color that was unattractive

▼ **Image 4.** Chicken salami developed with QDS process® technology.

to the consumer. Similarly, neither natural antioxidants nor artificial ones added specifically for that function were used beyond those that may be found naturally in the aromatic spices used in preparation of the product.

Once the required pH of 5.0 was reached, the product was considered to be sufficiently stable to proceed, after freezing, to drying with QDS process® technology, obtaining a shelf life of over 120 days and ensuring the required food safety by means of drying with QDS process® technology until reaching an Aw of below 0.9. This combination of pH and Aw was enough to complete the shelf life studies within the required time and without any detection of oxidation by any of the tasting panels.

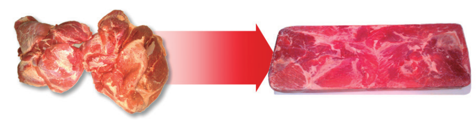
The product exceeded the required scoring thresholds established by the tasting panels during development and product shelf life, the qualities most highly valued being the winey look of the lean meat and the clean natural flavor. A slight acidity was detected, evaluated positively by the panelists as typical of cured sausage.

▼ **Image 5.** "Clean label" Spanish-type salami developed with QDS process® technology.

Dry cured ham in mold

Due to the high level of interest among major meat processors worldwide in obtaining whole-muscle products with characteristics similar to those of a traditional product obtained from a whole piece of ham or shoulder, but prepared in a mold and with total production times of a few days, an accelerated curing and fermentation process was developed to facilitate the production of restructured product bars with the sufficient cohesion and strength to be sliced industrially and with a sufficient level of final proteolysis to confer on the finished product a natural texture, without the usual rubbery feel of products with accelerated drying in molds from 3 to 6 months, depending on the size of the piece.

▼ **Image 6.** Pieces of shoulder after salting (left) and shaped and fermented log (right).



To achieve the stated objective, a patented process was applied consisting in different steps where the crucial step was the application of a fermentation step to the product in extreme temperature conditions so that the starter culture used would generate an intense proteolysis action in a matter of only a few days, once the product had undergone the salting step. It was possible to control this fermentation thanks to the immediately following freezing step, which provides the possibility of abruptly stopping any evolution of the product once the desired characteristics have been obtained. The appropriate type of cut and meat preparation for subsequent salting was also developed, as well as the application of the starter culture and final binding of the bar to be sliced. The preliminary process prior to freezing varied from between 10 and 15 days depending on the size of the pieces used and the degree of trimming of the fat and collagenous membranes.

The ability to obtain a greater or lesser drying with QDS process® technology allowed for the development of products with or without acidification during fermentation, since the versions without acidification had a final pH of about 5.7 and were dried to a greater degree to obtain an Aw of below 0.9 and thereby stabilize the product throughout its entire shelf life. To the versions without acidification and with a pH of below 5.3, the level of cooking loss applied was sufficient to obtain an Aw below 0.92 in the finished product and to ensure the inhibition of Listeria monocytogenes growth throughout its shelf life. This adjustment of drying loss was done by using the same conditions during drying with the QDS process® system, varying only the total processing time to adjust the level of loss to the desired Aw value.

The end result was evaluated in consumer studies where the different products developed with QDS process® technology were compared with references existing on the market of cured mold-dried shoulder and ham sold sliced and packaged, and the result was similar for both process types, although a significant number of consumers made comments indicating that the texture of the product developed with QDS process® technology seemed more tender and softer.

CONCLUSIONS

In a constantly evolving market where a customer such as mass distribution becomes a competitor through distribution labels, only through the constant generation of new references, products and formats that are a novelty and at the same time provide the consumer and the processor with added value can a player in the meat industry maintain and expand a commercial label and thereby maximize profits.

Moreover, it is not only this generation of new concepts that is required, but also constant monitoring of the market and benchmarking to be alert to any trend in existing references, and the process of development and production must be flexible enough to respond both to promotions as well as to the adjustments demanded by customers and consumers.

Having examined the application of hurdle technology in the processing of traditional uncooked cured products and the limits imposed by such technology in the development of new products, and considering the technological synergy provided by fermentation and drying with QDS process® technology, thanks to the disruption of the process by an intermediate freezing step, it can be concluded that QDS process® technology not only is capable of reproducing the existing sliced industrial product, but can also generate exponential development of innovation, with new concepts, formats and lines, when its full potential is exploited in combination with a perfectly-designed fermentation step, thanks to the synergistic effect of an intermediate freezing step that enables you to overcome the typical limitations of hurdle technology applied to the development of cured products

Not only does this freezing step generate a synergistic effect between the processes of fermentation and drying with QDS process® technology, but also, thanks

▼ **Image 7.** Mold-cured ham developed with QDS process® technology.

to the organoleptic stability of the frozen product under proper conditions, it breaks the interdependence of the steps prior to QDS process® drying, which facilitates coordination between production planning and market demands, essential to carrying out a specific plan of promotion to generate a greater market impact.

BIBLIOGRAPHY

• FLORES, A., 2013. QDS Process: de la Tecnología a los Modelos de Negocio. Metalquimia.

• LEISTNER, L., (1995). Principles and applications of hurdle technology. In Gould GW (Ed.) New Methods of Food Preservation.

• FSIS, 1999. FSIS Appendix A: Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat and Poultry Products. Disponible en: http://www.fsis.usda.gov/wps/wcm/connect/212e40b3-b59d-43aa-882e-e5431ea7035f/95033F-a.pdf?MOD=AJPERES

• LEISTNER, I., (2000). Basic aspects of food preservation by hurdle technology. International Journal of Food Microbiology.

• ARNAU, J., (2011). Problemas de los embutidos crudos curados. Eurocarne, 2011.

• HUI, Y. H., GUERRERO LEGARRETTA, I., MIANG HOONG, L., MURRELL, K.D., WAI-KIT, N., (2004). Handbook of Frozen Foods.

• RÖDEL, W., (2001). Water activity and its measurement in foods. Instrumentation and sensors for the food industry. Chapter 16.

• COMAPOSADA, J., 2013. Shelf Life Stability of fermented sausages produced with the QDS process® technology: US Pepperoni and German Salami case studies. Metalquimia, S.A.U.

• BOTSOGLOU, N.A., FLETOURIS, D.L., PAPAGEORGIUS, G.E., VASILOPOULOS, V.N., MANTIS, A.J., TRAKATELLIS A., (1994). Rapid, sensitive and specific thiobarbituric acid method for measuring lipid peroxidation in animal tissue, food, and feedstuff samples, J. Agric. Food Chem; vol. 42, pp. 1931-1937.

• ROLFE, M.D., RICE, C.J., LUCCHINI, S., PIN, C., THOMPSON, A., CAMERON, A.D.S., ALSTON, M., STRINGER, M.F., BETTS, R.P., BARANYI, J., PECK, M.W., HINTON, C.D. (2012). Lag Phase Is a Distinct Growth Phase That Prepares Bacteria for Exponential Growth and Involves Transient Metal Accumulation. Journal of Bacteriology; 194(3): 686–701.

• PRATS, C., LÓPEZ, D., GIRÓ, A., FERRER, J., VALLS, J., (2006). Individual-based Modelling of bacterial cultures to study the microscopic causes of the lag phase. *J. Theor. Biol*. Volume 241, Issue 4, 939–953.

• U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE. 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

• STOLZ, H., ESPIG, F., KRETZSCHMAR, U. (2011): Fact sheets on all the tested products in the appropriate language. Deliverable No. 6.3 of ECROPOLIS Project. Research Institute of Organic Agriculture (FiBL), Frick, Switzerland.

ACKNOWLEDGMENTS

We would like to thank all those who participated in the development of QDS process® technology for their contribution to the project and, most especially, all the meat processors who have incorporated QDS in their industrial process.