

Additives and ingredients in the manufacture of whole muscle cooked meat products

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INTRODUCTION

This article gives a description of the additives and ingredients that can be used in manufacturing whole muscle cooked meat products. The ingredients and additives described are perfectly applicable to ham and shoulder, as well as to cold cuts and other cooked meat products included within the same manufacturing philosophy. Throughout the article, this entire range of products will be referred to with the generic name of cooked ham.

We make a distinction between ingredients and additives as the constituents of cooked ham. When we talk about ingredients, we mean those constituents which are present in nature and are consumed as a matter of course in a normal diet, while additives are to be understood as any substance not normally consumed which is added intentionally for technological or organoleptic purposes.

Although there are many existing texts on food additives and ingredients in general, few have dedicated special attention to describing which of these products are useful and how they should be used in the manufacture of cooked ham.

This article describes, in summarized fashion, the principal additives and ingredients commonly used in this field and their functional properties, and ends by giving some indications regarding preparation and injection of brines.

INGREDIENTS

Meat

The meat used in the manufacture of whole muscle cooked meat products may be ham or shoulder, bone-in or boneless, skin-on or skinless, and with varying degrees of fat, nerves and tendons trimmed, which will depend on the product to be produced and on the consumer tastes of each particular country. The description of meat's biochemical properties and characteristics is not part of this article's objective,

and therefore no further details are outlined here. Meat preparation varies widely depending on production goals, ranging from bone-in, skin-on ham with no trimming whatsoever, to products completely cut into separate muscles or smaller pieces, completely trimmed of all fat, tendons and nerves.

Water

In most cooked ham products, the second most important ingredient is the water added. Technologically, the water in brine preparations must comply with a number of requirements:

First, it must be hygienic, sanitary water of high chemical quality, given its use in a food product destined for human consumption.

From a technological point of view, the water must be as soft as possible (free of Ca^{2+} and Mg^{2+} ions and heavy metals). Knowing the *degree of hardness of the water* to be used is very important, since a high concentration of ions can negatively affect the water holding capacity of the finished product. Also, the presence of iron, copper and other metals in saline solutions, in addition to the toxicological risks, can partially destroy the ascorbate, present in brine as an antioxidant, and affect color stability in the finished product.

Salt

Table salt or sodium chloride has been used since ancient times in the preparation of meat, thanks to its capacity to reduce water activity, facilitating product preservation as well as contributing to its flavor.

Salt is now used in cooked ham in concentrations that fluctuate around 2%, and its use is restricted only in those dietetic products labeled as having a low sodium content. In the case of cooked dietetic ham, salt is partially replaced by other ingredients, in particular potassium chloride, a product with a

similar water activity depressor capacity but which gives the ham a bitter metallic taste that must be counteracted with flavoring agents.

In addition to the above-mentioned functions, technologically salt plays an important role in solubilizing meat proteins and expanding their quaternary structures, since it provides the principal aid to the product's ionic strength, weakening the electrostatic unions existing among the groups carboxyl and ammonium and therefore contributing to water holding capacity and muscular binding in the finished cooked meat product.

Sugars

Sugars are used in cooked ham basically as water activity depressors, although they also play an important role in product taste. Sugars are usually used in mixtures with compositions that vary according to what effects are desired in the finished cooked product. The properties and effects of the sugars commonly used in manufacturing cooked ham are summarized below.

• **Saccharose:** The principal mission of sucrose, or sugar, in sugar mixtures for cooked ham is to contribute to the finished product's flavor, since its use as a water activity depressor is limited by its sweetening power. In cooked ham its concentration must not exceed 0.8-0.9%, higher concentrations result in an abnormally sweet taste that cannot be counteracted by the addition of salt. A lesser proportion (about 0.5%) compensates for relatively high salt concentrations, which alone would make the ham too salty, and gives the product a pleasant background flavor.

• **Dextrose:** Because dextrose, or glucose, has much less sweetening capacity than sugar and a greater osmotic pressure in solution, it is commonly used as a water activity depressor in brine. With well-balanced brines, it can reach concentrations of more than 3% in the finished product without negatively affecting the product's taste. The main disadvantage of using dextrose occurs in countries with a hot climate in which proper refrigerating facilities cannot be guaranteed throughout the duration of product storage. Dextrose is a

▼ Automatic Brine Preparation System: BRINMIX.



monosaccharide which is digested directly by many microorganisms, including lactobacilli, thereby accelerating their growth rate, especially if refrigeration is inadequate, shortening the product's shelf life and presenting problems of excessive acidity caused by lactic acid.

- **Lactose:** Its use and characteristics are very similar to those of dextrose, although it has a somewhat different taste which is reminiscent of its original source, milk. One of its forms, α -lactose, is also digested directly by lactobacilli, so that there is also some risk in using lactose in countries with a hot climate.

- **Fructose:** The use of fructose is limited because its sweetening effect is much more powerful than sugar's.

- **Glucose syrups:** Glucose syrups are sugar mixtures obtained by hydrolysis of starches. The principal ingredient in these mixtures is dextrose, in proportions that range from 30% to 60%, and the remainder is composed of monosaccharides and oligosaccharides with varying chain sizes. Their use and characteristics are similar to those of dextrose and glucose, although their use involves less bacteriological risk in countries with insufficient cooling facilities. Another basic advantage of glucose syrups, as compared to dextrose and glucose, is that they are usually significantly more economical. They are sold in a caramel-colored liquid syrup form, with about 50% solid content, or they are also sold desiccated in powdered form.

- **Dextrins:** Dextrins are also produced by starch hydrolysis, usually thermal hydrolysis, and differ from glucose syrups in that they are higher in the content of oligosaccharides with a higher molecular weight. The dextrose content of these products is usually between 2% and 20%. Their use in manufacturing cooked ham has the disadvantage of sometimes causing colorings with iodine/potassium iodide solution, similar to those of starches, so that their use in non-starch products is limited to such small amounts that they serve little purpose. They are not very useful in starch products

either, since they lose their gelling capacity during the hydrolysis process.

Proteins

Proteins and hydrolyzed proteins are used in cooked ham for two main reasons: to increase the finished product's protein content, and for their water holding capacity. Their use can be limited by legislation as well, due to organoleptic reasons (because of the flavor they confer to the cooked product). As functional proteins, the most commonly used in the manufacture of cooked ham are:

Milk Proteins:

- **Milk wheys:** These correspond to the soluble fraction of milk proteins and present concentrations of 10% to 40%, otherwise made up mainly of lactose. They have the disadvantage of a low protein content and little (compared to other proteins) water holding capacity. They have the advantage of causing little alteration to the finished product's flavor.

- **Lactoalbumins:** These are milk wheys purified by ultrafiltration, in which protein concentrations can reach up to 80%. Also with little effect on the product's flavor, a better water holding capacity is attained with their use than with normal milk wheys. They have the disadvantage of a high capacity for emulsifying air and forming stable foams, and they are expensive.

- **Caseinates:** With a moderate water holding capacity, they contribute well to protein content, due to protein concentrations of over 90%. They give a pleasant taste to cooked ham, but have the disadvantage of interfering with solubilization of muscular proteins, when used in high concentrations, which can give rise to poor binding. They are also expensive.

Blood proteins:

- **Blood plasma:** Due to its coagulative properties, blood plasma has an improved water holding capacity

and an acceptable level of protein content (about 70% in powdered form). When liquid or frozen blood plasma is used, there are serious microbiological risks that require very careful handling of the product. These risks disappear when sterilized powdered plasma is used, but the desiccation process results in an unpleasant flavor, noticeable in cooked ham with high concentrations of powdered blood plasma.

Collagen protein:

- **Partially hydrolyzed collagen:** This is obtained by the partial hydrolysis of collagen. In contrast with natural collagen, these proteins are soluble in water or brine and have a high protein content (84-90%). Their use in cooked meat products is due to their water holding capacity, their gelling properties and their high protein content.

- **Dried skin powder:** Made from dehydrated ground pork skin, it has a good water holding capacity and a high protein content (over 80%) because it is basically collagen that still retains its functional properties. The main disadvantage is that the proteins are basically insoluble and therefore, not easily incorporated into injection brines without obstructing filters and needles of injection equipment.

Egg proteins:

Egg albumins can be used in cooked meat products: They have a good water holding capacity, gelling power and high protein content (over 85%). They also confer good flavor to the finished product, but are expensive.

Vegetable proteins:

The most commonly used vegetable proteins are soy proteins, either as isolates or in concentrates. Isolate proteins offer a number of advantages over concentrates: Higher protein content (90% as compared to 60-70%), better solubility (concentrates usually have a significant amount of

insoluble substances, which can cause blockage of equipment during the injection process), and better flavor. Soy proteins have an improved water holding capacity and are fairly inexpensive, making them widely used in those products in which their addition is permitted by law. They have the disadvantage of sometimes giving the ham a disagreeable flavor when used in high concentrations. Due to the controversy that has arisen in regard to GMO (Genetically Modified Organisms), the use of soy proteins has been affected, and in some products their use is avoided altogether.

In general, all the above-mentioned proteins have both positive and negative effects, so that they are best used in cooked ham in mixtures that combine the desirable properties in such a way that their negative effects are reduced to a minimum.

Protein hydrolysates:

Because hydrolyzed proteins have no water holding capacity, except for their effect as water activity depressors, their function is limited to protein addition and flavoring. The most commonly used for their contribution to protein content are hydrolyzed collagens and proteins from mechanically-recovered meat. Collagen contributes more than 100% in proteins, since in the analysis of collagen the nitrogen must be multiplied by 5.5 in order to obtain the total protein, while in the meat products the nitrogen content is multiplied by 6.25, and the hydrolyzed collagens usually have more than 90% in proteins.

Hydrolyzed vegetable proteins are also used in small doses for their contribution to flavor, and so are considered within the group of flavorings.

Starches

In high-yield products, and in countries where their use is permitted by law, starches are used for their water holding capacity. Normally used

in cooked ham without chemical modifications, these starch products are polysaccharides that gel when exposed to heat, forming a three-dimensional network that holds great amounts of water.

Most starches gel at temperatures of between 65° and 75° C., the gelling temperature depending on the size of particles.

The most commonly used starches are those derived from wheat, potato, corn and manioc. Wheat starch, with a gelling temperature of 65°C, has the advantages of giving good flavor and providing good product texture. Potato starch, with a gelling point of around 70°C, has a very high water holding capacity, but results in a rather unpleasant product flavor and not very satisfactory texture. Corn starch and starches derived from yucca or manioc, widely used in Latin America, all have properties somewhere in between those of the two above-mentioned starches.

It must be kept in mind that, in general, starches do not withstand excessively high temperatures or prolonged cooking, and they have the problem of retrogradation. To solve these inconveniences, modified starches have been developed, in

which their natural chemical structure has been modified in order to reinforce the bonding between different chains and thereby obtain more thermally stable, less fragile products and to minimize the phenomena of retrogradation.

Fibers

Vegetable fibers are understood as various types of polysaccharides, other than starches, that constitute the cellular walls of cereals and vegetables, and which cannot be assimilated by the human digestive system. Depending on the raw material and on the extraction process, they include cellulose, hemicellulose, pectins, lignin, etc., in quantities that can range from 55 to 85%. Thanks to their chemical structure, vegetable fibers provide a number of advantages from a technological point of view, such as a good water holding capacity and improved product texture. They are currently in use in meat products as a substitute for fatty material, to reduce their caloric value.



Flavorings

The last ingredients used in manufacturing cooked ham are flavorings. The types of flavoring used vary widely and include liqueurs and wines, fruit juices, hydrolyzed vegetable proteins, Mallard reaction products, oleoresins derived from natural spices, fruits, vegetable and spice infusions, smoke extracts, etc.

ADDITIVES

Colorings

Cochineal Carmine is universally the coloring most commonly used in the manufacture of cooked ham, since it gives the ham a natural-looking pink tone. It is a natural red coloring extracted from the desiccated bodies of female insects of the *Coccus Cacti* Species, grown on the cactus, *Nopalea coccinellifera*, which is found in Peru, Guatemala, Mexico and the Canary Islands. It takes 140,000 insects to obtain 200 g of Cochineal carmine with a 50% concentration. The main coloring agent present in carmine is carminic acid (C₂₂H₂₀O₁₃).

Its most advantageous characteristic is its capacity to remain stable when exposed to light, pH variations, and thermal processes.

It is usually extracted from carminic acid in the form of aluminum-calcium lake, with a minimum carminic acid content of 50%. Since this form is not water-soluble, in order to be used in brines it must first undergo dissolution in diluted alkalis, such as ammonia or carbonate.

It is easier to use in the water-soluble forms that are made from this lake and usually have a carminic acid content of between 21% and 50%.

The main coloring agent in the water-soluble extract from bixa, or annatto, is norbixin sodium salt, a coloring that belongs to the carotenoid group. In

spite of its orange color, it is redder than most other carotenes, and for this reason is sometimes used in meat products. One disadvantage, when used in cooked ham, is that the pH usually present in this product become yellowish and unstable when exposed to light. It also has the problem of causing coloration of the fatty tissues.

Beet Red, made up principally of Betanin, has the disadvantage of poor stability when exposed to light and heat.

Stabilized hemoglobin, sterilized and dehydrated, is also sometimes used in cooked ham. Its main disadvantage is that when used in sufficient amounts to have a visible effect on the finished product's color, it has poor stability when exposed to light and oxygen, causing the slice to become brownish within minutes.

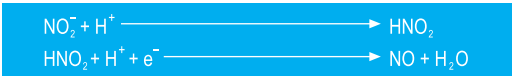
Caramel is used in cooked ham as a coloring only in the product's outer gelatin covering or as a simulated smoke substitute.

Like the rest of artificial coloring agents (Red 2G, Red 40, Ponceau 4R, etc.), its use is becoming more restricted all the time, given the worldwide tendency to prohibit the use of artificial colorings in cooked ham.

Nitrites

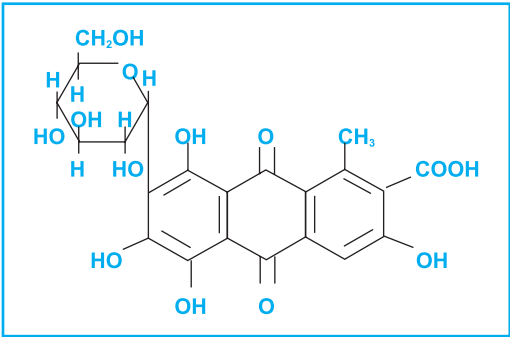
Although its action is basically as a preservative, nitrite has a variety of effects on cooked ham.

Nitrite as such does not act on the meat. It is the nitrous oxide molecule that is the principal agent responsible for the effects produced. This molecule is formed from nitrite in the following chemical reactions:



Free nitrous oxide formed in this way is highly reactive and partially reacts with myoglobin to form nitrosomyoglobin, the pigment responsible for cooked ham's characteristic pinkish color. The rest of the nitrous oxide, not fixed by the myoglobin, undergoes a number of different processes: A part is lost through direct evaporation, while another part continues the reduction process until nitrogen is formed and evaporates as well. Another part reacts with the muscular proteins and fats. The remainder reacts with the antioxidizing additives, especially with ascorbate and erythorbate.

The proportion of nitrous oxide that decomposes without directly intervening in color formation depends on the characteristics of the brine used and the processing conditions, among other factors. Because of this decomposition, additional nitrite, from 125 to 250 ppm depending on the type of ham being processed, must be supplied to the product in order to guarantee good color stability. Usually the higher the product yield, the greater the level of nitrites required. In any case, the brine must be balanced in such a way that the nitrite concentration does not exceed the limits demanded by existing legislation.



Color formation begins when nitrous oxide reacts with the myoglobin to form nitrosomyoglobin, which subsequently decomposes into globin and nitrosomyochromogen, the real coloring agent responsible for the pinkish color typical of these products. This group is produced by fixation of nitrous oxide to the myoglobin's central tetrapyrrolic ring, which is released by the protein. Nitrosomyochromogen is also generated from the remains of hemoglobin present in the meat, contributing as well to the finished product color. This pigment as such is unstable when exposed to light and oxygen. Its stability is increased by high-temperature cooking (a minimum of 65° C is required to acquire minimal stability), by a finished

product pH that is not excessively high, and by the presence of antioxidants in brine.

Although the chemical process involved in making nitrite an effective preservative is not fully understood, nitrite has a proven bacteriostatic effect on Enterobacteria, *Clostridium Perfringens* and *Staphylococcus Aureus*, and is particularly lethal for *Clostridium Botulinum*. Since the latter microorganism is very resistant to thermal processing, the addition of nitrite is practically the only way to prevent transmission of botulism through meat products.

Nitrates

Potassium nitrate was the first nitrifying agent to be used in manufacturing salted meat products. This substance is found, in small amounts, in rock salts used in ancient times for salting meat. Nitrate as such does not have a nitrifying action on meat. Its effects are derived from its transformation into nitrite through the action of nitrate-reductases, enzymes produced by lactobacilli, enterobacteria, and other microorganisms.

The use of nitrate in cooked ham has often been questioned since, during the cooking process, the nitrate-reductase-forming bacteria are reduced to a very low level and, at the same time, maturation times prior to cooking tend to be very short, 72 hours at most, so that the conversion of nitrate to nitrite is minimal.

In any case, cooking destroys most, but not all, of the bacterial flora. A minimal formation of nitrites from nitrates continues after cooking cycle, providing an important and progressive contribution during the product's shelf-life. This newly-forming nitrite allows a certain regeneration of the pigment, contributing to color stability. For this reason, combined curing with mixtures of nitrate and nitrite, using nitrate levels of between 75 and 150 ppm, is a common practice in the manufacture of cooked ham.

Preservatives

The use of preservatives represents one of the earliest preservation methods used, but thanks to advances in thermal processing, refrigerating networks and improved manufacturing conditions,



▼ Crushing mill for brine preparation: MOLISTICK.



the need for their use has been reduced and most legislation is very restrictive in this respect.

In some countries, preserving salts of sorbic or benzoic acid are still used. Sorbates, usually potassium sorbate, have little effect on the normal pH levels of cooked ham. They are good inhibitors of mould growth, but are much less effective with yeasts and bacteria. Benzoates are even less effective than sorbates, since their only active form, benzoic acid, is significantly present only at pH levels of less than 4. In fact, both sorbates and benzoates are of very doubtful use in manufacturing cooked ham, even though they continue to be used in many places, perhaps for historical reasons.

At present, other types of more natural preservatives are being used, such as those derived from lactic acid (sodium lactate and potassium lactate). These compounds are able to reduce water activity in the product, and also have antimicrobial properties against pathogenic bacteria such as *E. coli*, *C. botulinum* and *L. monocytogenes*.

Recently, in some countries sodium diacetate has been approved for use in meat products as an antibacterial agent, principally against *Listeria monocytogenes*. It can be used alone, but in many cases it is used in combination with other compounds such as sodium or potassium lactate.

Due to the growing demand of consumers for less industrialized, more natural and healthier products, much research has been done on the use of new substances like plant extracts and essential oils. These substances that come from plants, herbs and vegetables contain active principles characterized by their antimicrobial and antioxidant properties. Because of their plant origin, there is no legal limit to their use, but in low doses they have no preserving effect and very high doses can result in a series of organoleptic characteristics that make the food product unfit for consumption.

Studies have also been done concerning biopreservation (extending the shelf life of food products by means of natural microflora or its metabolites) with lactic acid bacteria that produce bacteriocins (natural antibiotics). At present, there is no legal limit to their use, but among other inconveniences is the fact that they can cause allergic reactions and the appearance of microbial resistance to these bacteriocins. In addition, they do not withstand strong technological processing, such as thermal treatment, so that their use is not viable in the manufacturing of cooked ham.

Antioxidants

Of all the antioxidants authorized for use in cooked ham by differing legislation, the most universally used are sodium L-ascorbate and its optical isomer, sodium erythorbate. Of the two, the former is permitted by all existing legislation, while the latter is not authorized in some countries. The argument for such prohibition is that the former is a product consumed in a normal diet as vitamin C or ascorbic acid, whereas the latter is not and has only 5% the vitamin action of ascorbate.

Since the technological action of both products is identical, everything described below in regard to the properties and functions of ascorbate is equally applicable to erythorbate, the basic difference being that the latter is less costly.

Sodium ascorbate has three basic functions in its application to the manufacture of cooked ham, which are derived from its chemical behavior as a powerful reducing agent.

The first of these functions is its action as a nitrite reducer. Ascorbate reduces nitrite to nitrous oxide, facilitating nitrosomyoglobin formation, and thereby accelerating the formation of the pink color. Without the presence of ascorbate, this reaction would be produced in the same way, by the natural reducing agents existing in the meat, but this

would require much longer maturation periods and much greater amounts of nitrite in order to obtain a satisfactory color. It is easily demonstrated by analytical tests that residual nitrite levels are much lower in the finished product when ascorbate is used in the formulation.

Secondly, ascorbate contributes decisively to color stability in the finished meat product. This can be attributed to its reducing properties (antioxidizing effect), which act to inhibit the formation of peroxide radicals in the product's surface when exposed to ultraviolet light and oxygen. It is these radicals that are principally responsible for pigment decomposition. In addition, ascorbate's accelerating effect on nitrous oxide formation contributes to retarding pigment decomposition, simply because of the change in equilibrium that takes place in this reaction when nitrous oxide is released.

Finally, ascorbate contributes to preventing the formation of cancer-promoting nitrosamines by blocking the formation of nitrosating agents (N_2O_3) being originated from the nitrous oxide.

In manufacturing cooked ham, the addition of ascorbate should always be done in the form of salt. Even though the addition of ascorbic acid to injection brines, which usually have slightly

alkaline pH, would serve to make sodium ascorbate effective in the solution, using the acid form in brines requires a great deal of caution, so that it should be ruled out. The reason for this is that nitrite reacts very violently with ascorbic acid in an acid medium, producing irritating nitrous vapors, so that ascorbic acid addition should be avoided once the nitrite has been dissolved in the brine, already having an alkaline pH as a result of phosphate action. Even so, a small amount of nitrous vapors is produced.

Because sodium ascorbate is insoluble in fatty tissues, it has little antioxidant effect on them. In manufacturing cooked ham, the types of antioxidants for fat, such as tocopherols, butylhydroxyanisole (BHA), or butylhydroxytoluene (BHT), are not usually used.

Of the substances classified as antioxidant reinforcing agents, the only ones used in cooked ham are tri-sodium citrate and sodium lactate. The former is used primarily for its buffering and chelating properties, and the latter for its action as a water activity depressor agent and for its inhibiting effects on bacterial growth, in particular, on lactobacilli.

Phosphates

Phosphates have two basic functions in cooked ham. They produce a spectacular increase in water



holding capacity, and they facilitate solubilization and extraction of myofibrillar proteins, responsible for intermuscular binding in cooked ham.

Current knowledge of the mechanisms of phosphate action is insufficient to fully explain the spectacular effects produced. The polypeptidic chains of proteins are joined together in their tertiary and quaternary structures by electrostatic bonds, hydrogen bridges, disulfide bridges, and bridges made up of divalent cations, especially calcium and magnesium. The protein's hydrating capacity (and therefore, its water holding capacity during the cooking process) will usually increase proportionally as this tertiary and quaternary structure becomes less compact (in the same way a sponge, with the meat's proteins being like a squeezed sponge, must be allowed to expand in order to be able to retain water). This expansion is obtained by breaking the greatest number possible of these bonds. The reduction of the electrostatic bonds is achieved by increasing the medium's ionic strength, basically through the action of salt. One of the known mechanisms of phosphates is their chelating action on calcium and magnesium, loosening the bonds formed by these metals and allowing protein expansion.

Phosphates have various other known actions that facilitate solubilization and extraction of myofibrillar proteins. Myofibrillar proteins, actin and myosin, constitute approximately 50% of the total meat proteins, and their water holding capacity is much greater than that of sarcoplasmic proteins.

Myofibrillar proteins are found in muscle, together in the form of actomyosin, which is insoluble. In live animals there exists a continual equilibrium of association and disassociation between actin and myosin to form actomyosin. The displacements of this equilibrium are responsible for muscular contraction and relaxation. Actomyosin disassociation is produced with the consumption of ATP (Adenosinetriphosphate), which acts as the

medium for energy transmission in living bodies. Once the animal has died, ATP continues to be consumed in this reaction until it has run out, the moment in which the muscles become fixed in a contracted state ("Rigor mortis"). The process of protein solubilization constitutes, in a certain sense, an inversion of this "rigor mortis" process. Actin and myosin are found joined together in actomyosin mostly by calcium bonds, on which phosphates seem to act.

When actin and myosin are separated, they find an optimum medium for solubilization, with the help of a mechanical process (massaging), in the saline and pH conditions of brine. Phosphates also act to influence the pH conditions. Even though in concentrations commonly used, the injected mass's pH increases no more than 0.5 points, phosphates contribute with their buffering effect to homogenizing the pH in different muscles, lessening the exudative effects of PSE (Pale, Soft, Exudative) muscles.

Even so, the buffering and chelating actions of phosphates seem too weak to account for phosphate effectiveness (products with a much greater chelating capacity have little effect on water holding and solubilization of actin and myosin), which indicates that phosphates may exercise some action similar to that exercised by ATP in live muscle tissue (in tests conducted by the Technology Department of METALQUIMIA, S.A.U., the results of adding ATP to brines have been comparable to results obtained by pyrophosphate addition). However, this is no more than a supposition, and in the literature on this subject there are no studies that prove or disprove this theory, which continues to be open to discussion.

As for the type of phosphates to be used, it is generally accepted that effective action is produced only in the form of pyrophosphate (diphosphate). Because this product is highly insoluble in water (and more so in the saline conditions of brine), mixtures of tripolyphosphate, pyrophosphate and

hexametaphosphate are usually used in cooked ham. Both the former and the latter hydrolyze in aqueous mediums, gradually releasing pyrophosphate. Depending on the characteristics of the product being manufactured, various combinations of these phosphates are used, in any of their forms such as sodium, potassium or acid salts. Orthophosphate has practically no effect on water holding capacity, which partially confirms the theory that it is pyrophosphate which is responsible for effective action, given that two orthophosphate molecules cannot join together to form one pyrophosphate molecule in a brine environment.

Good effectiveness is usually achieved with doses of no more than 5 g/kg phosphate added, although the mixture's proportions must be controlled carefully depending on product objectives.

Stabilizers

Both carrageenans and alginates are algae extracts. Carrageenans (derived from red algae) are polysaccharides formed by linear galactose chains with varying degrees of sulfation that determine different fractions (Kappa, Lambda and Iota carrageenans). They are obtained by boiling the algae in water or alkaline solutions for several hours, followed by drying or alcohol precipitation. Alginates, extracted from brown algae, are polysaccharides formed by linear chains of D- Mannuronic and L-Guluronic acids. To obtain these polysaccharides, the algae are treated in an acid medium in order to eliminate the calcium which insolubilizes alginates, then dissolved by an alkaline treatment to obtain sodium alginate, which can then be transformed into alginic acid or calcium alginate.

Of these substances, the most commonly used in the manufacture of cooked ham are carrageenans. Commercial mixtures are usually made up of varying proportions of the three fractions, Kappa, Lambda,

and Iota, complemented by small amounts of gums and some salt, usually potassium chloride.

The properties of these mixtures and, therefore their applications, vary according to their compositions. Some mixtures have an enhanced viscosity so that they can be used as brine stabilizers. Other mixtures are formulated to produce the opposite effect that is, to increase brine viscosity as little as possible in order to take advantage of the carrageenans' water holding capacity (stabilizing effect) without damaging the ham's muscular structure. Mixtures of the latter type are used for certain products in which injection of excessively viscous brines leads to the formation of brine deposits and pockets between the muscular fibers, deposits which cannot be distributed by mechanical massaging action and appear in the finished product as transparent gelled zones between the open fibers.

Carrageenan mixtures are used in injection brines as well as being added during the massaging phase. The main purpose of their use is their stabilizing effect. Carrageenans gel, retaining a great deal of water in the gels that are formed.

The mixture's composition decisively affects the characteristics of the gel formed, influencing its hardness, flexibility, transparency, color and syneresis. For example, including potassium chloride in the mixture will significantly increase the gel's hardness.

Carrageenans also have synergic effects with some gums, such as caruba gum, which greatly increases the water holding capacity of carrageenan gels, as well as reducing syneresis. For this function, as water retainers, carrageenans are usually used in concentrations of between 2 and 5 g/kg in the finished cooked meat product

Gums are commonly used as stabilizers in brine. Chemically, they are also saccharides, but usually have a branched structure, and are derived from various sources. Arabic gum (produced by acacias) and tragacanth gum, both vegetable exudates, are

rarely used in manufacturing cooked ham. Some gums are extracted from grains, such as caruba gum (extracted from carob trees) and guar gum (extracted from guar seeds). Both are generically galactomannans, that is, linear mannose chains with galactose branches, and both are frequently used in high yield cooked ham due to their strong stabilizing effect. They do not have gelling properties and, in excessive concentrations, can hinder the gelling of myofibrillar proteins, causing increased cooking loss and even muscular unbinding in cooked ham. Xanthan gum is a gum of microbial origin. It has a stabilizing capacity, greater than that of galactomannans, together with a synergic effect, and is especially useful in cooked ham when combined with guar gum. Like the galactomannans, xanthan gum has no gelling capacity and must be used with the same precautions.



Flavor enhancers

Flavor enhancers are substances that, without altering the product's innate flavor, increase the smell and taste of this flavor. The mechanism that produces this phenomenon is not at all clear. On the one hand, it seems that they act directly on the nerve endings, making them especially sensitive to flavors, but on the other hand, it can be demonstrated that they have no effect whatsoever on the four basic flavors (sweet, salty, acid, and bitter).

The most universally used flavor enhancer is monosodium glutamate, industrially produced by fermentation of molasses. In cooked ham, doses of between 0.2 and 1 g/kg finished product are used. Other flavor enhancers that produce good results are sodium inosinate and sodium guanylate. These nucleotides have greater flavor enhancing power than glutamate and their combinations have interesting synergic effects that allow them to be used in doses considerably smaller than glutamate. They are not often used in cooked ham, basically because of their high cost.