

## Alternative Curing

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### TRADITIONAL VS “NATURAL” CURING

#### History of Curing

Curing is an ancient process, whereby meat was originally preserved by the addition of salt. In their textbook, “The Meat We Eat”, Romans *et al.*, (2001) traced the origins of salt curing of meat to the Sumerian culture, which emerged in the Tigris and Euphrates valleys, approximately 4,000 B.C. It is commonly believed that the salt used in early meat curing was contaminated with salt peter (potassium nitrate), which contributed to a sustained, desirable red color of meat after exposure. Shortly after, additional benefits including a longer storage life before spoilage also were realized. As the industry developed, the additional multifunctional contributions of curing ingredients to cured meats became well-recognized.

The term “cure” can be used as a noun or a verb. According to Sebranek (2010) and Pegg and Shahidi (2000), “to cure” means to add nitrite and/or nitrate with salt to a meat product to achieve preservation. Additionally, the term “cure” is often used to describe the chemical entities of nitrite and/or nitrate when utilized with salt for meat preservation. Moreover, the terms “curing” or “cure” are used typically when nitrite and/or nitrate are added to a meat product.

Traditionally, meat curing has been associated with processed meats for the purpose of altering color, flavor, safety, and shelf-life characteristics (Sebranek & Fox, 1985). Curing impacts meat product attributes, resulting in unique product characteristics, when compared to fresh meat products. It is not clear from published literature when meat processors discovered that in fact nitrite, and not nitrate was responsible for successful meat curing. Experiments in the late 1800s demonstrated that nitrate in the cure was converted to nitrite by nitrate-reducing bacteria, since nitrite was found in cured meat and in the curing pickle when only nitrate was initially added to the cure solution (Polenske, 1891). Additionally, in a separate experiment, Lehman (1899) and Kisskalt (1899) both concluded that the typical color of cured meats was attributed to nitrite and not nitrate. Thus, it is well established that nitrite, added directly or derived from nitrate, is required for meat curing reactions. Nitrite is truly a unique ingredient, as there has been no known substitute for its ability to impart characteristic color, flavor and antimicrobial properties in cured meats (Sebranek & Bacus, 2007b).

The practice of curing has not been without periodic concern. The use of nitrate and nitrite for meat curing became controversial in the 1970’s following a report that carcinogenic nitrosamines might be formed in cured meat products (Lijinsky and Epstein; 1970). The nitrite controversy led to expanded research efforts in the past 40 years, most of which focused on the refinement of improved meat curing practices to minimize the potential for nitrosamine formation, such as prohibiting nitrate and requiring a cure accelerator in bacon, and the establishment of now defunct “USDA nitrosamine monitoring” program.

Traditional or conventional meat curing, as we know it today, involves the direct addition of nitrite (typically in the form of sodium nitrite), which allows for a known amount of nitrite to be added to the product. Existing USDA guidelines strictly regulate the use of sodium nitrate and/or sodium nitrite in cured meat. However, for products cured with natural sources of nitrate or nitrite, such as vegetable juice or celery juice powder, regulations are less clear.

## REGULATIONS

### Traditionally Cured Meat Product Regulations

USDA regulates nitrite based on meat block weight and not total formulation (weight of meat and non-meat ingredients) or finished product weight. The regulations allow up to 200 ppm of in-going nitrite for pumped or massaged cured meats, except bacon, and up to 156 ppm of in-going nitrite for comminuted cured meats (USDA, 1995). For most cured meat products, USDA policies hold nitrite to no less than 120 ppm, in-going, if requiring refrigeration, and 40 ppm if shelf-stable. Bacon is a special situation because of the concern for possible nitrosamine formation during frying. The regulations for pumped or massaged bacon specify a level of 120 ppm in-going nitrite, in combination with 550 ppm of erythorbate, or equivalent reducing agent. Dry-cured products are allowed to have 625 ppm sodium nitrite, in-going. Currently, the USDA does not allow the use of nitrate (sodium nitrate) in bacon manufacturing.

### Natural and Uncured Meat Product Regulations

According to the USDA Food Standards and Labeling Book (USDA, 2005), products labeled “natural” are those in which the meat components and their ingredients cannot be more than minimally processed (those traditional processes used to make food edible or to preserve it or to make it safe for human consumption; e.g., smoking, roasting, freezing, drying, and fermenting) or those physical processes which do not fundamentally alter the raw product and/or which only separate a whole, intact food into component parts (e.g., grinding meat, separating eggs into albumen and yolk, and pressing fruits to produce juices; USDA, 2005). Natural products may not contain any artificial flavorings, coloring ingredients, or chemical preservatives, or any other artificial or synthetic ingredients (21 CFR 101.22; USDA, 2005). However, there is no clear definition for “natural,” since some natural ingredients, such as salt have dual functions as flavorings or “natural” preservatives (Sebranek & Bacus, 2007a). Beets, an arguably “natural” source of pigment, are disallowed as coloring agents in natural products, while paprika, also a natural source of pigment, is considered acceptable by USDA as a seasoning ingredient.

Products labeled “uncured” are those that are not allowed to contain purified (or synthetic) sources of nitrate or nitrite. This labeling distinction was created in a response to consumer interest in nitrate/nitrite absent versions of processed meat products traditionally containing these ingredients. The labeling term “uncured” was required to prevent consumer confusion since the absence of curing would result in visual and organoleptic differences. However, today, the labeling standard “uncured” is also used for products that are indirectly cured with ingredients containing natural sources of nitrate/nitrite. This issue has created significant confusion for consumers, as products labeled uncured can and often have the same color, aroma and flavor characteristics as their traditionally-cured counterparts. As for meat products manufactured using “natural” sources of nitrate for curing, the 2006 US Code of Federal Regulations (9 CFR 319.2) requires processors to label the products as “uncured” and “no nitrates or nitrites added except those naturally occurring in ...(celery juice powder or other ingredient identified by USDA to have potential of containing a natural source of nitrate or nitrite).”

Several meat industry companies and meat associations have petitioned the USDA to reconsider their position on the labeling of uncured/alternatively cured products. In a petition from Applegate Farms, it has been requested that the product no longer be labeled “uncured,” since the alternatively-cured products have similar quality characteristics to sodium nitrite-cured products. Applegate Farms realizes natural products do contain nitrites (even though they are naturally occurring). However, the USDA has not yet published a ruling since they are waiting for more research concerning the ability of natural cure ingredients to inhibit pathogen growth of pathogenic bacteria including *Listeria monocytogenes*, *Clostridium perfringens* and *Clostridium botulinum*.

# MANUFACTURING OF “ALTERNATIVE” CURED MEAT PRODUCTS

## Ingredients Used in Alternatively-Cured Meat Products

There are no explicit categories of “approved” ingredients for alternatively-cured meats. Thus, ingredients commonly used in these products must fit into existing categories. Much of this requirement is governed by labeling allowances. For truly uncured products, all ingredients except for those for curing (sodium/potassium nitrate/nitrite, sodium erythorbate, sodium ascorbate, etc.) are allowed. However, when a product is labeled “natural” or “organic,” only ingredients that meet these labeling criteria can be used. Thus, the ingredients used in alternatively-cured products are typically chosen for multi-functional purposes, such as vegetable juice powder used for flavoring and also for curing due to its natural occurring nitrate/nitrite content. Some ingredients commonly used in alternatively-cured meat products include sea salt, evaporated cane juice, raw or turbinado sugar, lactic acid starter culture, and natural flavorings, such as celery juice, celery juice concentrate, or vegetable juice powder. Again, they are added primarily for flavor or other allowed purposes, with a secondary function of curing, safety or quality improvement.

## Source of Natural Nitrate or Nitrite

A variety of plant or vegetable ingredients may be used as a natural nitrate/nitrite source, but their distinctive flavors or colors limit their use. Vegetable or plant ingredients are chosen for their ability to supply nitrate, but nitrate concentrations vary widely among types of plants and plant parts (Lorenz, 1978). Vegetable juice powders may contain as much as 2.5% nitrite or more than 25,000 ppm (Sindelar, 2007c). Commercial celery juice powder has approximately 27,462 ppm nitrate (~2.75%; Sindelar et al., 2007c). As the technology advances, the concentration of natural nitrate and nitrite also is increasing since vegetable juice powders can exceed 4.0% (40,000 ppm) nitrate and 2.5% (25,000 ppm) nitrite.

According to the National Academy of Sciences (1981), vegetables were found to contain 1,500 to 2,800 ppm nitrate. Sebranek (2006) reported the nitrate content of several vegetable juices: carrot with 117 ppm nitrate, celery with 2,114 ppm nitrate, beet with 2,273 ppm nitrate, and spinach with 3,227 ppm nitrate. As such, celery juice powder was chosen as a common substrate since it was determined to be highly compatible with processed meat products, because it has very little vegetable pigment, and a mild flavor profile (Sebranek and Bacus, 2007). With these attributes, celery does not appear to detract from the finished product flavor or appearance.

Sea salt is another common ingredient used in natural meat products. Sea salt is obtained by evaporation of seawater, is usually unrefined without addition of free-flow additives, and retains the natural trace minerals that are characteristic of the source (Heinerman & Anderson, 2001; Kuhnlein, 1980). Sea salt is a GRAS (generally recognized as safe) substance. When incorporated in foods, salt must comply with the Food Chemicals Codex tolerances for purity (Codex, 2006). Solar-evaporated sea salt must be at least 97.5% sodium chloride with specific limits on calcium/magnesium, arsenic, and heavy metals content (Codex, 2006). Sea salt has been suggested as a possible source of nitrate; however, limited analytical information suggests that the nitrate content of sea salt is relatively low (Sebranek and Bacus, 2007b). A study reported that salt from the Mediterranean Sea contained 1.1 ppm of nitrate and 1.2 ppm of nitrite (Herrador *et al.*, 2005). Cantoni *et al.* (1978) conducted an experiment that analyzed ten samples of three grades of sea salt for their nitrate and nitrite content. The authors found that the sea salt samples contained 0.3 – 1.7 ppm nitrate and 0 – 0.45 ppm nitrite, quantities that would be insignificant for curing functions.

Another common ingredient used in naturally-cured products is raw sugar/turbinado sugar. Turbinado sugar is obtained from the evaporation of sugar cane juice, followed by centrifugation to remove molasses. However, there is no evidence that there are significant nitrate or nitrite concentrations in raw sugar (Sebranek & Bacus, 2007).

## Source of Nitrate Reductase

If nitrate is used for meat curing, it must be reduced to nitrite before curing reactions can proceed. This step is accomplished by nitrate reduction via a nitrate reductase enzyme present in certain bacteria, which is then involved with important nitrate-to-nitrite reduction reactions. Lactic acid starter cultures used for fermented sausage, such as *Lactobacillus plantarum* and *Pediococcus acidilactici*, do not reduce nitrate (Olesen et al., 2004; Casaburi *et al.*, 2005). However, cultures of coagulase-negative cocci such as *Kocuria varians*, *Staphylococcus xylosum*, *Staphylococcus carnosus* and others can reduce nitrate to nitrite (Olesen *et al.*, 2004; Casaburi *et al.*, 2005). This reduction occurs at specific temperatures and for a minimum time.

For commercially produced nitrate-reducing cultures, this temperature is normally 38-42°C and held for a minimum of 2 hours for adequate nitrite formation (Casaburi, *et al.*, 2005). Nitrate reduction can be achieved at temperatures as low as 15-20°C, but 30°C is a more effective temperature (Casaburi, *et al.*, 2005) for these reactions.

To eliminate the need for an incubation step in the manufacturing process, ingredient companies have started manufacturing pre-converted vegetable juice powders. Most often, pre-converted vegetable juice powders are manufactured with celery juice powder and typically mixed with sea salt. By utilizing a pre-converted vegetable juice powder, manufacturers can eliminate the timely step of incubation and proceed directly into the cooking process for the specific meat product.

### Source of Natural Cure Accelerator

Cure accelerators are important for curing as they increase the effectiveness of nitrite resulting in improved quality and safety attributes. The curing reaction is favored by reducing conditions and reduced pH of the meat and the meat system, respectively. Thus, “natural” cure accelerators include acidifiers such as vinegar, lemon juice solids, and reducing agents like cherry powder (Sebranek & Bacus, 2007). Cherry powder is high in ascorbic acid (Vitamin C), which functions as a strong nitrite reducing agent, but does not have a large impact on product pH, as has been observed with other ingredients. Cure accelerators, which reduce pH, are generally not favored in processed meats, due to reduced moisture retention from more acidic conditions. This observation is a special concern since phosphates and many other traditional water binders cannot be used for natural or organic products.

## CURRENT RESEARCH IN NATURALLY-CURED MEAT PRODUCTS

### Quality Attributes

Celery powder, a naturally occurring nitrate source, when combined with a starter culture, is one of the most commonly used sources of nitrite in natural and organic meat products. However, incubation time and celery juice concentration are important variables when using this alternative. Sindelar *et al.* (2007b) evaluated the effects of incubation time and vegetable juice content in naturally-cured sausage. As expected, residual nitrate level decreases as incubation time increases and occurs as nitrate is converted to nitrite by bacterial reduction. Residual nitrate levels will be higher in products containing vegetable juice powder, when compared to products containing sodium nitrite since vegetable juice powder has a higher level of nitrate to begin with. Additionally, residual nitrite in meat products will decrease with days of storage. The researchers also found that there was no difference in color between naturally-cured and conventionally-cured hams. This observation is important to the meat industry since it demonstrates that natural products can be made with similar color characteristics. Furthermore, lipid oxidation did not differ for naturally-cured and conventionally-cured hams. These findings demonstrate that traditionally-cured ham products can be manufactured utilizing vegetable juice powders with a starter culture.

Alternatively-cured products are likely to have a shorter shelf life than nitrite-cured products since less nitrite is present in the final product and because other preservatives such as lactates, curing accelerators, and antioxidants, are not used (Bacus, 2006). Research in recent years also has focused on the use of “clean label” antimicrobials and natural antimicrobials in naturally-cured meats. Jackson *et al.* (2011) concluded that meat products containing natural nitrate/nitrite and a natural antimicrobial can have similar residual nitrite levels, as compared with conventionally-cured products. Sullivan (2011) reported increased redness for natural nitrate and natural nitrite-cured hams when measured by a Hunter Colorimeter, but the differences would probably not be detectable by consumers. The natural antimicrobials used by Jackson *et al.* (2011) and Sullivan (2011) were a blend of cultured sugar and vinegar and a blend of cherry, lemon, and vinegar powder.

Sensory research has shown that the use of vegetable juice powder in naturally-cured meats can impart a vegetable taste, depending on the concentration used. Sindelar *et al.* (2007a) concluded that hams cured with 0.4% vegetable juice powder had more vegetable flavor than hams cured with conventional sodium nitrite. However, Sindelar *et al.* (2007b) concluded that cooked sausages cured with either 0.2% or 0.4% vegetable juice powder had no detectable vegetable flavor and aroma or objectionable flavor or aroma, when compared to cooked sausages cured with sodium nitrite. The use of vegetable juice powder in certain cured meats may lead to a decrease in consumer acceptance, since consumers would not expect to taste vegetable flavor in a meat product.

## Food safety

The establishment of minimum in-going nitrite concentration is considered critical to subsequent product safety (Sebranek & Bacus, 2007b). Since in-going nitrite and nitrate are not controlled in natural and organic cured meat products, the safety of the product can be a concern. Researchers over the past several decades have demonstrated that nitrite is effective at inhibiting pathogens, especially anaerobic spore formers including *Clostridium botulinum*. Over the past several years, more research has focused on the effectiveness of natural ingredients used in alternative curing to inhibit foodborne pathogen growth. However, research mainly has focused on *L. monocytogenes* and *C. perfringens*. Sullivan (2011) investigated the use of natural nitrate alone and in combination with natural antimicrobials (a blend of cultured sugar and vinegar and a blend of cherry, lemon, and vinegar powder). The study concluded that natural nitrate and natural nitrite, along with the use of any of the natural antimicrobials, resulted in similar growth of *L. monocytogenes*, as compared to a sodium nitrite-cured ham. However, the use of natural nitrite with no antimicrobial resulted in similar growth of *L. monocytogenes*, as compared to uncured (no cure) ham. Jackson et al. (2011) also determined that *C. perfringens* grew faster in uncured and natural nitrite-cured hams and sausages with no natural antimicrobial, as compared with conventionally-cured hams and sausages containing natural nitrate and antimicrobials. This study assessed the growth of the pathogen inoculated after cooling of the products, an important point to note relative to control of this pathogen with appropriate product cooling in commercial environments. A review of the two research studies suggests that the use of natural nitrate and nitrite, even with natural antimicrobials, could result in proliferation of *C. perfringens* and *L. monocytogenes*. Consequently, there is still a need for further studies that evaluate additional pathogens and to fully evaluate the effects of alternative curing during the entire curing process (injection to packaging).

Recent research by Gipe (2012) suggests that the pre-converted celery juice powder (natural nitrite) and celery juice powder (natural nitrate) with a starter culture are just as effective at inhibiting *E. coli* O157:H7, *L. monocytogenes*, and *Salmonella Typhimurium*, as purified sodium nitrite in bacon. However, sodium nitrate was found to be more effective for the inhibition of *C. perfringens* and the outgrowth of *C. perfringens* vegetative cells; a finding that may challenge the safety of “alternatively-cured” meats because sodium nitrite is used specifically in cured meats due to its ability to inhibit *C. botulinum*. This study concluded that “natural cures” have a limited ability at inhibiting *C. perfringens*, which suggest that they may have a limited ability at inhibiting *C. botulinum*. Additional research is needed to fully define the ability of natural cure ingredients to inhibit foodborne pathogens.

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