A comparison of residual nitrite and nitrate, lipid oxidation, cut-surface color, and sensory and visual characteristics for nitrite-added and no-nitrite- or -nitrate-added Canadian-style bacon

by

Laura Jean Baseler

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Program of Study Committee:
Joseph Sebranek, Major Professor
Claire Andreasen
Dennis Olson

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ABSTRACT

The objective of this research was to compare residual nitrite, residual nitrate, lipid oxidation, and sensory and visual characteristics of conventionally cured Canadian-style bacon containing sodium nitrite to no-nitrite- or -nitrate-added Canadian-style bacon (naturally cured) during 7 or 12 weeks of storage. Three treatments were used for the first and second experiments: control, natural cure (NC) using celery powder with a nitrate reducing culture, and natural cure with cherry powder (NCCP) with a nitrate reducing culture; all of the pork loins used for these treatments were mechanically injected with brines. Six treatments were evaluated in a third experiment: control, control with ascorbate (NA), natural cure with preformed nitrite in celery powder (NCEL), NC, NCCP, and natural cure with lemon powder (NCLP); all treatments in the third experiment were processed by grinding the pork loins, then mixing with the ingredients. All natural cure treatments included celery powder and starter culture as ingredients and finished products were found to contain both residual nitrite and nitrate after incubation of the products for nitrate conversion. The control had significantly more ($P<0.05$) residual nitrite than NC and NCCP in the first experiment whereas in the second and third experiments the control and NC treatments had significantly more residual nitrite than NCCP. The control had significantly less residual nitrate ($P<0.05$) than the naturally cured treatments in the first experiment, but significantly more ($P<0.05$) in the second experiment. NCLP had significantly less residual nitrate ($P<0.05$) than NCCP in the third experiment, but no other treatments were significantly different. Significant differences between TBARS values were observed only in the third experiment where NC and NCLP had significantly higher levels of TBARS ($P<0.05$) than all other treatments. The control was significantly darker and more red ($P<0.05$) than NC

and NCCP in the first experiment, while in the second experiment it had similar lightness and redness to NCCP when evaluated by a Hunter Lab instrument. No significant differences ($P>0.05$) between the treatments for lightness or redness were found in the third experiment. Results from sensory panelists indicated that the control had more cured meat color intensity and was more tender, but contained more off-flavor ($P<0.05$) than NC and NCCP. According to the panel scores, NC and NCCP had significantly greater cured meat flavor intensity and overall were rated as having better flavor acceptability ($P<0.05$) than the control, although these results were not consistent with chemical analyses. These results demonstrate that natural curing processes can be successfully utilized for both injected and ground and then formed Canadian-style bacon.

CHAPTER 1. GENERAL INTRODUCTION

Consumer interest in naturally cured meats has been increasing recently. The popularity of these products is attributed to the perceptions that they are healthier, taste better, and are of higher quality, although these traits may be disputed. In order for a meat product to be labeled as natural it cannot contain artificial flavoring, coloring, chemical preservatives, or artificial or synthetic ingredients. Conventionally cured meats commonly contain ingredients such as sodium nitrate or sodium nitrite, which are considered preservatives; these ingredients are not allowed in naturally cured products and must be replaced. Unfortunately, nitrite is a key ingredient that imparts the characteristic color and flavor of cured meats, inhibits the formation of *Clostridium botulinum* spores, and prevents lipid oxidation and rancidity. Despite the fact that chemically produced nitrite cannot be added to naturally cured products and that these products are often not processed the same as conventionally cured meats, consumers still expect the products to have a similar appearance, flavor, shelf-life and be free of harmful pathogens.

In order to produce a naturally cured meat product that meets the needs of consumers, vegetable ingredients that are naturally high in nitrate are used in conjunction with nitrate reducing starter cultures to produce nitrite during a fermentation process. Meat with ingredients added through mechanical mixing, or by injecting the meat with brine, is incubated at elevated temperatures of 35-37° C for an extended time period. This process can lead to unpredictable results due to inconsistent conversion of nitrate to nitrite by bacteria resulting in varying levels of residual nitrate and nitrite in these products.

When levels of residual nitrite are too low, they may not be adequate to prevent botulism or could result in more rapid lipid oxidation and a shorter shelf-life. With high

levels of residual nitrite, there is the concern of nitrosamine formation, which has been linked to cancer. In addition, maximum levels of residual nitrate and nitrite are regulated by the USDA Food Safety and Inspection Services. Therefore one of the goals of this research was to measure the residual nitrate and nitrite levels of Canadian-style bacon, a common conventionally and naturally cured meat product, in several ingredient formulations of both conventionally cured and naturally cured products processed in a standardized cooking cycle. The second goal was to determine if different levels of residual nitrate and nitrite in naturally cured Canadian-style bacon significantly affected quality aspects such as color, sensory characteristics, and lipid oxidation compared to conventionally cured Canadian-style bacon.

Thesis Organization

This thesis is organized into four chapters. The first chapter is a general introduction to naturally cured meat products. The second chapter is a literature review that highlights the differences between conventionally and naturally cured meat products, the functions of the different ingredients that are commonly used to produce these products, and current consumer preferences concerning organic and natural foods. The third chapter describes the experimental design and findings from the research conducted. The fourth chapter outlines the general conclusions of this research.

CHAPTER 2. LITERATURE REVIEW

I. Conventional Curing

One of the first allusions to the conventional curing of meat can be found in The Iliad, written by Homer in 850 B.C. It has been suggested that the sprinkling of salt onto meat in The Iliad, most likely as a method of preservation in that time period, was an inadvertent act of curing meat through the use of salt contaminated with nitrates. Throughout the ages it was noticed that the use of particular types of salt for preservation produced a reddish-pink color in meat, which is now known to be associated with the curing process (Ray, 2003).

Curing is defined as the addition of nitrate or nitrite to a meat product (Pearson and Tauber, 1984). The application of nitrate or nitrite can be done in a variety of ways; one of the more common methods is by dissolving them in a brine and mechanically injecting the brine into meat. Today, brines that are meant to cure meat typically include ingredients such as salt, phosphates, erythorbate or ascorbate, and sodium lactate in addition to nitrite and/or nitrate. Each of the components in the brine has a distinct role in the production of cured meats such as Canadian-style bacon, pastrami, and ham.

Salt

Salt was initially used before refrigeration was available for its ability to preserve meat by decreasing the water accessible to bacteria (Romans et al., 1994). Salt acts by decreasing the water activity (a_w), water that is available for use by microorganisms, in meat which inhibits the growth of most bacteria (Coultate, 2002). Table salt is the form of salt most commonly added to meat, while sea salt has become a popular alternative used in natural meat products. Table salt is typically 95 to 99.99 percent sodium chloride which has been purified after being obtained by mining rock salt or evaporating sea water (Salt

Institute, 2007). Sea salt is produced by evaporating sea water through natural solar heat, but unlike table salt, sea salt it is not extensively purified (Ritz, 1996). Sea salt often comes from the Mediterranean Sea and may contain minerals such as calcium and nitrate (Ganor et al., 1998).

More recently, the importance of salt in processed meats has been primarily as a flavoring agent designed to meet consumer expectations. Sodium chloride may be added to meat products in any amount as it is categorized as generally recognized as safe (GRAS) by the Food and Drug Administration (FDA). When including sodium chloride in meat, it must be taken into account that it is self-limiting at different amounts depending on individual preferences. In addition to being unpalatable at high amounts, large quantities of salt are associated with an increased rate of rancidity in meats (Chang and Watts, 1950).

Sodium chloride is included in meat formulations for its ability to extract protein and aid in protein swelling. Munasinghe and Sakai (2004) found that sodium chloride became more effective at extracting protein as meat pH increased from 6.0 to 6.5. As protein swells, there are more locations for water to bind to the protein, this decreases free water available and can increase the cook yield through water retention (Baublits et al., 2006).

Phosphate

Phosphate is a relatively water-insoluble compound, and in order for phosphate to rapidly dissolve in water, it should be the first substance added when making a meat curing brine. When mixing phosphate into a brine, it is important to keep in mind that phosphate will dissolve more quickly in warmer water temperatures. A maximum of 0.5 percent of phosphate is allowed in finished meat products, yet in some instances this may impart a soapy flavor to meat. Taste panelists have detected a slightly soapy flavor when 0.3 percent

phosphate was added to turkey and beef patties (Craig et al., 1996), although when 0.5 percent phosphate was added to restructured reindeer steak, panelists did not note changes in sensory characteristics (Penfield et al., 1992).

Phosphate is commonly added to brines to increase the pH of meat, which improves the water holding capacity (WHC) of meat by causing proteins to swell. Knipe et al. (1985) found that a higher raw pH, increased protein solubility, emulsion stability, and WHC occurred when tetrasodium or tetrapotassium pyrophosphates were added to meat emulsions. Zorba et al. (1993) also found that the emulsion capacity of meat can be enhanced by increasing the amount of phosphate added. The reduction of warmed-over flavors (WOF) in reheated meats can also be accomplished through the addition of phosphates. An injection of phosphate into pork roasts that were reheated was found to produce significantly less WOF in the pork roasts as compared to the control which did not receive phosphate (Smith et al., 1984). Similarly, Mann et al. (1989) found that phosphate prevented WOF in roast beef that was precooked and vacuum packaged. In addition, roast beef treatments that did not include phosphate showed lower yields and greater cooking losses.

In general, as the pH of meat increases, formation of cured color decreases. Baker et al. (1970) found that frankfurters became paler in color as their pH was increased. The formation of nitric oxide is necessary for the production of cured color; if meat is more acidic, the formation of nitric oxide from nitrous acid occurs more quickly (Shank et al., 1962). Even so, it has been suggested that cured color is not solely influenced by meat pH. Phosphate, which makes meat more basic, can be added to meats to enhance their color stability and make them more desirable to consumers. The addition of phosphate to fresh uncured meat increases its pH and causes the meat to retain a darker color. Mixing sodium

tripolyphosphate (STPP) with pork trimmings produced a more pleasing product when evaluated for raw color against a control that did not contain STPP (Schwartz and Mandigo, 1976). Redness, as determined by Hunter a* values was significantly higher ($P < 0.05$) in steaks that received tetrasodium polyphosphate than those that did not (Baublits et al., 2006). However, in cured meat the addition of phosphate can decrease the production of nitric oxide and the formation of a pink-red cured color, but if given enough time, phosphatases that are naturally found in meat can breakdown added phosphates, which seems to improve cured color (Molins, 1991). Waiting at least 60 minutes before cooking a prepared cured meat emulsion that contained phosphate allowed development of a cured color similar to meat emulsions without phosphate (Knipe et al., 1988).

Through the addition of phosphate to meat, decreased WOF, improved cook yield, increased shelf-life and, in uncured meat, a more desirable red color can be obtained.

Sodium Lactate

For the past 15 years, the use of sodium lactate at a maximum of 4.8 percent of the formulation to control bacterial growth in meat products has been well documented. Miller and Acuff (1994) found that applying 3 or 4 percent sodium lactate to beef top rounds helped restrict the proliferation of *Salmonella typhimurium*, *Listeria monocytogenes*, and *Escherichia coli* O157:H7. Results have also shown that sodium lactate can lengthen shelf-life and keep thiobarbituric acid (TBA) values low ($P < 0.05$) in catfish fillets (Williams et al., 1995). The effects of sodium lactate on sensory qualities were investigated by O'Connor et al. (1993), who reported that a taste panel deemed sodium lactate-treated ground pork to have a more intense salty flavor and juiciness ($P < 0.05$) than the control. Sodium lactate can also improve the appearance of fresh meat by helping the meat keep its red color longer. In a

21 day study, Brewer et al. (1991) observed that fresh pork sausage injected with one percent lactate retained its red color for the entire study, while fresh pork sausage without the addition of lactate maintained its color for 17 days.

Nitrate and Nitrite

In the past, sodium or potassium nitrate was commonly used to cure meats. There were several methods for adding this nitrate, including a dry cure, immersion cure, injection cure, or adding it to chopped meat and then mixing. With each method of application, there are specific regulations that dictate the amount of nitrate that can be included. For example, a dry cure, where the cure ingredients are rubbed onto the surface of the meat, can contain a maximum of 105 grams of sodium nitrate per 45.45 kilograms of meat; whereas only 82.5 grams of sodium nitrate is allowed when it is directly mixed with comminuted meat (USDA-FSIS, 2005c). In injection and immersion cures, ingredients, including up to 700 ppm sodium nitrate, are dissolved in water to create a brine. The brine may then be mechanically injected into meat for an injection cure, or the meat can be placed directly into the brine and left to soak for a predetermined amount of time for an immersion cure. In order to ensure curing by adding nitrate through any of the previously mentioned methods, the nitrate must be converted to nitrite and the amount of nitrite allowed in a finished meat product cannot exceed 200 ppm. Environmental factors such as moisture and pH, and the effectiveness of nitrate-reducing bacteria all impact the amount of nitrite produced from nitrate. Due to the unpredictable nature of these factors, using nitrate to cure meats is typically only done in dried, uncooked products where it is necessary for nitrate to be slowly converted to nitrite, which can impart a darker red color to the meat, such as in dried sausage (USDA-FSIS, 2005b).

Nitrate that is added to meat is converted to nitrite by particular strains of bacteria; this conversion is necessary for the formation of the characteristic pink color associated with cured meats (Aberle et al., 2001). In order for meat to develop a pink color, nitrate or nitrite must be altered to form nitrosylhemochrome. The first step (Figure 1) in this process is the reduction of nitrate to nitrite by nitrate-reducing bacteria (Shank et al., 1962). This can be accomplished through the use of starter cultures that contain *Kocuria varians*, which is in the *Micrococcaceae* family, or *Staphylococcus carnosus*, from the *Staphylococcaceae* family. Both of these bacteria can produce nitrate reductases that will convert nitrate to nitrite (USDA-FSIS, 2005a). This process is dependent on the number of nitrate-reducing bacteria present, the temperature, moisture and salt content, and the pH in the environment (USDA-FSIS, 2005c). Other bacteria that are present can also influence the rate of nitrite production. *Staphylococcus xylosus* has been shown to have sixteen strains that are capable of stimulating the growth of *K. varians* K4 and four strains that inhibit its growth (Tremonte et al., 2007). *K. varians* and *S. carnosus* are pH sensitive and will die as lactic acid producing bacteria lower the pH during fermentation processes. In addition, the nitrate reductases produced by these organisms are not active at a low pH (Smith and Hui, 2004).

Once nitrite is formed in meat, it is in equilibrium with nitrous acid, this reaction is pushed towards nitrous acid when nitrous acid is converted to nitric oxide (Figure 1). The formation of nitric oxide is accelerated when reductants such as erythorbate and ascorbate are present (Borchert and Cassens, 1998). Reductants accelerate the production of nitric oxide by reacting with nitrous acid to form nitric oxide, water, and dehydroascorbate (Izumi et al., 1989). Nitric oxide then binds to iron in myoglobin, a protein naturally found in muscle, by taking the place of a water molecule bound to myoglobin, to produce nitric oxide myoglobin,

which has a bright red pigment and is an unstable molecule (Fennema, 1996). Upon heating a meat product to a minimum of 65.6° C the globin portion of nitric oxide myoglobin is denatured by the heat to form nitrosylhemochrome (Figure 1), the stable pink pigment of cured meat (Fox, 1966).

Figure 1. Reactions occurring in the conversion of nitrate to nitrosylhemochrome

Bacterial reduction: Nitrate (NO_3-) $\rightarrow$ Nitrite (NO_2-)	(1)
Nitrite (NO_2-) $\leftrightarrow$ Nitrous acid (HNO_2)	(2)
Nitrous acid (HNO_2) $\rightarrow$ Nitric oxide (NO)	(3)
Nitrous acid (HNO_2) + reductant $\rightarrow$ 2 NO + 2 H_2O + dehydroascorbate	(4)
Nitric oxide (NO) + myoglobin $\rightarrow$ Nitric oxide myoglobin	(5)
Nitric oxide myoglobin in the presence of heat $\rightarrow$ Nitrosylhemochrome	(6)

When the significance of nitrite was discovered through scientific research in the early 20th century, the direct use of sodium or potassium nitrite took the place of nitrate and became a standard way to ensure that proper color formation developed rapidly and consistently and no longer relied on the effectiveness of nitrate-reducing bacteria.

In addition to promoting color development, nitrite also acts as an antimicrobial agent by inhibiting the formation of *Clostridium botulinum* spores (Christiansen, 1974) and inhibiting the growth of *Listeria monocytogenes* (AMI, 2007). It has been reported that a minimum of 40 to 80 ppm of residual nitrite in meat is required to prevent *Clostridium botulinum* spore formation (Aberle et al., 2001). Nitrite can also decrease the rate of lipid oxidation, thereby increasing the shelf-life of the meat product (Wesley et al., 1982).

Mahoney et al. (1979) found that levels as low as 25 mg sodium nitrite per kg of meat could decrease rancidity by complexing nitric oxide, formed from sodium nitrite, with iron normally found in meat. Similarly, Younathan and Watts (1959) concluded that oxidation of unsaturated fats occurs more quickly in uncured, cooked meats than in cured meats because iron that is not bound to nitric oxide can act as a catalyst for oxidation. Yetim et al. (2006) found that addition of nitrite to kavurma, a type of fried meat, could significantly reduce the level of oxidation, measured by thiobarbituric acid, peroxide, and free fatty acids, as compared to a control which did not have nitrite added.

Sensory panels have determined that a characteristic flavor, whose identity has yet to be determined, is imparted by nitrite and is strong enough to be detected by taste panelists. Cho et al. (1970) determined that heavy amounts of smoke added to pork did not deter panelists from correctly separating pork samples that contained nitrite from those that did not during taste tests. The affect that nitrite has on texture is still being debated. According to Randall and Voisey (1977) the addition of nitrite, up to 1000 ppm, to chopped ham did not change its texture. However, as little as 40 ppm of nitrite in combination with sorbate in mortadella, a type of Italian cured sausage, was enough to give it a more firm texture than mortadella that contained only sorbate (Al-Shuibi and Al-Abdullah, 2002). Nitrite is responsible for performing many essential functions in cured meats, which has made it all but impossible to find another single compound to replace it.

Since 1926, the USDA has highly regulated the use of nitrite and nitrate for the safety of consumers. At a 1 g dose, nitrite is lethal to an adult human (Borchert and Cassens, 1998). Current regulations state that a maximum of 30 grams of sodium or potassium nitrite per 45.45 kilograms of meat for dry cure, or 7.5 grams of sodium or potassium nitrite per 45.45

kilograms of chopped meat is permitted. A maximum of 105 grams of sodium nitrate per 45.45 kilograms of meat for dry cure or 82.5 grams of sodium nitrate per 45.45 kilograms of chopped meat is allowed. A total amount of 200 ppm of nitrite is tolerated in finished product, whether nitrite or nitrate was initially added (IFT, 1972). Placing a limit on residual nitrite, nitrite that is found in the product after processing, can decrease the chance that nitrosamines, which have been shown to be carcinogenic in laboratory animals, will form when the product is cooked (Cassens et al., 1978). Nitrosamines tend to form more often in fried bacon, which is subjected to high cooking temperatures, than in other meat products, therefore nitrate is no longer allowed in bacon and only 120 ppm of sodium nitrite is permitted in injected and immersion cured bacon and up to 200 ppm of sodium nitrite is allowed in bacon that is dry cured (USDA-FSIS, 2005c). Interestingly enough, Pensabene et al. (1974) found that bacon cooked in a microwave did not cause the formation of nitrosamines, but that nitrosamines were produced when bacon was fried at temperatures at or above 135° C.

Reductants

Sodium and potassium erythorbate or ascorbate are routinely added to brines for cured meat. Erythorbate and ascorbate accelerate the development of cured color by reducing nitrite to nitric oxide and in doing so they help achieve a uniform color in meat products (Watts, 1952). Wesley et al. (1982) found that erythorbate could improve the development of a cured color in meat and the stability of that color even when amounts of nitrite as small as 50 ppm were added. Ascorbate and erythorbate have also been shown to help control the development of rancidity in cured meats (Lee and Shimaoka, 1984).

Through the use of reductants, the amount of residual nitrite in finished cured meats can be decreased substantially. Brown et al. (1974) found that residual nitrite levels were lower in hams that were treated with 455 or 568 ppm ascorbate than in hams containing 227 ppm ascorbate. Keeping residual nitrite at a low level is an important way to reduce the potential for nitrosamine formation in meat products. Nitrosamines are formed when nitrite reacts with secondary amines and typically occurs at high temperatures, such as when bacon is fried (Sen et al., 1973). Bharucha et al. (1979) determined that free proline in bacon serves as the main secondary amine which reacts with nitrite to form *N*-nitrosopyrrolidine. It has been suggested that although nitrosamine formation in meat increases with higher cooking temperatures, the production of nitrosamines is not completely dependent on the cooking temperature. Beatriz et al. (1997) found that bacon made from turkey, beef, a mixture of pork and turkey, or a mixture of beef and turkey, had significantly lower amounts of *N*-nitrosodimethylamine and *N*-nitrosopyrrolidine than conventional bacon even when all of the products were fried at 177° C. Nitrosamine production in meats should be avoided since nitrosamines have been shown to be carcinogenic (Tricker and Preussmann, 1991). In both rats and mice, nitrosamines have initiated the formation of cancer in the urinary bladder (Okajima et al., 1998; Grubbs et al., 2000). In humans, there seems to be an association between gastric cancer and the ingestion of nitrosamines in cured meat (Larsson et al., 2006; Jakszyn and González, 2006).

Similar to nitrites and nitrates, erythorbate and ascorbate levels are regulated by the USDA. A maximum of 550 ppm of erythorbate or ascorbate can be added to meat, which is equivalent to 22.5 grams of sodium ascorbate mixed with 45.45 kilograms of chopped meat (Romans et al., 1994). The goal is to have adequate levels of residual nitrite to inhibit

botulinum toxin from forming, decrease rancidity, and impart a pink cured color and characteristic cured flavor, while at the same time avoiding nitrosamine formation.

II. Natural Curing

Natural curing has the same basic principles as conventional curing, but different ingredients are used to cure the meat. The process of natural curing is comparable to conventional curing, it can be done by an immersion cure, injection cure, or direct addition of cure ingredients to chopped meat with subsequent blending. Of particular importance to immersion and injection cures is the formation of a brine. A brine for natural curing is water with dissolved ingredients such as sea salt, raw sugar, starter culture, and celery powder, which can be added to meat by mechanical injection or through soaking the meat in the brine.

The phrase 'naturally cured' is typically synonymous with the statement 'no nitrite or nitrate added,' the latter of which has become a popular gimmick on product labels. Consumer interest in natural and organic meat products that contain fewer additives, or no additives, has spurred this trend. In order for a meat product to be labeled natural, it must meet the guidelines in the USDA Food Standards and Labeling Policy Book (USDA, 2005). The requirements for natural meats (p. 116) are listed below.

> "The term 'natural' may be applied only to products that do not contain any artificial flavor or flavoring, coloring ingredients, or chemical preservatives (as defined in 21 CFR 101.22), or any other artificial or synthetic ingredients; and the product and its ingredients are not more than minimally processed."

In order to meet the above specifications for a natural product, certain ingredients that are used in conventional cures must be replaced. Phosphate, erythorbate or ascorbate, and the direct addition of nitrate or nitrite are not allowed in natural products but are usually found in conventional curing brines. Other ingredients that are permitted by law may be

replaced by substances that are more highly regarded by consumers who are interested in purchasing natural or organic products, such as the substitution of raw sugar for sucrose.

Changing formulations to meet government guidelines and consumer expectations for natural meats requires more than a simple substitution of one ingredient for another. Many of the components used in curing brines have more than one function and may have to be replaced by more than one ingredient. Celery powder, particular strains of bacteria in starter cultures, raw sugar, and sea salt are commonly found on the label of naturally cured products, yet are absent in conventionally cured meats. The role that these different ingredients play is important for producing a natural product that looks and tastes the same as the conventional product.

Celery Powder

In natural products, celery powder may serve as a replacement for chemically formed nitrite or nitrate. It has been determined that many vegetables naturally contain high amounts of nitrate, examples include: celery, spinach, beets, lettuce, and broccoli. The amount of nitrate accumulation in plants varies among plant species and even among leaves and stems from the same plant (Cárdenas-Navarro et al., 1999). A study by Muramoto (1999) found that iceberg lettuce had an average of 792 mg/kg fresh weight of nitrate, while romaine lettuce had an average of 1080 mg/kg fresh weight of nitrate. Growing conditions and stresses such as droughts or pest damage can influence the amount of nitrate found in vegetables (National Academy of Sciences, 1972). Siciliano et al. (1975) found a range of 1600 to 2670 ppm nitrate in celery and 0.4 to 0.5 ppm nitrite. In commercially prepared vegetable juice powder, also known as celery powder, Sindelar et al. (2007) found nitrate levels of 27462 ppm.

Due to restrictions on the maximum nitrate allowed in meat products, the varying amounts of nitrate found in vegetables presents a problem. In addition, the amount of nitrate converted to nitrite by nitrate-reducing bacteria in a starter culture is also variable. High amounts of nitrite in meat may pose a health hazard through the toxic nature of nitrite or, on the other hand, a very low level of nitrite may not inhibit *Clostridium botulinum* spores from germinating and producing toxins. Because the formation of nitrite is essential for the production of cured meat characteristics, the issues above point out potentially unpredictable steps in the manufacture of natural products with vegetables in place of chemically added nitrite or nitrate.

Sea Salt

Sea salt contaminated with saltpeter (potassium nitrate) can serve as a source of nitrate. It has been shown that sea salt collected from the Mediterranean Sea is composed of both sodium chloride and nitrate (Ganor et al., 1998). Saltpeter is a naturally occurring substance that may be found on rocks and in some caves (Rosenfeld, 2000). It has been thought that The Iliad contained the first recorded use of saltpeter where the saltpeter was applied to meat and resulted in inadvertent curing. Through time, it was discovered that potassium nitrate, not the sea salt itself, was responsible for the pink color in cured meat, at which point nitrate was purposefully added to meat products (McLachlan, 1967). In order for the saltpeter to have caused a color change in the meat, bacteria must have first reduced the nitrate to nitrite (Lewis et al., 1925). A recent push for natural products by consumers has prompted some companies to resort back to using a natural source of nitrate, such as sea salt, to cure meat. Although, it must be noted that not all sea salt contains nitrate and in some

cases the amount of nitrate in sea salt is not substantial enough to cause a color change in meat products.

Starter Cultures

Starter cultures containing lactic acid producing bacteria have commonly been used to ferment sausages. Both *Pediococcus* and *Lactobacillus* in the family Lactobacillaceae are gram positive bacteria that produce lactic acid when they metabolize carbohydrates. Some of the more common species utilized in meat starter cultures are: *L. sakei* (Hüfner et al., 2007), *L. plantarum* (Kutter and Sulakvelidze, 2005), *P. acidilactici*, and *P. pentosaceus* (Hui, 2001). Lactic acid producing bacteria are often used to ferment meat, yogurt, beer, and silage, in addition to other foods and beverages. During fermentation, meat becomes more acidic due to lactic acid production, while the generation of ethanol, carbon dioxide, lactic acid and other metabolic products are responsible for the characteristic flavor of fermented meat (Atlas, 2006). Lactic acid bacteria are also useful in controlling certain pathogenic bacteria through direct competition for resources and by the production of bacteriocins (Metaxopoulos et al., 2002). Vermeiren et al. (2004) found that lactic acid starter cultures played an important role in inhibiting the growth of *Listeria monocytogenes*.

The addition of a starter culture to non-fermented products has been used as a method to naturally cure meat. Starter cultures can include non-lactic acid producing bacteria, such as *Kocuria varians* and *Staphylococcus carnosus* which have served as nitrate-reducing bacteria capable of converting nitrate from vegetable or sea salt sources to nitrite (USDA-FSIS, 2005a). These gram positive organisms can produce nitrite in natural meat products, thus giving them the color and flavor characteristics of conventionally cured meat.

Cherry Powder

Cherries are known to contain ascorbic acid, which is a common reductant used in meat curing. Fisher and Dodds (1955) found that Royal Anne cherries contained 4.1 mg ascorbic acid per 100 g of cherries with a standard deviation (SD) of 1.77; interestingly they also noted that raw sticks of celery contained 4.9 mg ascorbic acid per 100 g celery with a SD of 2.10. The West Indian or Barbados cherry (*Malpighia punicifolia* L.) has one of the highest contents of ascorbic acid in fruits and vegetables. In partly-ripe cherries, Asenjo and Moscoso (1950) found ascorbic acid levels from 1135 mg to 1916 mg per 100 g of cherries, and in ripe cherries the ascorbic acid content ranged from 557 mg to 1246 mg per 100 g of cherries. Partly-ripe, or half-ripe, cherries were described as having a combination of pink, red, and green colors on their surface, with the pink or red occupying less than half of the exterior, while ripe cherries were completely red in color (Fitting and Miller, 1960). In 1946, Asenjo and Freire De Guzmán analyzed West Indian cherries and found ascorbic acid levels between 1030 and 3309 mg per 100 g of cherries. These authors also noted that the degree of ripeness affected the ascorbic acid content in cherries; cherries that were less ripe had more ascorbic acid. In contrast to the high ascorbic acid levels in the West Indian cherry, Pantelidis et al. (2007) detected levels of only 103 mg ascorbic acid per 100 g of cherries in the Cornelian cherry (*Cormus mas*). Demir and Kalyoncu (2003) found even lower levels of ascorbic acid in the Cornelian cherry, reporting a range of 48.39 mg to 73.11 mg per 100 g of cherries.

Cherry powder, or other sources naturally containing ascorbate, may be used as an alternative to industrially manufactured sodium ascorbate which is not allowed in naturally cured meat products. The use of fruits or vegetables as a source of ascorbate should be done

with caution because the level of ascorbic acid is dependent on the variety used, the temperature of storage, and the type of container used for storage (Ferguson and Scoular, 1949). Factors such as the season and geographic location where the cherries are grown can also influence ascorbic acid content (Kader and Rolle, 2004). The application of gibberellic acid, a plant growth hormone, to Bing cherries has been shown to increase their ascorbic acid content from 5.4 mg to 7.0 mg per100 g of cherries, which is a 29 percent increase (Drake et al., 1978).

Ascorbic acid in cherry powder should function the same as sodium ascorbate that is directly added to meat products, although little research has been done in this area. The conversion of nitrite to nitric oxide, the acceleration of the curing process, and similar cured color stability would be expected if the same amount of ascorbic acid, provided by cherry powder, was substituted for sodium ascorbate. Ascorbic acid and sodium ascorbate are optional ingredients and are permitted at a maximum level of 469 ppm and 547 ppm, respectively, in most cured meats. Bacon is an exception, to help control nitrosamine formation in injected and massage-cured bacon the addition of 550 ppm sodium ascorbate is required (FSIS, 2005c).

Lemon Powder

Lemons are a type of citrus fruit that contain many different acids, the most commonly known are ascorbic acid, malic acid, and citric acid. Güçlü et al. (2005) determined that the content of ascorbic acid in lemon powder was higher than that found in lemon juice, ranging from 62.7 $\pm$ 0.3 to 71.8 $\pm$ 0.4 mg ascorbic acid/100 ml lemon powder and 20.5 $\pm$ 0.3 to 29.4 $\pm$ 0.5 mg ascorbic acid/100 ml lemon juice, depending on the method used to determine the content. The ascorbic acid content in lemon juice has been shown to

decrease more rapidly over time when lemon juice is not refrigerated and when the cap on the juice is left open (Kabasakalis et al., 2000).

Lemon juice is very acidic due to the high amounts of acid it contains. Fresh lemon juice has been reported to have a pH of 2.3 (Moufida and Marzouk, 2003), while the pH of lemon juice concentrate has been measured as 1.82 (Burdurlu et al., 2006). The addition of an acidic compound, such as lemon powder, to a meat product can serve many purposes. Citric acid in lemon juice can be used to treat food products harboring *Salmonella typhimurium* to reduce their bacterial loads (Sengun and Karapinar, 2004). Similar to cherries, ascorbic acid found in lemon powder can accelerate the conversion of nitrite to nitric oxide thereby promoting cured color formation and cured flavor development. Acidulants, such as malic acid, can synergize with antioxidants to inhibit rancidity (Furia, 1972). In addition, lemon juice contains high levels of polyphenols which act as antioxidants by scavenging free radicals (Gorinstein et al., 2001).

Raw Sugar

The decision to replace refined sugar with raw sugar or turbinado sugar in naturally cured meats is typically done for consumer appeal. The inclusion of raw sugar or turbinado sugar on a label's ingredient list can reinforce the natural image of a product. Raw sugar is purified to remove contaminants, yet remains a golden-brown color and has not been processed as much as refined sugar. Although it has been thought that raw sugar contains substantially more vitamins than refined sugar, Krehl and Cowgill (1955) analyzed several types of sugar produced in different locations and found that, while vitamins are indeed found in raw sugar, the levels were insignificant to human daily dietary requirements. Turbinado sugar is raw sugar that has been steam processed to create a light gold-colored

sugar by removing some of its molasses (Riegel and Kent, 2003). Turbinado sugar is produced from sugar cane juice (O'Connor, 2007) and is similar to refined sugar in that it contains sucrose (Greeley, 1992).

Natural and Organic Markets

In recent years, consumer interest in purchasing natural and organic products has increased. According to a 2004 survey of consumers by Whole Foods Market, this interest lies in the belief that organic products are better for the environment, taste better, are healthier, are of higher quality, and purchasing organics helps support small and local farmers. Although many of these statements can be refuted, it is undeniable that these ideas influence purchasing habits and that the popularity of organic foods is expanding. As of 2002, organic products were sold in 73 percent of conventional grocery stores and the amount of certified organic farmland doubled between 1992 and 1997, to 1.3 million acres (Dimitri and Greene, 2002). According to Willer and Yussefi (2007) there are now almost 4 million acres of land in the U.S.A. being used to produce organics. Between 1999 and 2000, the organic market increased from $6.5 billion to $7.8 billion (Kortbech-Olesen, 2002), while in 2002 that number reached $23 billion and rose to $33 billion in sales in 2005 (Willer and Yussefi, 2007). With a positive trend towards organic goods becoming widespread, food products such as naturally cured, no-nitrite- or -nitrate-added meat products, have become widely accepted. As consumers pay more attention to label claims and ingredient lists on packages, more changes in the current market for cured meats are likely. An advertisement push for naturally cured meats has already begun. These products typically contain vegetable sources of nitrate in place of chemically produced nitrite and rely on starter cultures for the conversion of nitrate to nitrite. With variations in naturally cured meat preparation

procedures among companies, it is important that standards for cook cycles are determined, that meat products have a safe level of nitrite, and that their appearance meets consumer expectations.

One of the naturally cured meat products that is now being marketed is Canadian bacon, more commonly labeled as Canadian-style bacon. Canadian-style bacon has become popular as an excellent pizza topping. Canadian-style bacon is a boneless meat product that is made from pork loins (IMPS 414) and is composed mainly from the longissimus muscle which is located along the back (dorsal topline) of the pig on either side of the vertebral column from behind the shoulders to the ilium (USDA, 2005). To produce conventionally cured Canadian-style bacon, the loin is removed from the carcass, trimmed, and typically injected with a meat curing brine containing sodium nitrite. The meat may be tumbled or directly stuffed into casings or a mold to shape it. It will then be cooked and/or smoked, cooled, and sliced (Varnam and Sutherland, 1995). The processing of Canadian-style bacon includes key steps that are very similar to those involved in the manufacture of most conventionally cured meat products. More recently, natural Canadian-style bacon has been offered in grocery stores as a no-nitrite- or -nitrate-added product. To achieve the same results as conventional curing, the processing of naturally cured Canadian-style bacon and the ingredients added to the brine must be modified. Because manufactured sodium nitrite or nitrate are no longer allowed in the curing brine, these compounds are often replaced by vegetable products that contain a natural source of nitrate.

The conversion of nitrate to nitrite in naturally cured products can produce inconsistent results, which is a major problem when consumers expect a meat product to have a uniform appearance and taste. In order for naturally cured Canadian-style bacon to

resemble conventionally cured Canadian-style bacon, the amount of celery powder that needs to be added and the concentration of nitrate in the celery powder needs to be known. The starter culture must be given enough time to convert ample amounts of nitrate to nitrite, which requires extra steps in the cooking cycle. The objectives of this research are to 1) determine if conventionally cured, naturally cured, and naturally cured with cherry powder Canadian-style bacon are significantly different in taste, 2) determine if a. conventionally cured with either ascorbate or erythorbate used as the reductant, b. naturally cured with celery powder containing preformed nitrite, c. naturally cured, d. naturally cured with cherry powder, and e. naturally cured Canadian-style bacon with lemon powder are significantly different in appearance, 3) analyze the amount of residual nitrite and nitrate in each of the treatments being studied, and 4) analyze lipid oxidation in each of the treatments being studied.

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CHAPTER 3. A COMPARISON OF RESIDUAL NITRITE AND NITRATE, LIPID OXIDATION, CUT-SURFACE COLOR, SENSORY AND VISUAL CHARACTERISTICS FOR NITRITE-ADDED AND NO-NITRITE- OR -NITRATE-ADDED CANADIAN-STYLE BACON

Abstract

The objective of this research was to compare residual nitrite, residual nitrate, lipid oxidation, and sensory and visual characteristics of conventionally cured Canadian-style bacon containing sodium nitrite to no-nitrite- or -nitrate-added Canadian-style bacon (naturally cured) during 7 or 12 weeks of storage. Three treatments were used for the first and second experiments: control, natural cure (NC) using celery powder with a nitrate reducing culture, and natural cure with cherry powder (NCCP) with a nitrate reducing culture; all of the pork loins used for these treatments were mechanically injected with brines. Six treatments were evaluated in a third experiment: control, control with ascorbate (NA), natural cure with preformed nitrite in celery powder (NCEL), NC, NCCP, and natural cure with lemon powder (NCLP); all treatments in the third experiment were processed by grinding the pork loins, then mixing with the ingredients. All natural cure treatments included celery powder and starter culture as ingredients and finished products were found to contain both residual nitrite and nitrate after incubation of the products for nitrate conversion. The control had significantly more ($P<0.05$) residual nitrite than NC and NCCP in the first experiment whereas in the second and third experiments the control and NC treatments had significantly more residual nitrite than NCCP. The control had significantly less residual nitrate ($P<0.05$) than the naturally cured treatments in the first experiment, but significantly more ($P<0.05$) in the second experiment. NCLP had significantly less residual nitrate ($P<0.05$) than NCCP in the third experiment, but no other treatments were significantly

different. Significant differences between TBARS values were observed only in the third experiment where NC and NCLP had significantly higher levels of TBARS ($P<0.05$) than all other treatments. The control was significantly darker and more red ($P<0.05$) than NC and NCCP in the first experiment, while in the second experiment it had similar lightness and redness to NCCP when evaluated by a Hunter Lab instrument. No significant differences ($P>0.05$) between the treatments for lightness or redness were found in the third experiment. Results from sensory panelists indicated that the control had more cured meat color intensity and was more tender, but contained more off-flavor ($P<0.05$) than NC and NCCP. According to the panel scores, NC and NCCP had significantly greater cured meat flavor intensity and overall were rated as having better flavor acceptability ($P<0.05$) than the control, although these results were not consistent with chemical analyses. These results demonstrate that natural curing processes can be successfully utilized for both injected and ground and then formed Canadian-style bacon.

Introduction

Certain meat products, such as Canadian-style bacon, ham, bacon, and frankfurters are well known for their characteristic cured meat properties. The process of curing means that nitrite or nitrate, which can be converted to nitrite by bacteria, have been directly added to the meat (Pearson and Tauber, 1984). This can be accomplished by rubbing the ingredients on the meat's surface and then allowing enough time for ingredients to be absorbed, by mixing the ingredients in water to form a brine which the meat can be immersed in or the brine can be injected into the meat, or by chopping or grinding the meat, adding nitrite or nitrate, and then mixing. Regardless of the method by which nitrite or nitrate is added, the United States Department of Agriculture - Food Safety and Inspection Service strictly regulates the amount that can be included (USDA-FSIS, 1995).

Currently, a number of meat products which are normally cured, including Canadian-style bacon, have been marketed as natural or no-nitrite- or -nitrate-added. This is not surprising given that consumer interest in natural and organic products has increased and that consumers are willing to pay premiums for these items (Sebranek and Bacus, 2007). In order for a product to be labeled as natural, it must follow the regulations put forth in the USDA Food Standards and Labeling Policy Book. This means the product cannot contain artificial flavoring, artificial coloring, chemical preservatives, or other artificial or synthetic ingredients, and that the product is minimally processed (USDA, 2005). Nitrate, nitrite, ascorbate, and erythorbate which are common ingredients found in cured meats are not allowed to be directly added to natural products. In order to meet these guidelines, yet maintain the appearance and flavor of the meat product which consumers are accustomed to,

many processors have turned to natural ingredients that contain natural sources of nitrate, which are not regulated by the USDA.

Vegetables, such as celery, contain high levels of nitrate (Siciliano et al., 1975). Celery juice can be concentrated and dried to form a powder that is easily added to meat. When a nitrate reducing starter culture is also added, the bacteria convert the nitrate to nitrite. The addition of cherry or lemon powder, which are acidic and contain reducing agents, allows the conversion of nitrite to nitric oxide to occur more rapidly. This step is accelerated by adding ascorbate or erythorbate in conventionally cured meats and is necessary for the development of cured flavor and color. The amount of nitrate found in celery and other vegetable powders can vary considerably and could result in inadequate or excessive amounts of residual nitrite in the finished product. When residual nitrite levels are too low, there is the potential for *Clostridium botulinum* growth whereas levels that are too high can be directly toxic or could result in carcinogenic nitrosamine formation.

Therefore, it is important to control the amount of residual nitrite in naturally cured meats while maintaining the appearance and flavor that consumers expect. The objectives of this study were to compare sensory and visual characteristics, residual levels of nitrite and nitrate, and lipid oxidation during storage in conventionally and naturally cured Canadian-style bacon.

Materials and Methods

Sample Preparation

Experiment 1

Frozen boneless pork loins (IMPS 414) were purchased from a local supplier and placed in a cooler overnight to thaw at the Iowa State University (ISU) Meat Laboratory. A

local meat processing firm helped procure the pork loins but did not fund this experiment. Two brines were prepared, a natural cure and a conventional cure. The distilled water for the brines was weighed a day in advance and stored in a cooler at 5° C overnight. Ingredients for the brines were measured and stored at 5° C (Table 1). On the day of processing, the thawed pork loins were weighed into three approximately twenty kilogram batches. The batches were randomly labeled: control, natural cure (NC), or natural cure with cherry powder (NCCP). Brines were blended with a mixer using a Baldor washdown duty motor (Baldor Electric Co., Fort Smith, AR, U.S.A).

The natural cure brine contained sea salt and raw sugar in place of commercial salt and sugar to make the Canadian-style bacon typical of a natural or organic meat product. The control brine contained curing salt (6.25% sodium nitrite), sodium erythorbate, and phosphate which are ingredients that are not allowed in natural and organic meat products, therefore they were not included in the natural cure brine. Celery powder and a starter culture were added to the natural cure brine but not the control brine since these ingredients are not included in conventional Canadian-style bacon.

The natural cure brine was injected at 126% of the raw meat weight into the natural cure treatment batch and natural cure with cherry powder treatment batch with a Townsend injector (Model P192-270, Townsend Engineering, Des Moines, IA, U.S.A.). The conventional cure brine was injected at 126% of the raw weight into the control batch. The loins were macerated with a Stork Protecon macerator (Type No. PMT-41, Oss, Netherlands), weighed, and if necessary, brine was added to the meat for tumbling to ensure the 126% target weight. The three batches were randomly placed in similarly sized tumblers: Josef Koch AG vacuum tumbler (Malters, Switzerland), Higashimoto Kikai Co. Ltd. vacuum

massager (Nava, Japan), Country Pride vacuum tumbler (Model 200, Country Pride, Minneapolis, MN, U.S.A). All batches were vacuum tumbled continuously for two hours at eight revolutions per minute. After two hours, cherry powder (0.0022% of the batch weight; Veg Dry Cherry 515, Florida Food Products, Inc., Eustis, FL, U.S.A.) dissolved in water (0.0026% of the batch weight) was added to the tumbler containing the natural cure with cherry powder treatment. At the same time, maltodextrin (0.0022% of the batch weight) was dissolved in water (0.0026% of the batch weight) and was added to the tumblers containing the control and natural cure treatments. Maltodextrin is a polysaccharide composed of dextrose and was added to the control and natural cure treatments in place of the cherry powder for the NCCP treatment to keep the processing procedures of the three treatments as similar as possible. Maltodextrin is a relatively inert compound that was expected to have minimal effects on the control and NC treatments. The batches were then vacuum tumbled continuously for one hour at eight revolutions per minute. The meat was removed from the tumblers, placed in Styrofoam coolers and transported to a local USDA inspected meat processing facility. Equipment at the USDA-inspected facility was used to process this product, but the meat processing facility did not fund this experiment. The pork loins were stuffed into approximately 8.3 cm diameter pre-smoked, shirred fibrous casing (T-Shirr #4 Smok-E#1, Visko Teepak, Mariehamn, Finland) using a Vemag stuffer (Model HP 10C, Vemag Maschinenbau GmbH, Verden, Germany), randomly placed on a smokehouse truck, and held in a cooler at 5° C overnight. The NC and NCCP batches were incubated in an Alkar smokehouse (Model 6000, Alkar Engineering Corp., Lodi, WI, U.S.A) at 40.6° C (Table 2) until the internal temperature of the product reached 37.8° C, then held for two hours at that temperature. Total incubation time was 5.5 hours. The control treatment was

then added to the Alkar smokehouse after the incubation phase was completed and all three treatments were cooked for 3.6 hours resulting in a total cooking time of 9.1 hours for the NC and NCCP treatments. After reaching a 70° C internal temperature, the pork loins were chilled overnight in a cooler at 5° C. The casings were peeled and the loins were sliced at 110 slices per kilogram using a Ryowa America slicer (Model RC-7800, Elk Grove Village, IL, U.S.A.), 113.5 grams of sliced meat was placed in each Rapid Packaging pouch (PPOU 6”x8.5”, Minneapolis, MN, U.S.A) and vacuum packed. The packages were brought back to the ISU Meat Laboratory and placed in boxes in a cooler at 2° C until analyses were performed. The experiment was conducted twice.

Experiment 2

Frozen boneless pork loins (IMPS 414) were purchased from a local supplier, delivered to ISU Meat Laboratory, and placed in a cooler at 5° C to thaw overnight. Two brines were prepared, a conventional cure and a natural cure brine. The ingredients for the brines were weighed and placed in a cooler overnight (Table 3). The ingredients included in the brines in the second experiment were slightly different than those used in the first experiment. Dried honey, which was included in both brines in the first experiment, was not added to either the conventional cure brine or the natural cure brine in the second experiment because sensory panelists indicated the Canadian-style bacon was noticeably sweet. Honey and sugar composed three percent (one and a half percent each) of the final product in the first experiment while in the second experiment no honey was added and sugar composed 1.7 percent of the final product. The formulation change was necessary to decrease the sweetness of the product. Since many Canadian-style bacon products do not contain honey, honey was eliminated from the formulation rather than decreasing both the sugar and honey

content, to make the product more typical of Canadian-style bacon products. Potassium lactate was not included in either brine in the second experiment since the USDA-FSIS no longer allowed meat products containing lactate to place an “all natural” claim on their label since lactate could be considered a preservative due to its antimicrobial effects. Previously, sodium lactate from a corn source was an accepted ingredient in natural products.

On the day of processing, the ingredients for the brines were dissolved in distilled water using a mixer with a Baldor washdown duty motor (Baldor Electric Co., Fort Smith, AR, U.S.A). The loins were weighed out into three groups of approximately fourteen kilograms each. The batches were randomly labeled: control, natural cure, or natural cure with cherry powder. The brines were injected into the loins for a target of 123% of the raw weight of the loins using a Townsend injector (Model P192-270, Townsend Engineering, Des Moines, IA, U.S.A.). Due to the changes in the brine formulation, particularly an increase in the percent of distilled water in the brine, the pork loins were injected to achieve 123% the raw weight of the loins rather than 126% which was the target in the first experiment.

The control brine was used for the control treatment, while the natural cure brine was injected into both the natural cure and natural cure with cherry powder treatments. The batches were each placed in separate tumblers (Model DVTS 50, Daniels Food Equipment, Parkers Prairie, MN, U.S.A.) and continuously vacuum tumbled for two hours at eight revolutions per minute. After two hours, maltodextrin (0.0022% of the batch weight) was dissolved in water (0.0026% of the batch weight) and was added to the tumblers for the control and natural cure treatments. At the same time, cherry powder (0.0022% of the batch weight; Veg Dry Cherry 515, Florida Food Products, Inc., Eustis, FL, U.S.A.) dissolved in water (0.0026% of the batch weight) was added to the tumbler containing the natural cure

with cherry powder treatment. The treatments were then vacuum tumbled continuously for one hour at eight revolutions per minute, then randomly placed on a smokehouse truck and stored in a cooler at 5° C overnight. The following morning the treatments were cooked (Table 2) in an Alkar smokehouse (Model MT EVD RSE 4, Alkar Engineering Corp., Lodi, WI, U.S.A.) and then chilled overnight. The loins were sliced at 0.635 cm using a Bizebra slicer (Model SE12D, Bizebra GmbH & Co., Balingen, Germany) and then vacuum packed with a Multivac packaging machine (Model A6800, Multivac Inc., Kansas City, MO, U.S.A) into Cryovac bags (7”x14”, Cryovac Sealed Air Corp., Duncan, SC, U.S.A) with eight slices per bag. The bags were stored in boxes in a cooler at 2° C until analyzed. The experiment was conducted twice.

Experiment 3

Frozen boneless pork loins (IMPS 414) were purchased from a local supplier and placed in a cooler at 5° C to thaw overnight at the ISU Meat Laboratory. Ingredients were weighed and stored in a cooler at 5° C (Table 4). Similar to the second experiment, potassium lactate and honey were not included in any treatments in the third experiment. Red Arrow LFBN smoke, which was included in all treatments in the first and second experiments, was also not added to any treatments in the third experiment. Red Arrow LFBN smoke is a low flavor smoke that is meant to be added to brines. LFBN smoke was not included in the third experiment since the processing procedure was modified and ingredients were directly added to ground meat rather than dissolved in water to form a brine. In addition, LFBN smoke was not added because it can be considered an artificial flavor which is not allowed in natural products.

For this experiment, the loins were ground with a 0.63 cm plate using a Biro grinder (Model 75424852, Biro MFG Co., Marblehead, Ohio) and weighed into six groups of twenty kilograms each. The groups were randomly labeled: control, control with sodium ascorbate, natural cure with preformed nitrite in celery powder, natural cure, natural cure with cherry powder, and natural cure with lemon powder. The ingredients (Table 4) were added to the ground meat to achieve a final product weight that was 126% of the raw weight of the pork loins. The ingredients were mixed with the ground pork for two minutes in a Higashimoto mixer (Model 90.3.3, Higashimoto Kikai Co. Ltd., Nava, Japan). The processing method was changed in the third experiment to replicate procedures that are used for restructured cured meats in commercial meat processing.

The ground pork loin and ingredient mixture was stuffed into approximately 8.8 cm diameter fibrous casing (Visko Teepak, Mariehamn, Finland) using a Risco vacuum stuffer (Model RS 4003-165, Risco USA Corp., South Easton, MA, U.S.A.), randomly loaded onto a smokehouse truck, and chilled overnight. The following morning the meat was thermoprocessed (Table 2) in an Alkar smokehouse (Model MT EVD RSE 4, Alkar Engineering Corp., Lodi, WI, U.S.A.) and chilled overnight in a cooler at 5° C. The casings were peeled, the Canadian-style bacon was sliced at 0.635 cm per slice and eight slices were placed in Cryovac bags (7”x14”, Cryovac Sealed Air Corp., Duncan, SC, U.S.A.). The product was vacuum packed using a Multivac packaging machine (Model A6800, Multivac Inc., Kansas City, MO, U.S.A), placed in boxes, and stored in a cooler at 2° C until analyzed. The experiment was conducted twice.

Analyses

Residual nitrite, residual nitrate, thiobarbituric acid reactive substances (TBARS), and color were analyzed in all three experiments. Sensory and visual evaluations were done in the first experiment only. In the first experiment, the analyses were conducted following 0, 2, 4, 6, 8, 10 and 12 weeks of storage. In the second and third experiments, the measurements were taken following 0, 1, 2, 3, 5 and 7 weeks, except for residual nitrate which was measured at weeks 0, 1, 3 and 7 for the third experiment.

Residual Nitrite

The Association of Official Analytical Chemists (AOAC) method was used to analyze samples for residual nitrite (AOAC, 1990). All samples were analyzed in duplicate and the measurements were averaged prior to statistical analysis.

Residual Nitrate

Samples were removed from the cooler on the sampling date and frozen until they could be analyzed. Residual nitrate measurements were analyzed in duplicate using the method described by Ahn and Maurer (1987).

Thiobarbituric Acid Reactive Substances

TBARS were measured on duplicate samples using the cured meat method outlined by Zipser and Watts (1962). The absorbance of the samples at 532 nm was recorded using a Beckman DU 640 spectrophotometer. The total mg of malonaldehyde equivalents per kilogram of meat was determined by multiplying the absorbance measurement by 7.8, which was derived from a standard curve.

Color

Color (L*, a*, b*) was measured on the surface of meat slices wrapped in Saran Wrap using a Hunter Lab Labscan spectrocolorimeter (Hunter Associated Laboratories Inc., Reston, VA, U.S.A.) for the first and second experiments. The spectrocolorimeter was standardized using a black and white tile (X=81.72, Y=86.80, Z=91.46). The Hunter Lab Labscan spectrocolorimeter model XE (Hunter Associated Laboratories Inc., Reston, VA, U.S.A.) was used during the second and third experiments. The spectrocolorimeter was standardized using a black and white tile (X=80.45, Y=85.37, Z=90.79). The white tile was wrapped in Saran Wrap before standardization for all three experiments. In the first experiment, a port size of 3.048 cm and a viewing area of 2.54 cm was used to take three measurements on three meat slices for a total of nine measurements for each treatment. In the second experiment, a port size of 1.778 cm and viewing area of 1.27 cm was used when taking two measurements on three meat slices for a total of six measurements for each treatment. This procedure was performed using both spectrocolorimeters for measurement comparison during the second experiment. In the third experiment, two measurements were taken on three meat slices for a total of six measurements for each treatment; a port size of 1.778 cm and viewing area of 1.27 cm was used. In all three experiments the light source was set at D65, equivalent to noon daylight, and there was a 10° observer field.

Consumer Sensory and Visual Evaluations

A sensory group of volunteer panelists, ranging from seven to eleven participants per week from a local meat processing firm, evaluated the sensory and visual appearances of the Canadian-style bacon at weeks 0, 2, 4, 6, 8, 10, and 12. Several of the panelists were present every week that evaluations were performed, while other panelists were only present for a

few of the time points when evaluations were conducted. Sensory panelists came from the following departments: sales and marketing, quality assurance, research and development, and production and purchasing. Some of the panelists had previously been involved in sensory and visual evaluations for other meat products, while other panelists had no prior experience. One week prior to the first evaluation, the panelists attended two two-hour training sessions where they learned about the standard visual and sensory characteristics for Canadian-style bacon, they were given a copy of the visual and sensory evaluation forms, and they practiced visual and sensory evaluations on Canadian-style bacon. The local meat processing firm, where the evaluations were conducted, helped train the panelists and set-up the rooms where evaluations were performed, but they did not fund this experiment.

When evaluating Canadian-style bacon, the panelists were presented one slice of each of the three treatments from the first experiment: control, natural cure, natural cure with cherry powder. Each sample was presented at room temperature on a separate white disposable paper plate and was labeled with a random three-digit number. The panelists were seated at different tables with their backs to one another in a room dimly lit with red light to mask sample color. The samples were first evaluated for sensory characteristics (Table 5). The panelists were then moved to a well-lit room and given a second set of the three samples which were labeled with different random numbers than the first set and asked to fill out a visual evaluation (Table 6). All characteristics were evaluated on an unstructured 15 cm line scale where panelists placed a hash mark on the line and labeled it with the three-digit number given to the sample. A ruler was used to measure how far the hash mark was located from the left edge of the line, a measurement of zero indicated the characteristic was

not present and a measurement of 150 mm indicated the sensory or visual characteristic was intense. This method is described by Prestat et al. (2002).

Statistics

Statistical Analysis Software's (SAS Institute Inc., version 9.1, Cary, NC, U.S.A.) Proc GLM with a Tukey's studentized range test was used to separate means and determine least significant differences. The model accounted for repetition and analyzed for week, treatment, and week x treatment interactions. Measurements were deemed significant if $P<0.05$ for Tukey's studentized range test.

Results and Discussion

Experiment 1

Residual Nitrite

In the first experiment, all three treatments had significantly different ($P<0.05$) mean residual nitrite values (Table 7). The control treatment had the highest level of residual nitrite and the natural cure with cherry powder (NCCP) treatment had the least. Both of the natural cure treatments had considerably less residual nitrite than the control. The cherry powder which is high in ascorbic acid, it contains approximately 5% ascorbic acid, resulted in the least residual nitrite probably due to the reducing activity of the ascorbic acid. Over time, the general trend of all three treatments was a decrease in residual nitrite (Figure 1).

Residual Nitrate

Residual nitrate was measured at weeks 0, 2, 4, 6, 8, 10, and 12 during storage for the first experiment. The mean residual nitrate level during the 12 weeks of storage was calculated (Table 7). The control treatment had significantly lower amounts of nitrate ($P<0.05$) than the two naturally cured treatments, yet contained a significant concentration

even though no nitrate was added. As expected, the natural cure treatments had the highest levels of nitrate and the lowest amount of nitrite since only nitrate was converted to nitrite (Table 7). During the 12 week storage period, the general trend was a slight increase in the residual nitrate for all three treatments (Figure 2).

Thiobarbituric Acid Reactive Substances

There were no significant differences in mean TBARS values among the three treatments in the first experiment (Table 7).

Color

In all three experiments, the cut surface of the Canadian-style bacon was analyzed for Hunter L*, a*, b* color values. The mean Hunter L*, a*, b* values during twelve weeks of storage were calculated (Table 8). The control in the first experiment was significantly darker and more red ($P<0.05$) than the naturally cured treatments (Table 8) indicating the control showed a more prominent cured color, which is most likely due to its higher level of nitrite. The control was also significantly less yellow ($P<0.05$) than the other treatments in the first experiment.

Consumer Sensory and Visual Evaluations

Sensory and visual evaluations were completed by panelists for the first experiment and the mean score for each sensory and visual characteristic over twelve weeks of storage was determined (Table 9). The control was scored as significantly ($P<0.05$) more tender, but with greater off-flavor and less acceptable flavor than NC and NCCP when comparing the average score during twelve weeks of storage. However, these results were not completely consistent with chemical analyses. When the sensory evaluation scores were analyzed per week, the control was significantly more tender ($P<0.05$) than NC only during weeks 8 and

12 (Table 10). The control treatment was thermoprocessed for 3.6 hours while the NC and NCCP treatments were thermoprocessed for 9.1 hours; increasing the cooking time of meat can result in an increased water loss during cooking and may account for the decreased tenderness noted in the naturally cured treatments. The control had greater off-flavor ($P<0.05$) than NCCP only during week 2 (Table 10). There were no significant differences ($P>0.05$) for flavor acceptability between the three treatments when comparing the sensory scores by week (Table 10). When analyzing the mean sensory scores, NCCP had the least amount of off-flavor and had the most acceptable flavor overall which fits with the general trend that as off-flavor decreased, acceptability increased. The control had a significantly lower ($P<0.05$) average cured meat flavor intensity than NC and NCCP (Table 9) which was surprising given that the control was a conventionally cured product, but this may have been due to differences among panelists' abilities to detect cured meat flavor or confusion about how to define the flavor of cured meat. NC and NCCP had a significantly higher cured meat flavor intensity ($P<0.05$) than the control treatment only at week 6 when the treatments were compared by week (Table 10). There were no significant differences ($P>0.05$) for the average or weekly sweetness scores among the treatments. The control was significantly less ($P<0.05$) salty than NC and NCCP at week 8. The control also had a significantly lower average saltiness score during the twelve week period than NC and NCCP which was expected since the control contained a lower percentage of salt due to the different ingredient formulations for the natural cure and control brines. The percentage of salt in the control brine was approximately one percent less than the percent of sea salt in the natural cure brine.

The control had significantly ($P<0.05$) greater cured meat color intensity than both NC and NCCP during week 6 (Table 11) and the control had a higher mean cured meat color

intensity (Table 9) than NC and NCCP during twelve weeks of storage. This was expected since the control had a higher level of initial nitrite, thus increasing the amount of red and pink cured meat pigment that was formed resulting in a significantly higher ($P<0.05$) Hunter a* value than in NC and NCCP. NC was significantly less ($P<0.05$) uniform in color during the twelve week storage period (Table 9) and all three treatments were significantly different ($P<0.05$) during week 12 with the control being the most uniform and the natural cure being the least uniform in color (Table 11). NC had a significantly higher ($P<0.05$) mean other color score than the control during the 12 week storage period (Table 9). Other color-related panelist comments included observations of blotchy areas of gray or tan, white streaks, and/or dark red blotches. When the treatments were compared by week, there were no significant differences between the three treatments for other color characteristics (Table 11).

Certain sensory and visual characteristics that were analyzed had a higher standard error of the means (SEM) per weekly sampling time point and/or for the twelve week average. This may have been due to panelist bias that could result from personal preferences or from previous experiences participating in sensory evaluations and training sessions for other products.

Experiment 2

Residual Nitrite

Similar to the first experiment, NCCP had the lowest residual nitrite mean ($P<0.05$) in the second experiment (Table 7), although in this case, NC and the control had similar mean nitrite concentrations. In general, all three treatments showed a decrease in residual nitrite during a seven week storage period (Figure 3). During weeks 0, 1, and 2, all three treatments had significantly different levels of residual nitrite ($P<0.05$), yet from week 3 to week 7 the

NC and control treatments had similar levels of residual nitrite (P>0.05). During the incubation process, the measurable nitrite in the NC treatment increased to its highest concentration after 4 hours, while the NCCP treatment peaked about 30 minutes later at the start of the third step in the cooking cycle (Figure 4). Both decreased in measureable nitrite throughout the rest of the cooking period.

Residual Nitrate

In the second experiment, residual nitrate was analyzed at weeks 0, 1, 2, 3, 5, and 7. Similar to the first experiment, the control was significantly different (P<0.05) from NC and NCCP but in the second experiment the control had more nitrate than the naturally cured treatments (Table 7). In the second experiment, NC and NCCP started with a lower initial nitrate level at week 0 than the control and also less than NC and NCCP in the first experiment (Figure 5). There was considerably less nitrate remaining in the two natural cure treatments suggesting a more complete conversion of nitrate to nitrite. Variation in the added ingredients, such as a lower concentration of nitrate in celery powder in the second experiment or the lack of honey and potassium lactate in the brine formulation in the treatments in the second experiment, might have affected the nitrate reduction to nitrite. During the 7 week storage period, the general trend was a slight decrease in the levels of nitrate for all three treatments.

Thiobarbituric Acid Reactive Substances

There were no significant differences in mean TBARS values among the three treatments in the second experiment (Table 7).

Color

The mean Hunter L*, a*, b* values during seven weeks of storage were calculated (Table 8). The NC treatment was lighter and had a lower a* value ($P<0.05$) than the control and NCCP in the second experiment (Table 8) and NCCP was significantly more yellow than the control ($P<0.05$). There was a large difference between the first and second experiments for a* values which may be due to variation in the pork loins used between the two experiments. By visual observation, the loins used in the second experiment appeared to contain more fat which would reduce surface redness measurement values. Further, when considering treatments in the same experiment, muscle fiber type variation and genetic differences between individual animals can affect the color of the finished product (Lonergan et al., 2003).

Experiment 3

Residual Nitrite

In the third experiment, the control treatment had a higher residual nitrite mean during seven weeks of storage ($P<0.05$) than the natural cure with preformed nitrite in celery powder (NCEL), NCCP, and the natural cure with lemon powder (NCLP) treatments (Table 7) but was not different from the NC treatment. NCEL and NCCP contained the lowest amounts of residual nitrite and were not significantly different from each other ($P>0.05$), but had significantly less residual nitrite ($P<0.05$) compared to the other four treatments. The NCEL treatment contained low amounts of nitrite throughout the entire experiment including the initial nitrite measurement that was conducted after the ingredients were mixed with the ground pork loins. This suggests that the ingredients in this treatment contained less nitrite and nitrate than in the other natural cure treatments. NCCP had similar nitrite levels to NCLP up until the treatments had been cooked for one hour, after this time point NCLP had

consistently higher nitrite levels throughout the entire experiment. This is most likely due to ingredient differences between the two treatments. The NCLP treatment contained lemon powder which is high in citric acid, it contains approximately 3% citric acid, and NCCP contained cherry powder which contains approximately 5% ascorbic acid. In addition, NCLP had slightly more water, sea salt, and raw sugar than NCCP although the differences were minor and therefore unlikely to contribute to the difference in residual nitrite levels between the two treatments. This suggests that the NCCP treatment may have reduced nitrite more completely than NCLP and thus contained less residual nitrite throughout the entire experiment. The control treatment containing ascorbate had somewhat less residual nitrite than the control without ascorbate but this difference was not statistically significant ($P>0.05$). As expected, the residual nitrite content in all six treatments decreased over time during the seven week storage period (Figure 6). During thermal processing, the nitrite levels in both NC and NCLP peaked after being incubated for 5 hours (Figure 7). For the NCCP treatment, the highest level of nitrite during incubation was observed after three and a half hours with relatively little change during the rest of the process.

In all three of the experiments, the naturally cured treatments resulted in measurable amounts of nitrite from nitrate without the addition of chemically formed nitrite and nitrate. The naturally cured products had zero or insignificant levels of nitrite prior to incubation. This indicates that the nitrate in the formulation ingredients, such as the celery powder, was effectively converted to nitrite. In each of the experiments, it was expected that during the incubation phase of the cook cycle, the amount of nitrite in the NC, NCCP, and NCLP treatments would increase over time as the nitrate in the celery powder was converted to nitrite by bacteria in the starter culture, and this was observed. This occurred despite the fact

that nitrite was undoubtedly reacting with meat components at the same time to produce nitric oxide and the resultant typical cured meat properties. Consequently, it is impossible to precisely determine how much nitrite was actually formed in each case. During the storage period of seven or twelve weeks it was expected that the residual nitrite would decrease over time as nitrite continued to be converted to other compounds such as nitrous acid and nitric oxide, and this was the general trend observed in all three experiments.

The treatments that did not have sodium nitrite directly added to them contained less residual nitrite, which was anticipated as the amount of nitrate converted to nitrite by bacteria can be variable depending on the initial concentration of nitrate in the celery powder, the temperature and duration of the incubation phase, and the health and activity of the bacteria in the starter culture. It is also likely that the levels of nitrate in the celery powder at the recommended usage level were too low to produce an amount of nitrite similar to that added directly to a conventional cure. NCCP and NCLP which contained reducing compounds and acidic substances, cherry powder and lemon powder respectively, most likely aided in a greater conversion of nitrite to pigment forming compounds and other reaction products which accounted for their lower levels of residual nitrite compared to the other naturally cured treatments.

Residual Nitrate

Residual nitrate was measured before cooking and at weeks 0, 1, 3, and 7 for all six treatments in the third experiment. The three naturally cured treatments with celery powder that contained nitrate rather than preformed nitrite (NC, NCCP, NCLP) had the highest levels of nitrate prior to cooking, as expected. Over the seven week storage period, the amount of nitrate in NCLP was significantly lower ($P<0.05$) than in NCCP, but no other differences

(P>0.05) were noted (Table 7). This may be due to differences in the content of nitrate in the raw materials, acidity of the lemon powder, or the modification of the processing procedure whereby ingredients were mixed with the ground meat rather than mechanically injected into an intact pork loin. The residual nitrate levels plateaued from week one to week seven, with the amount ranging from 9 to 23 ppm nitrate for the six treatments during that time period (Figure 8).

Thiobarbituric Acid Reactive Substances

In the third experiment, the NC and NCLP treatments had significantly higher (P<0.05) TBARS values (Table 7) than the other four treatments. The higher oxidation products found in these two naturally cured treatments might be explained by their relatively low levels of nitrite and a lack of phosphate, both of which help prevent rancidity. However, the NCEL and NCCP treatments resulted in low values for both residual nitrite and TBARS. For all practical purposes, due to the low TBARS values (<0.5) in all three experiments, no treatments at any sampling points would have been considered to have a rancid odor or flavor, and the slight differences in TBARS are not practically important.

Color

The mean Hunter L*, a*, b* values during seven weeks of storage were calculated (Table 8). There were no significant differences for lightness (L*) or redness (a*) among the six treatments in the third experiment based on the mean L* and a* values during seven weeks of storage (Table 8) which could be attributed to the processing procedure used. The pork loins were ground and mixed in the third experiment which would result in a better distribution of fat, more uniformity, and fewer light areas. The similar a* values indicate that each treatment showed a similar amount of cured color. The control, control with ascorbate,

and natural cure with preformed nitrite in celery powder treatments were significantly less yellow ($P<0.05$) than the NC, NCCP, and NCLP treatments. NCCP had significantly more yellow color to it than all other treatments ($P<0.05$). Despite the significant differences for yellowness, the Hunter b* values were quite low and the range was small (5.59-7.01) and it is unlikely that such a difference would be detected by consumers.

Summary

The most important differences between conventional and naturally cured Canadian-style bacon that were observed in this study were for residual nitrite, residual nitrate, instrumental color (Hunter Lab), and sensory and visual evaluations. In the first experiment, the control had significantly more ($P<0.05$) residual nitrite than NC and NCCP. In the second and third experiments, the control and NC treatments had significantly more residual nitrite than NCCP. Therefore, the addition of ingredients, such as ascorbic acid in cherry powder which is both a reductant and an acidic compound, to naturally cured products appears to result in less residual nitrite. While this is advantageous for color development, this needs further investigation to determine if adequate levels of residual nitrite are present to maintain protection from bacterial pathogens such as *Clostridium botulinum* and to help prevent lipid oxidation. Although there were significant differences among the treatments for residual nitrite, only the third experiment showed significant differences between TBARS values with NC and NCLP having significantly higher levels of TBARS ($P<0.05$) than all other treatments. This suggests that the amount of residual nitrite in the naturally cured treatments in most cases was sufficient enough to prevent lipid oxidation.

The amount of residual nitrate observed depended on the amount added as celery powder and the amount converted to nitrite, which resulted in variation between the

experiments. The control had significantly less residual nitrate ($P<0.05$) than the naturally cured treatments in the first experiment, but significantly more ($P<0.05$) in the second experiment. When nitrite is added to meat, a portion of it can be converted to nitrate (Honikel, 2008). The increase in nitrate and the subsequent decrease in nitrite in the control treatment in the second experiment, as compared to the first experiment, could be due to an increased conversion of nitrite to nitrate although the exact reason for this is not clear. The control brine in the second experiment did contain a higher percentage of phosphate than in the first experiment. Since phosphate is basic, an increased amount of phosphate in the brine should increase the pH of the pork loins. In meat, nitrite is normally in equilibrium with nitrous acid and under acidic conditions nitrous acid is converted to nitric oxide. Increasing the amount of phosphate added to the meat increases the pH of the meat which then slows the conversion of nitrous acid to nitric oxide which allows nitrite to take part in side reactions, one of which forms nitrate and could account for the residual nitrate results in the second experiment. Certainly, the differences in the ingredient composition of the brines in the first and second experiments may have contributed to at least some of the differences in the results of these two experiments.

Results from the Hunter Lab instrument for color, showed that the control was significantly less light and more red ($P<0.05$) than NC and NCCP in the first experiment, but was similar in lightness and redness ($P>0.05$) to NCCP in the second experiment. In the third experiment there were no significant differences found between the six treatments when lightness and redness were compared. This suggests that changes in the processing steps, such as grinding the pork loins and then mixing in the ingredients rather than dissolving the ingredients in water to form a brine that is mechanically injected into pork loins and then

tumbling the meat for three hours, can result in a more uniform naturally cured product with an appearance that cannot be differentiated from a conventionally cured product.

Sensory and visual evaluation by panelists indicated that the control was more tender and had more cured meat color intensity on average during the twelve week storage period ($P<0.05$) than NC and NCCP. The control was more uniform in color than NC ($P<0.05$). It is not clear why tenderness might differ but the increased thermoprocessing time for the naturally cured treatments may have resulted in increased water cooking losses and decreased tenderness in the naturally cured treatments. Increased cured meat color intensity and uniformity were expected in the conventionally cured product due to a greater concentration of added nitrite. However, the control had the most off-flavor and was considered to have the least acceptable taste of the three treatments, which was not consistent with chemical analyses. This difference was unexpected and not easily explained because TBARS values for the control and the naturally cured treatments were not different, but it may be due more to differences in the flavor of the ingredients in the control and natural cure brines than to a true off-flavor. The control brine contained regular commercial-grade salt and sugar, phosphate, sodium erythorbate, and sodium nitrite which were not found in the natural cure brine. Phosphates, in particular, have been reported to affect flavor in some cases (Chambers et al., 1992). The natural cure brine contained sea salt, raw sugar, celery powder, and a starter culture; all of which were not included in the control brine. NC and NCCP had comparable mean scores ($P>0.05$) that were significantly higher for cured meat flavor intensity and acceptability, and lower for off-flavor than the control ($P<0.05$) although these results were not completely consistent with chemical analyses. Certain sensory and visual

characteristics had a high SEM when the scores were analyzed, this may have resulted from panelist bias or insufficient sensory and visual evaluation training.

Conclusions

These results indicate that the production of a naturally cured Canadian-style bacon product that is perceived by consumers to be similar to or possibly better than conventionally cured Canadian-style bacon can be achieved by modifying processing procedures to include nitrate conversion or by using previously converted nitrite. Changing the brine formulation to include natural ingredients that will provide an acceptable amount of nitrite for curing reactions in the final product is the key to producing a naturally cured product with typical cured meat properties.

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Table 1. Brine formulations for the three treatments in experiment 1

Brine formulation for the control treatment (26% injection):

Ingredient	**Percent**
Distilled water	57.86
Potassium lactate	12.40
Salt	11.17
Sugar	7.44
Honey (dried)	7.44
Phosphate	1.49
Curing salt (6.25% sodium nitrite)	0.99
Red Arrow LFBN smoke	0.99
Sodium erythorbate	0.22

Brine formulation for the natural cure and natural cure with cherry powder treatments (26% injection):

Ingredient	**Percent**
Distilled water	58.28
Potassium lactate	12.41
Sea salt (388915, Foran, Oak Creek, WI, U.S.A.)	12.12
Raw sugar	7.44
Honey (dried)	7.44
Celery powder (Veg Dry 503, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.24
Red Arrow LFBN smoke	0.99
Starter culture (CS 299 Bactoferm, Chr. Hansen Inc., Horsholm, Denmark)	0.08

Table 2. Thermal processing cycle used for the Canadian-style bacon study

Step	Time (min)	Dry bulb (°C)	Wet bulb (°C)	IT (°C)	Relative humidity	Exhaust dampers
1	-	40.6	39.4	37.8	93%	Auto
2	120	40.6	39.4	37.8	93%	Auto
3	60	71.1	46.1	-	26%	Auto
4	75	73.9	46.1	-	22%	Auto
5	30	76.7	-	-	-	Auto
6	30	76.7	65.6	-	60%	Auto
7	1	82.2	82.2	70.0	100%	Closed
8	20	10.0	-	-	-	Auto

Natural cure, natural cure with cherry powder, and natural cure with lemon powder treatments were added at the start of step 1, all other treatments were added at the start of step 3.

Table 3. Brine formulations for the three treatments in experiment 2

Brine formulation for the control treatment (23% injection):

Ingredient	**Percent**
Distilled water	72.19
Salt	13.94
Sugar	9.28
Phosphate	1.86
Red Arrow LFBN smoke	1.24
Curing salt (6.25% sodium nitrite)	1.22
Sodium erythorbate	0.27

Brine formulation for the natural cure and natural cure with cherry powder treatments (23% injection):

Ingredient	**Percent**
Distilled water	72.71
Sea salt (388915, Foran, Oak Creek, WI, U.S.A.)	15.12
Raw sugar	9.28
Celery powder (Veg Stable 501, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.55
Red Arrow LFBN smoke	1.24
Starter culture (CS 299 Bactoferm, Chr. Hansen Inc., Horsholm, Denmark)	0.10

Table 4. Ingredient formulations for the six treatments in experiment 3

Ingredient formulation for control treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	72.52
Salt	13.70
Sugar	9.13
Phosphate	1.83
Maltodextrin	1.35
Curing salt (6.25% sodium nitrite)	1.20
Sodium erythorbate	0.27

Ingredient formulation for control with ascorbate treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	72.52
Salt	13.70
Sugar	9.13
Phosphate	1.83
Maltodextrin	1.35
Curing salt (6.25% sodium nitrite)	1.20
Sodium ascorbate	0.27

Ingredient formulation for natural cure with preformed nitrite in celery powder treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	72.70
Salt	13.73
Sugar	9.15
Phosphate	1.83
Maltodextrin	1.35
Celery powder (Veg Stable 504, Florida Food Products, Inc., Eustis, FL, U.S.A.)	0.97
Sodium erythorbate	0.27

Ingredient formulation for natural cure treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	73.04
Sea salt (388915, Foran, Oak Creek, WI, U.S.A.)	14.86
Raw sugar	9.13
Celery powder (Veg Stable 501, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.52
Maltodextrin	1.35
Starter culture (CS 299 Bactoferm, Chr. Hansen Inc., Horsholm, Denmark)	0.10

Ingredient formulation for natural cure with cherry powder treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	73.04
Sea salt (388915, Foran, Oak Creek, WI, U.S.A.)	14.86
Raw sugar	9.13
Celery powder (Veg Stable 501, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.52
Cherry powder (Veg Stable Cherry 515, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.35
Starter culture (CS 299 Bactoferm, Chr. Hansen Inc., Horsholm, Denmark)	0.10

Ingredient formulation for natural cure with lemon powder treatment (final weight is 126% of raw weight):

Ingredient	**Percent**
Water	74.03
Sea salt (388915, Foran, Oak Creek, WI, U.S.A.)	15.06
Raw sugar	9.25
Celery powder (Veg Stable 501, Florida Food Products, Inc., Eustis, FL, U.S.A.)	1.54
Lemon powder (Veg Stable Lemon 520, Florida Food Products, Inc., Eustis, FL, U.S.A.)	0.02
Starter culture (CS 299 Bactoferm, Chr. Hansen Inc., Horsholm, Denmark)	0.10

Table 5. Sensory evaluation of Canadian-style bacon in the first experiment

Name_____ Date_____

Sensory Evaluation of Canadian Style Bacon
Water Added Fully Cooked

Taste the samples in the order presented to you. Please rinse your mouth with water before starting and between samples. Indicate the intensity of the attribute by making a vertical mark on that portion of the line that represents your evaluation. Label the vertical mark with the sample number.

Tenderness

None intense

Cured Meat flavor intensity

None intense

Saltiness

None intense

Sweetness

None intense

Off-Flavor

None intense

Acceptability

None intense

Comments:

Table 6. Visual evaluation of Canadian-style bacon in the first experiment

Name_____ Date_____

Visual Evaluation of Canadian Style Bacon
Water Added Fully Cooked

Taste the samples in the order presented to you. Please rinse your mouth with water before starting and between samples. Indicate the intensity of the attribute by making a vertical mark on that portion of the line that represents your evaluation. Label the vertical mark with the sample number.

Cured Meat Color Intensity

None intense

Uniform Color

None intense

Lightness

None intense

Other Color (please describe under comments)

None intense

Comments:

Table 7. Least square means for residual nitrite, residual nitrate, and thiobarbituric acid reactive substances (TBARS) for experiments 1, 2, and 3

Experiment 1	**Treatment**	**Residual Nitrite**	**Residual Nitrate**	**TBARS**
	Control	49.37^{b}	27.15^{c}	0.13^{b}
	Natural Cure	13.91^{c}	39.09^{b}	0.14^{b}
	Natural Cure with Cherry Powder	5.25^{d}	42.58^{b}	0.13^{b}
	SEM[a]	1.11	1.66	0.004
Experiment 2	**Treatment**	**Residual Nitrite**	**Residual Nitrate**	**TBARS**
	Control	18.94^{b}	34.09^{b}	0.11^{b}
	Natural Cure	15.44^{b}	24.68^{c}	0.13^{b}
	Natural Cure with Cherry Powder	10.27^{c}	24.52^{c}	0.12^{b}
	SEM[a]	1.22	1.01	0.01
Experiment 3	**Treatment**	**Residual Nitrite**	**Residual Nitrate**	**TBARS**
	Control	26.54^{b}	16.40^{bc}	0.07^{c}
	Control with Ascorbate	21.88^{bc}	13.80^{bc}	0.08^{c}
	Natural Cure	21.08^{bc}	14.25^{bc}	0.22^{b}
	Natural Cure with Preformed Nitrite in Celery Powder	6.99^{d}	14.19^{bc}	0.08^{c}
	Natural Cure with Cherry Powder	8.09^{d}	20.49^{b}	0.10^{c}
	Natural Cure with Lemon Powder	19.58^{c}	11.30^{c}	0.21^{b}
	SEM[a]	1.57	1.60	0.01

[a] Standard error of the means

[b-d] Means in the same column with different superscripts are different ($P<0.05$)

Least square means were calculated from the average of the values obtained for each analysis performed during twelve weeks of storage for experiment 1 and seven weeks of storage for experiments 2 and 3.

Table 8. Least square means for Hunter L*, a*, b* of Canadian-style bacon in experiments 1, 2, and 3

Experiment 1	**Treatment**	**Hunter L***	**Hunter a***	**Hunter b***
	Control	45.57[b]	15.47[b]	8.99[b]
	Natural Cure	50.92[c]	12.52[c]	10.00[c]
	Natural Cure with Cherry Powder	51.63[c]	12.34[c]	10.32[c]
	SEM[a]	0.76	0.32	0.15
Experiment 2	**Treatment**	**Hunter L***	**Hunter a***	**Hunter b***
	Control	63.37[b]	7.27[b]	8.55[b]
	Natural Cure	65.91[c]	6.57[c]	9.08[bc]
	Natural Cure with Cherry Powder	63.50[b]	7.43[b]	9.22[c]
	SEM[a]	0.52	0.19	0.17
Experiment 3	**Treatment**	**Hunter L***	**Hunter a***	**Hunter b***
	Control	58.69[b]	9.01[b]	5.59[b]
	Control with Ascorbate	59.15[b]	8.64[b]	5.63[b]
	Natural Cure	59.42[b]	8.45[b]	6.46[c]
	Natural Cure with Preformed Nitrite in Celery Powder	58.93[b]	8.48[b]	5.37[b]
	Natural Cure with Cherry Powder	59.01[b]	8.55[b]	7.01[d]
	Natural Cure with Lemon Powder	59.37[b]	8.69[b]	6.28[c]
	SEM[a]	0.34	0.14	0.08

[a] Standard error of the means

[b-d] Means in the same column with different superscripts are different ($P<0.05$)

Least square means were calculated from the average of the values obtained for each analysis performed during twelve weeks of storage for experiment 1 and seven weeks of storage for experiments 2 and 3.

Table 9. Least square means for sensory and visual evaluations of Canadian-style bacon in the first experiment

Sensory Evaluation Characteristics	Control	Natural Cure	Natural Cure with Cherry Powder	SEM[a]
Tenderness	91.31[b]	64.02[c]	64.96[c]	3.50
Cured Meat Flavor Intensity	76.83[b]	90.15[c]	91.85[c]	1.49
Saltiness	73.16[b]	96.54[c]	97.83[c]	2.48
Sweetness	59.70[b]	64.70[b]	65.68[b]	1.96
Off-flavor	27.75[b]	22.99[bc]	17.19[c]	1.94
Acceptability	88.94[b]	101.15[c]	110.13[c]	2.94
Visual Evaluation Characteristics	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Cured Meat Color Intensity	100.51[b]	66.90[c]	73.21[c]	3.86
Uniform Color	95.15[b]	59.33[c]	75.17[bc]	5.74
Lightness	94.47[b]	60.53[c]	68.70[c]	7.17
Other Color	17.39[b]	30.32[c]	23.14[bc]	3.09

[a] Standard error of the means

[b-c] Means in the same row with different superscripts are different ($P<0.05$)

Least square means were calculated from the average of the values obtained for each analysis performed during twelve weeks of storage.

Interpretation of the evaluation scores:

All evaluations were conducted on a 15 cm line scale. Each evaluation was measured in millimeters beginning with a score of zero mm on the left edge of the line and 150 mm on the right edge of the line. A score of zero mm indicated that the characteristic being evaluated was not present. A score of 150 mm indicated that the characteristic being evaluated was intense.

Table 10. Least square means for sensory evaluations at each sampling time point of Canadian-style bacon in the first experiment

Tenderness	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	92.78[b]	69.19[b]	68.86[b]	7.72
Week 2	89.05[b]	76.50[b]	72.70[b]	7.48
Week 4	91.32[b]	65.14[b]	65.37[b]	4.71
Week 6	86.93[b]	62.93[b]	51.36[b]	20.47
Week 8	100.38[b]	56.26[c]	69.88[bc]	4.80
Week 10	90.12[b]	67.78[b]	69.83[b]	11.59
Week 12	88.63[b]	50.38[c]	56.76[bc]	4.16
Cured Meat Flavor Intensity	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	71.14[b]	80.36[b]	84.55[b]	5.81
Week 2	84.35[b]	86.60[b]	86.85[b]	3.01
Week 4	62.28[b]	81.50[b]	83.36[b]	3.68
Week 6	69.36[c]	97.50[b]	98.15[b]	2.04
Week 8	83.13[b]	98.76[b]	100.57[b]	3.59
Week 10	82.00[b]	90.34[b]	89.83[b]	3.71
Week 12	85.57[b]	96.01[b]	99.63[b]	3.58
Saltiness	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	72.68[b]	87.50[b]	99.59[b]	8.71
Week 2	73.75[b]	91.95[b]	94.30[b]	3.01
Week 4	62.69[b]	102.05[b]	94.41[b]	6.87
Week 6	69.50[b]	101.57[b]	104.93[b]	11.47
Week 8	70.69[c]	95.82[b]	95.76[b]	2.09
Week 10	81.78[b]	95.00[b]	95.56[b]	4.11
Week 12	81.01[b]	101.88[b]	100.26[b]	7.10
Sweetness	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	60.46[b]	56.18[b]	56.37[b]	4.54
Week 2	64.15[b]	59.93[b]	69.45[b]	2.46
Week 4	53.96[b]	57.14[b]	65.14[b]	2.51
Week 6	54.43[b]	63.22[b]	67.00[b]	6.69
Week 8	56.75[b]	73.13[b]	63.01[b]	5.46
Week 10	65.22[b]	65.56[b]	66.84[b]	1.75
Week 12	62.94[b]	77.75[b]	71.94[b]	1.88

[a] Standard error of the means

[b-c] Means in the same row with different superscripts are different ($P<0.05$)

Off-flavor	Control	Natural Cure	Natural Cure with Cherry Powder	SEM[a]
Week 0	10.87[b]	14.09[b]	10.14[b]	3.66
Week 2	31.30[b]	21.50[bc]	15.70[c]	1.53
Week 4	28.10[b]	13.05[b]	16.32[b]	5.41
Week 6	35.93[b]	24.93[b]	14.00[b]	2.72
Week 8	28.13[b]	28.94[b]	14.88[b]	2.33
Week 10	26.84[b]	29.85[b]	16.89[b]	8.76
Week 12	33.13[b]	28.57[b]	32.38[b]	3.53
Acceptability	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	96.96[b]	102.59[b]	109.68[b]	7.31
Week 2	94.30[b]	108.40[b]	117.65[b]	3.95
Week 4	84.23[b]	100.86[b]	109.64[b]	9.77
Week 6	83.07[b]	98.43[b]	122.86[b]	6.71
Week 8	96.07[b]	103.07[b]	108.44[b]	3.86
Week 10	79.45[b]	90.68[b]	102.80[b]	10.43
Week 12	88.51[b]	104.01[b]	99.82[b]	4.32

[a] Standard error of the means

[b-c] Means in the same row with different superscripts are different ($P<0.05$)

Table 11. Least square means for visual evaluations at each sampling time point of Canadian-style bacon in the first experiment

Cured Meat Color Intensity	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	119.56[b]	66.07[b]	66.44[b]	10.28
Week 2	96.65[b]	57.55[b]	78.20[b]	13.14
Week 4	93.00[b]	69.37[b]	68.14[b]	21.42
Week 6	99.00[b]	76.22[c]	72.00[c]	1.40
Week 8	104.19[b]	71.07[b]	67.44[b]	9.78
Week 10	81.06[b]	70.28[b]	90.17[b]	5.06
Week 12	110.13[b]	57.75[b]	70.07[b]	9.58
Uniform Color	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	96.70[b]	72.82[b]	82.44[b]	11.43
Week 2	98.00[b]	59.65[b]	75.55[b]	15.96
Week 4	89.73[b]	68.64[b]	87.37[b]	13.86
Week 6	81.07[b]	63.93[b]	79.79[b]	13.47
Week 8	105.38[b]	42.13[b]	68.57[b]	23.48
Week 10	95.95[b]	69.17[b]	61.67[b]	21.85
Week 12	99.26[b]	39.01[d]	70.82[c]	2.04
Lightness	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	122.64[b]	52.46[b]	48.98[b]	16.80
Week 2	98.05[b]	73.85[b]	79.00[b]	17.19
Week 4	91.05[b]	65.27[b]	66.00[b]	34.94
Week 6	91.07[b]	70.64[b]	57.43[b]	8.21
Week 8	102.19[b]	60.88[b]	71.26[b]	28.42
Week 10	61.34[b]	46.89[b]	100.56[b]	8.46
Week 12	94.94[b]	53.75[b]	57.69[b]	26.08
Other Color	**Control**	**Natural Cure**	**Natural Cure with Cherry Powder**	**SEM[a]**
Week 0	10.85[b]	18.83[b]	9.11[b]	2.14
Week 2	18.66[b]	43.40[b]	26.70[b]	11.10
Week 4	25.57[b]	22.69[b]	17.85[b]	5.23
Week 6	21.17[b]	25.67[b]	25.75[b]	6.52
Week 8	8.17[b]	35.42[b]	28.58[b]	11.79
Week 10	14.34[b]	23.50[b]	24.00[b]	7.92
Week 12	23.01[b]	42.76[b]	30.00[b]	7.41

[a] Standard error of the means

[b-d] Means in the same row with different superscripts are different ($P<0.05$)

LIST OF FIGURES

Figure 1. Nitrite concentration in Canadian-style bacon treatments in experiment 1 over time

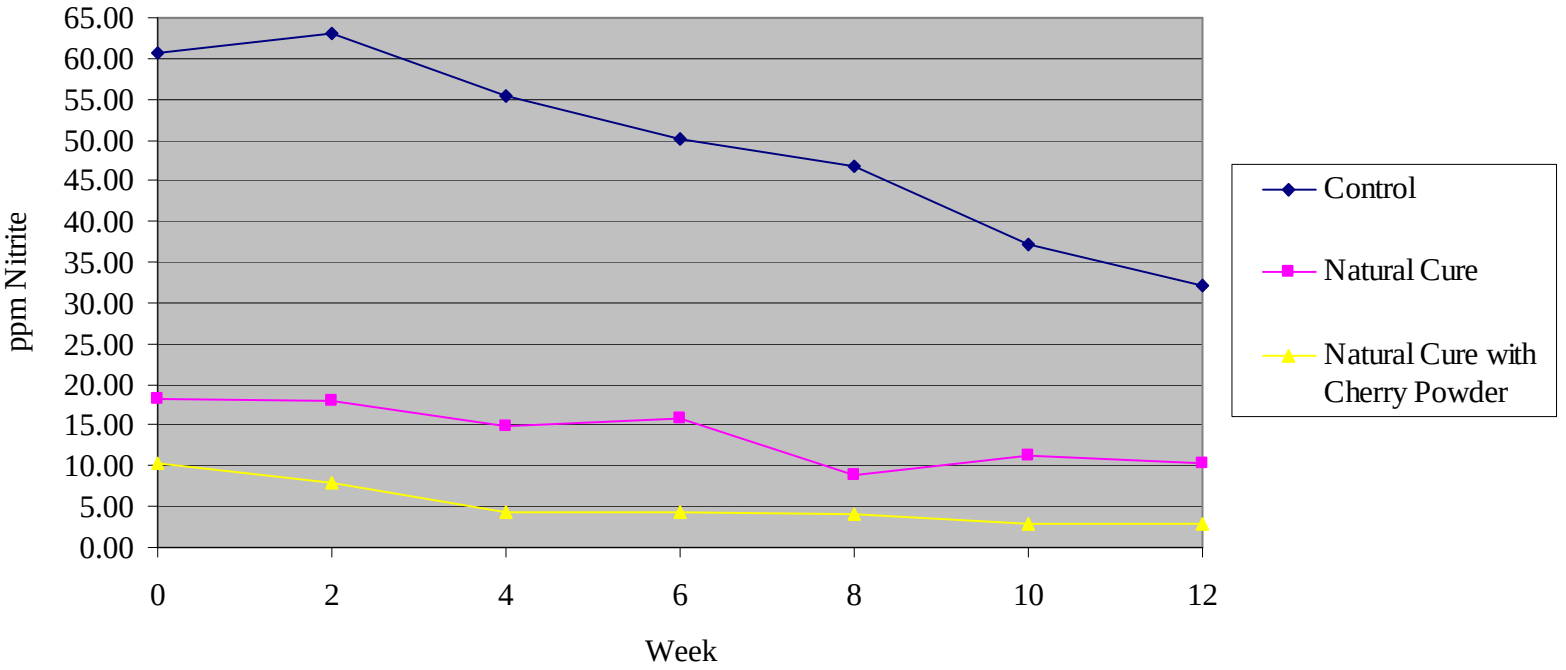


Figure 2. Nitrate concentration in Canadian-style bacon treatments in experiment 1 over time

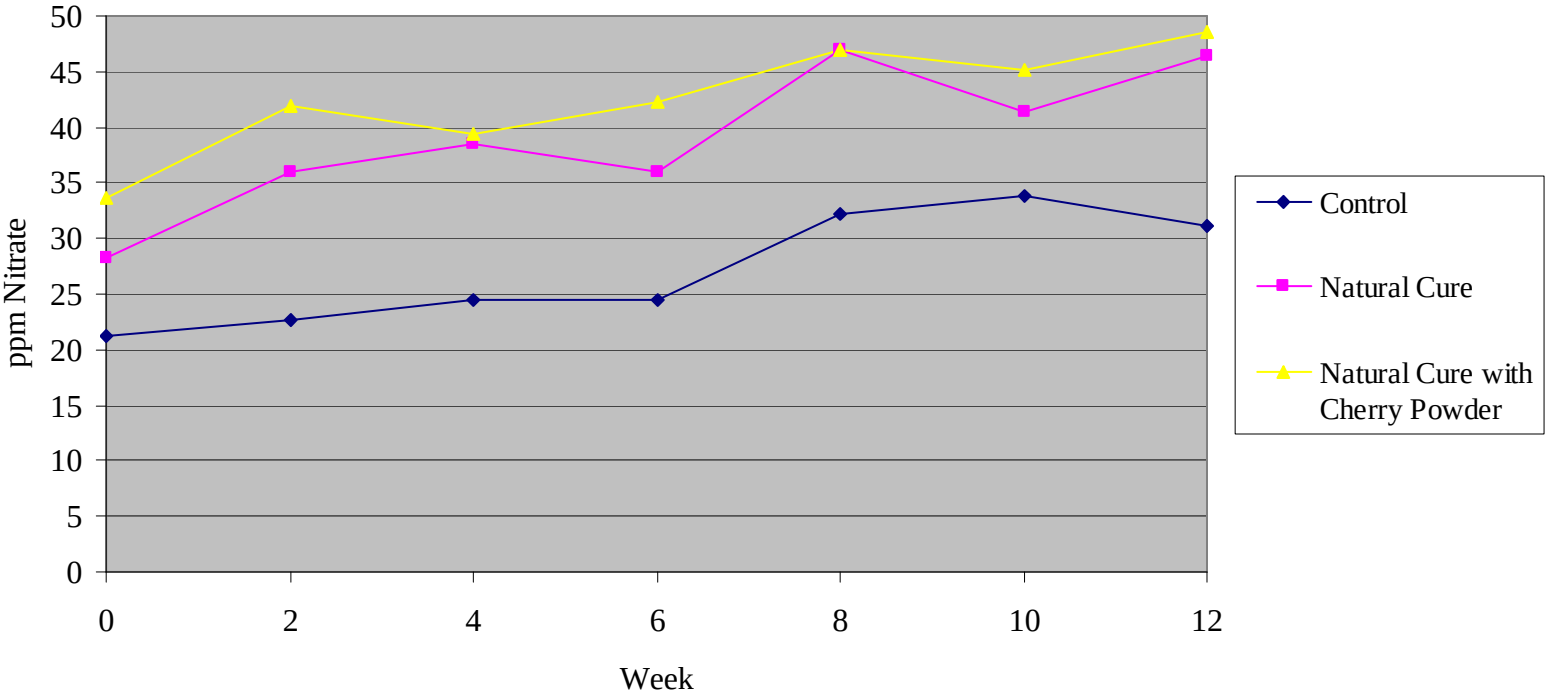


Figure 3. Nitrite concentration in Canadian-style bacon treatments in experiment 2 over time

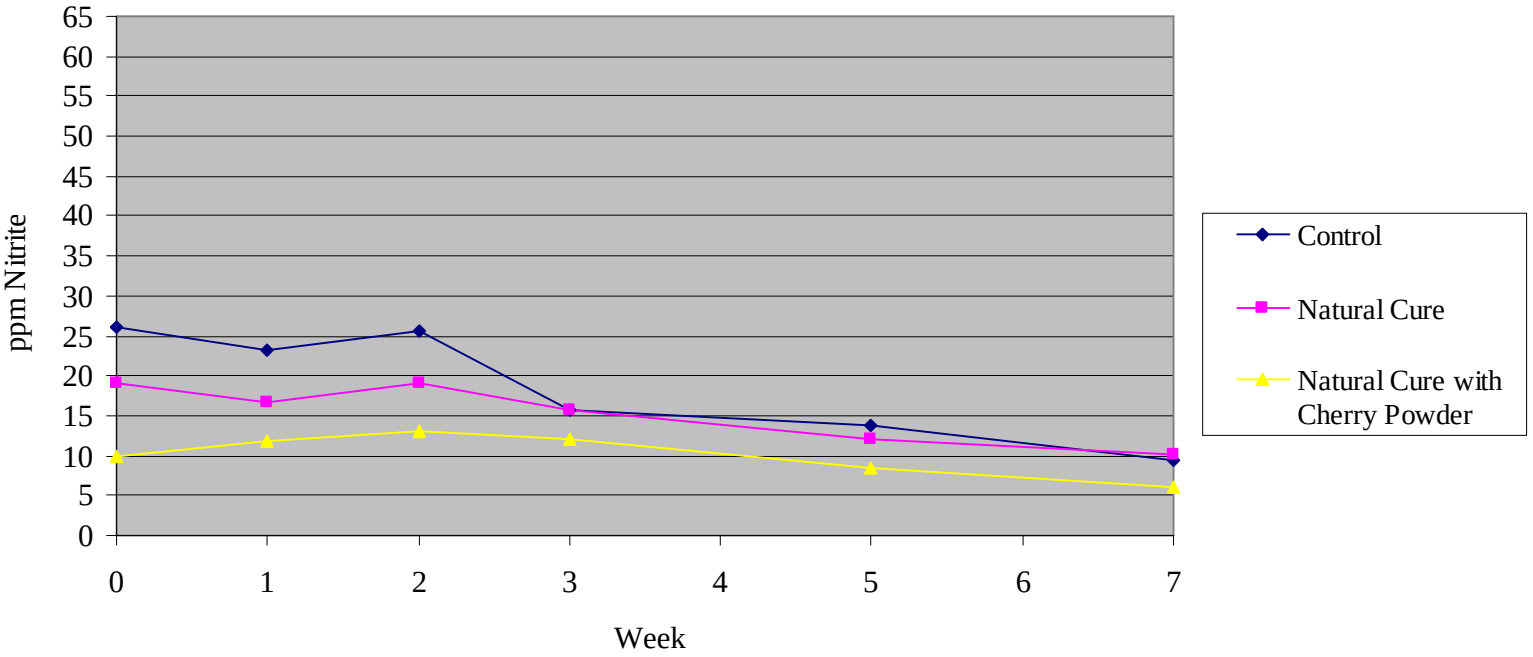
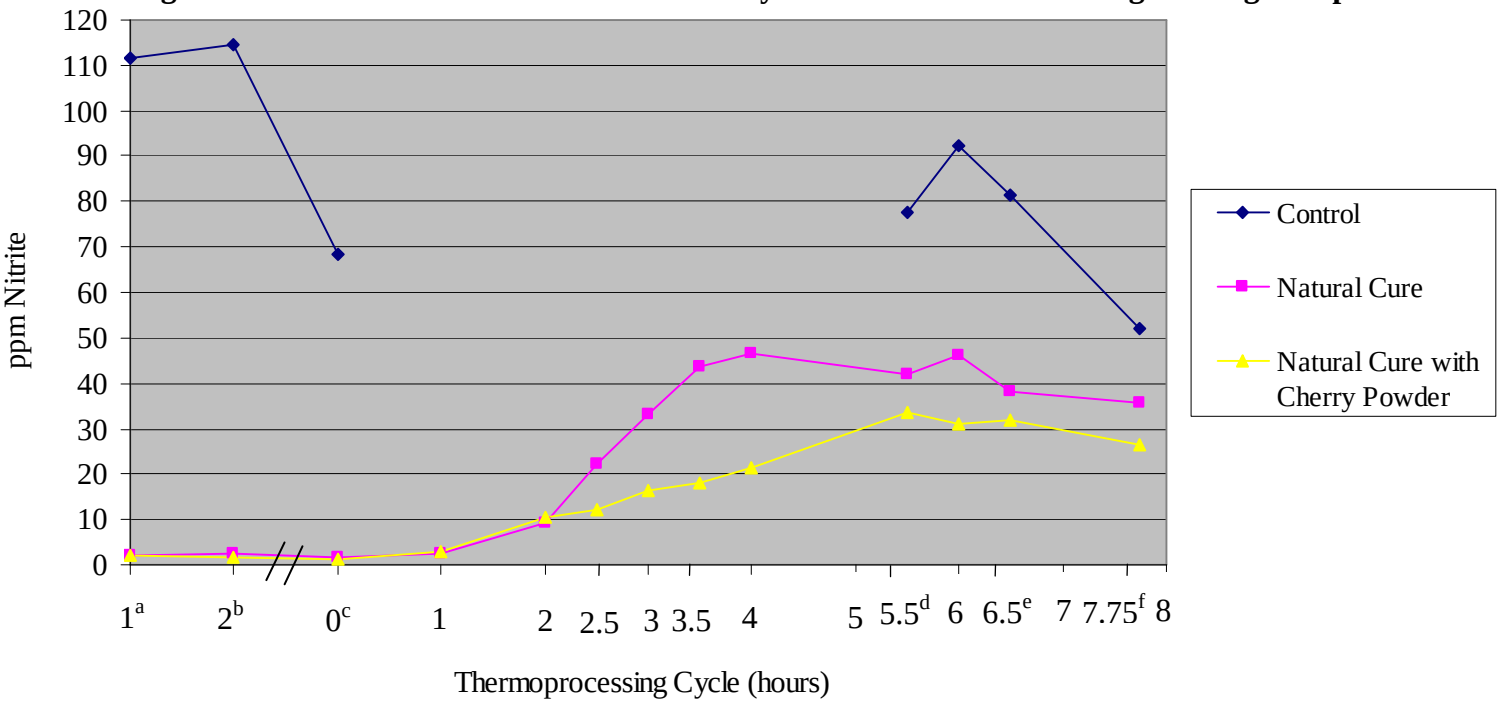


Figure 4. Nitrite concentration in Canadian-style bacon treatments during cooking in experiment 2



a: Immediately after brine was injected
b: Immediately after tumbling
//: Gap between day 1 and 2 of processing
c: Immediately before cooking
d: Start of cooking step 3 (end of incubation- see Table 2)
e: Start of cooking step 4 (see Table 2)
f: Start of cooking step 5 (see Table 2)
The control treatment was not sampled during the first portion of the cooking cycle as it did not undergo incubation.

Figure 5. Nitrate concentration in Canadian-style bacon treatments in experiment 2 over time

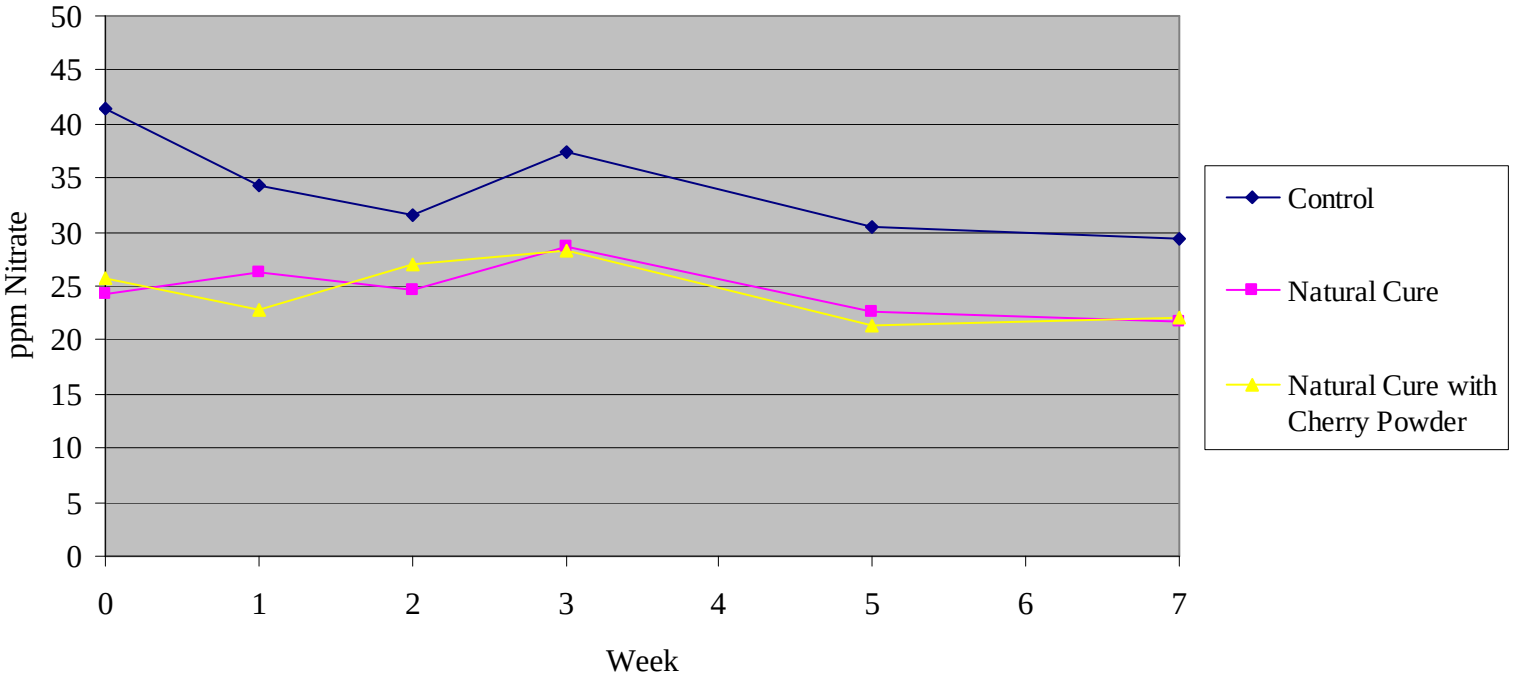


Figure 6. Nitrite concentration in Canadian-style bacon treatments in experiment 3 over time

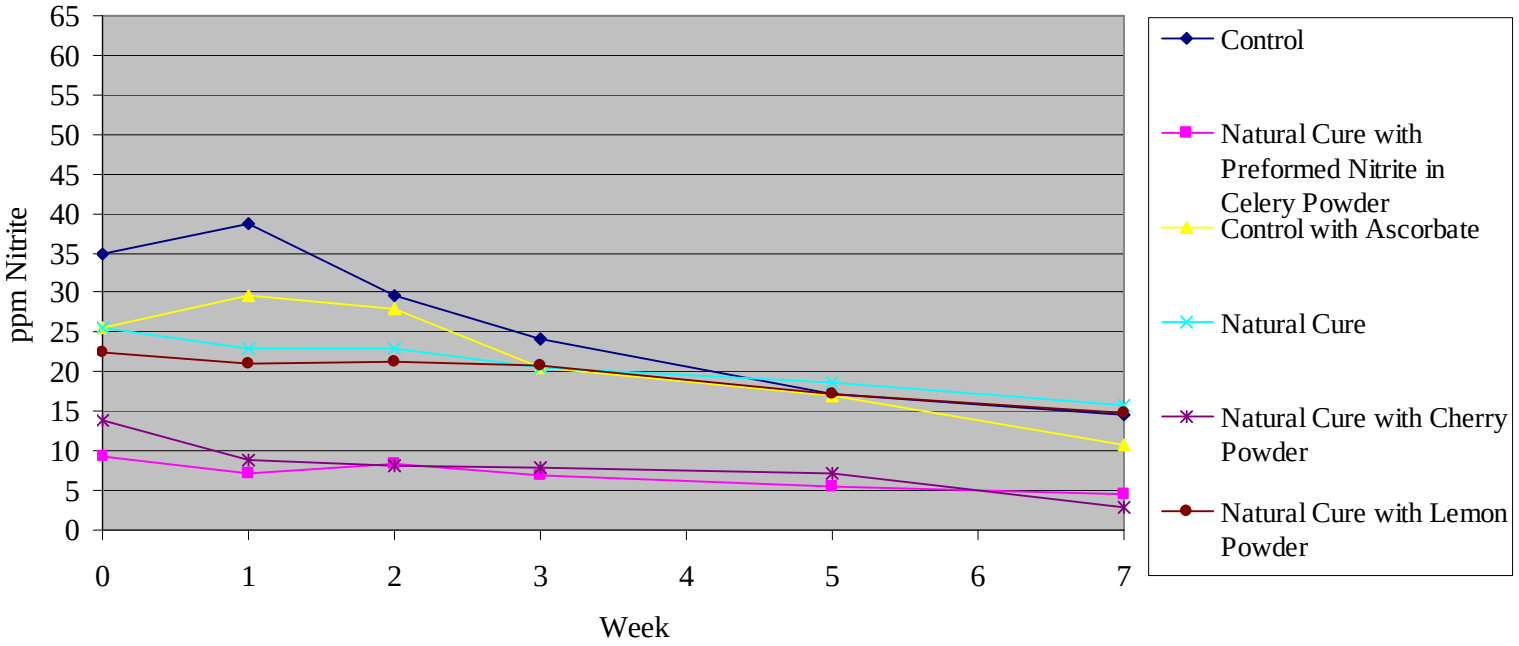
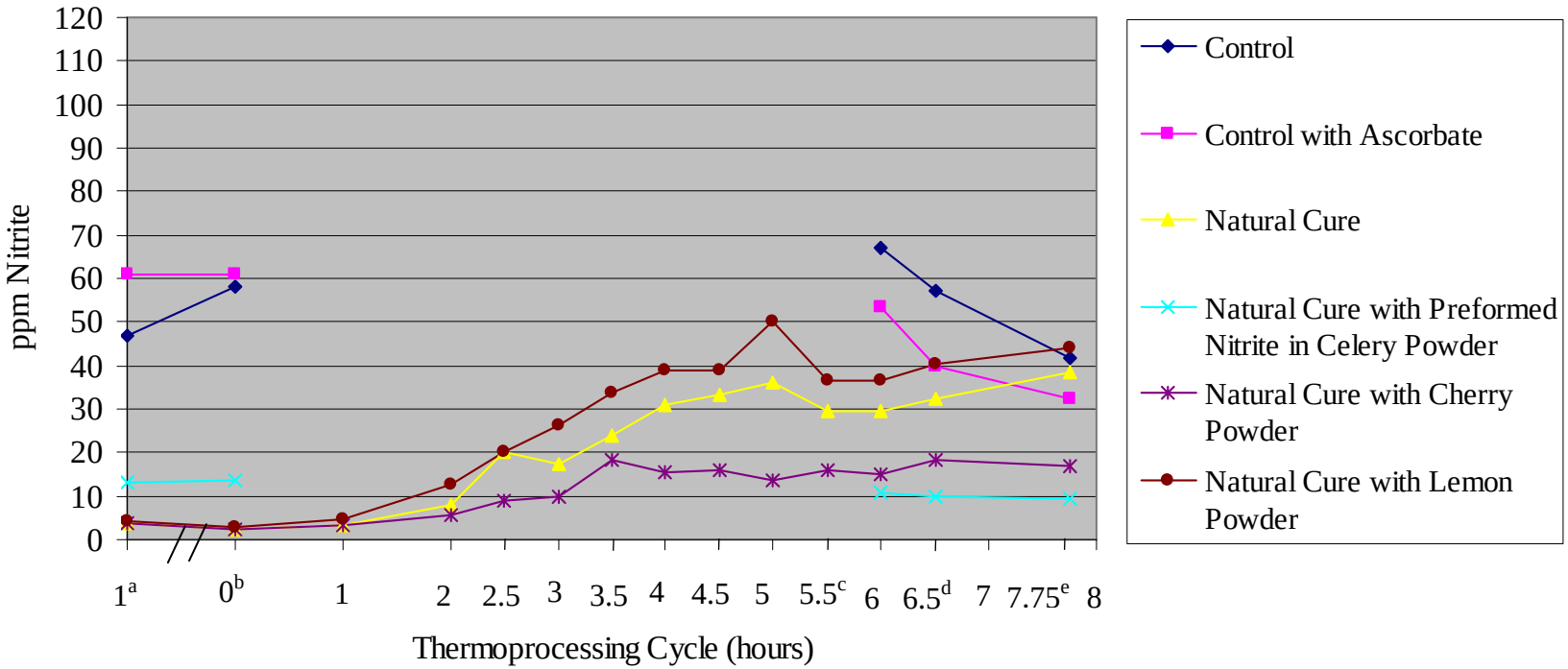
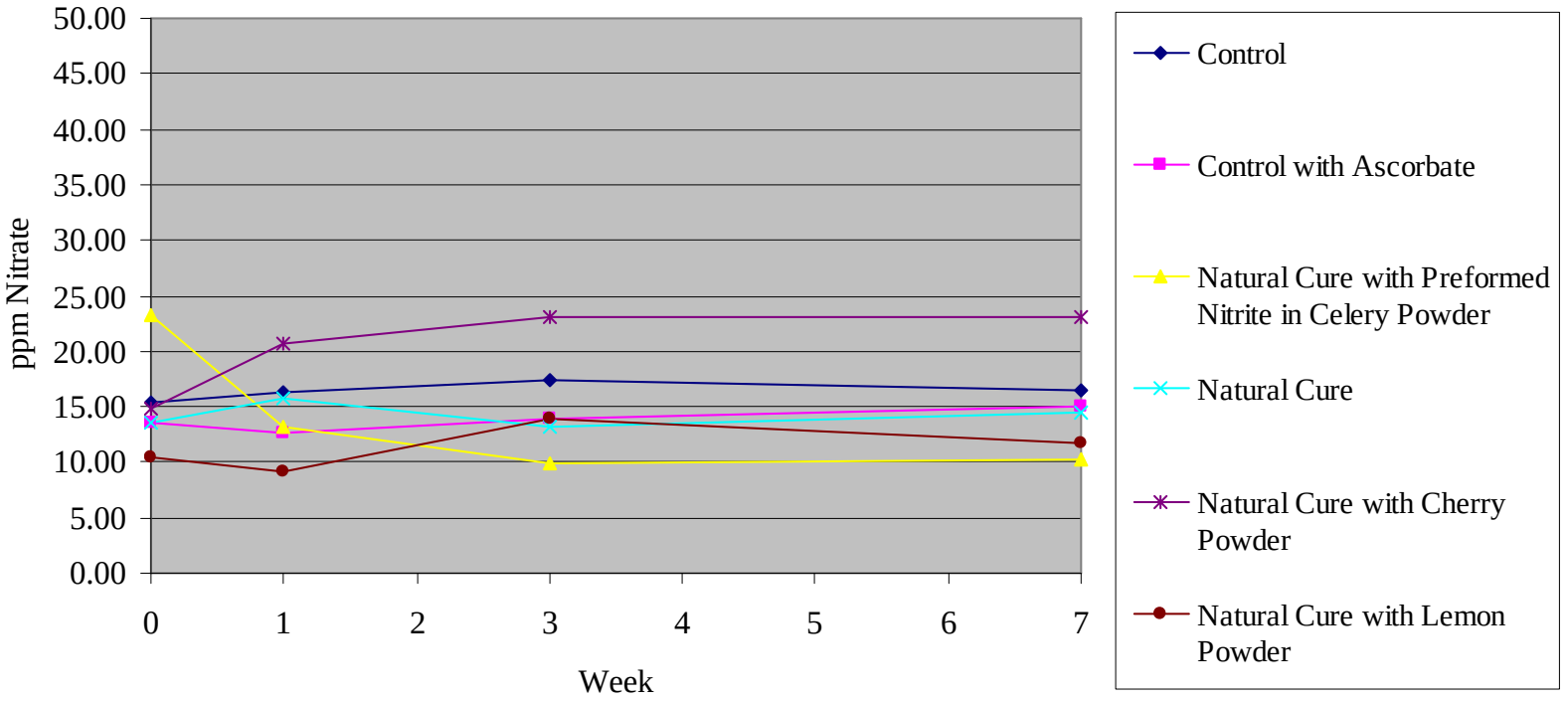


Figure 7. Nitrite concentration in Canadian-style bacon treatments during cooking in experiment 3



a: Between mixing and tumbling
//: Gap between day 1 and 2 of processing
b: Immediately before cooking
c: Start of cooking step 3 (end of incubation- see Table 2)
d: Start of cooking step 4 (see Table 2)
e: Start of cooking step 5 (see Table 2)
The control, control with ascorbate, and the natural cure with preformed nitrite in celery powder treatments were not sampled during the first portion of the cooking cycle as they did not undergo incubation.

Figure 8. Nitrate concentration in Canadian-style bacon treatments in experiment 3 over time



CHAPTER 4. GENERAL CONCLUSIONS

The purpose of this research was to determine if a Canadian-style bacon product produced without the direct addition of chemically manufactured nitrite or nitrate would have a comparable taste, appearance, and similar levels of residual nitrate and nitrite as Canadian-style bacon cured with nitrite. This is an important issue to investigate because meat products labeled as no-nitrate- or -nitrite-added, natural, or naturally cured are becoming increasingly popular with consumers. The results of these studies indicated that naturally cured Canadian-style bacon contained significant concentrations of residual nitrate and nitrite due to the inclusion of the ingredient celery powder which contains a natural form of nitrate, but that residual nitrite was typically less than that found in a conventionally cured product. The amount of nitrite produced from the nitrate by bacteria in the starter culture in naturally cured products, along with the processing and cooking procedures used, influenced how similar the naturally cured product could be to the conventionally cured product. Sensory and visual evaluations by panelists showed that the naturally cured Canadian-style bacon was at least equal to, and in some cases, may be more acceptable to consumers than the conventional product although these results were not always consistent with chemical analyses.

The shelf-life of naturally cured and conventionally cured Canadian-style bacon is expected to be comparable since it was observed during 12 weeks of storage that the TBARS values were similar between nitrite-added and nitrite- and -nitrate-free products. On the other hand, microbial spoilage could be an issue with the reduced concentration of nitrite observed in this study. In addition, food safety is also a concern when nitrite concentrations are reduced and further research should be done to establish a minimum level of celery

powder required in naturally cured products to prevent *Clostridium botulinum* spore germination and toxin production, and the growth of other pathogens. It was determined that measuring the amount of nitrite in the naturally cured products between 3.5 and 5 hours of incubation indicated the maximum level of measurable nitrite formed in the product. This information might prove to be useful as an indicator of whether adequate nitrate to nitrite conversion had occurred to ensure a safe meat product. If cooking cycles are adequately monitored, the inclusion of celery powder and a starter culture in a natural curing process could be used to produce Canadian-style bacon that meets consumers' sensory and visual expectations.

LIST OF APPENDICES

Appendix 1. Celery Powder (Veg Dry 503) Product Specification

FLORIDA FOOD PRODUCTS, INC.

Product Specifications and Information

PRODUCT NAME –Veg Dry 503

INGREDIENT DECLARATION – Celery powder (or natural flavors), sea salt, organic evaporated cane juice.

USE – Meats, dry soups and seasoning blends.

DESCRIPTION – Veg Dry 503 is a water soluble dried powder consisting of celery powder, sea salt, and organic evaporated cane juice. Anti-caking agents may be added.

USE RATE - 0.12%-0.18%

GENERAL SPECIFICATIONS	VEG DRY 503
APPEARANCE	Green/Tan, free flowing powder
MOISTURE	≤5%
pH (3.1% solution)	5.8-6.2
TOTAL PLATE COUNT	20,000 cfu/gm
YEAST & MOLD	100 cfu/gm max.
TOTAL COLIFORMS	Negative
PRESERVATIVES	None

PACKAGING - Available in 20 kg. vacuum sealed foil bag-n-box.

SHELF STABILITY AND STORAGE CONDITIONS - Store in cool, dry area not to exceed 90°F. When properly stored, the recommended shelf life is two years.

AVAILABILITY – Veg Dry 503 is available year round from inventory. Advance notice for quantities above 2,000 kgs. is required.

PROCESSING SEASON - December - June

The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change based on raw material variations.

Growers and Processors of Food and Cosmetic Ingredients
2231 W. Hwy 44 Eustis, FL 32727
(352) 357-4141

Revised: 4/18/07
Issued: 1/20/07

SP503

Appendix 2. Celery Powder (Veg Stable 501) Product Specification

FLORIDA FOOD PRODUCTS, INC.

Product Specifications and Information

PRODUCT NAME –Veg Stable™ 501

INGREDIENT DECLARATION– Celery powder (or natural flavors), sea salt.

USE – Meats, dry soups and seasoning blends.

DESCRIPTION – Veg Stable™ 501 is a water-soluble dried powder consisting of celery powder and sea salt. Veg Stable™ 501 is high in naturally occurring nitrates that are standardized with sea salt. Anti-caking agents may be added.

USE RATE - 0.2 - 0.4% of gross weight

GENERAL SPECIFICATIONS	Veg Stable™ 501
APPEARANCE	Green/Tan, free flowing powder
MOISTURE	≤5%
pH (5% solution)	6.0 - 7.0
TOTAL PLATE COUNT	20,000 cfu/gm
YEAST & MOLD	100 cfu/gm max.
TOTAL COLIFORMS	Negative
PRESERVATIVES	None

PACKAGING - Available in 20 kg. vacuum-sealed foil bag-n-box.

SHELF STABILITY AND STORAGE CONDITIONS - Store in cool, dry area not to exceed 90°F. When properly stored, the recommended shelf life is two years.

AVAILABILITY– Veg Stable™ 501 is available year round from inventory. Advance notice for quantities above 1,000 kgs. is required.

PROCESSING SEASON - December - June

The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change based on raw material variations.

Issued:11/9/07

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SP501

Appendix 3. Celery Powder (Veg Stable 504) Product Specification

FLORIDA FOOD PRODUCTS, INC.

Product Specifications and Information

PRODUCT NAME – Veg Stable™ 504

INGREDIENT DECLARATION – Celery powder (or natural flavors), sea salt.

USE – Meats, natural curing processes

DESCRIPTION – Veg Stable™ 504 is a water-soluble dried powder consisting of celery powder and sea salt. Veg Stable™ 504 is high in naturally occurring nitrites that are standardized with sea salt. Anti-caking (silicon dioxide) agents may be added.

GENERAL SPECIFICATIONS	Veg Stable™ 504
APPEARANCE	Green/Tan, free flowing powder
MOISTURE	≤5%
pH (3.1% solution)	7.5 - 9.5
TOTAL PLATE COUNT	20,000 cfu/gm
YEAST & MOLD	100 cfu/gm max.
TOTAL COLIFORMS	Negative
PRESERVATIVES	None

PACKAGING - Available in 20 kg. vacuum-sealed foil bag-n-box.

SHELF STABILITY AND STORAGE CONDITIONS - Store in cool, dry area not to exceed 90°F. When properly stored, the recommended shelf life is two years.

SUGGESTED USAGE - to 0.2 - 0.4% of gross weight

AVAILABILITY – Veg Stable™ 504 is available year round from inventory. Advance notice for quantities above 1,000 kgs. is required.

PROCESSING SEASON - December - June

The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change based on raw material variations.

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Revised: 11/9/07 SP504

Appendix 4. Cherry Powder (Veg Stable Cherry 515) Product Specification

FLORIDA FOOD PRODUCTS, INC.

Product Specifications and Information

PRODUCT NAME –VEG STABLE™ CHERRY 515

INGREDIENT LISTING- Cherry powder & Organic evaporated cane juice

USE – Meats, dry soups, beverages, health supplements, cosmetics and seasoning blends.

DESCRIPTION – Veg Stable™ CHERRY is a dried powder derived from fresh cherries and organic evaporated cane juice. Anti-caking agents may be added.

USE RATE – 0.1 - 0.5%

GENERAL	Veg Stable™ CHERRY
APPEARANCE	Tan, free flowing powder
MOISTURE	≤5%
pH (3 % solution)	5.8-6.2
TOTAL PLATE COUNT	20,000 cfu/gm max.
YEAST & MOLD	100 cfu/gm max.
TOTAL COLIFORMS	Negative
PRESERVATIVES	None

PACKAGING - Available in 20 kg. vacuum-sealed foil bag-n-box.

SHELF STABILITY AND STORAGE CONDITIONS - Store in cool, dry area not to exceed 90°F. when properly stored, the recommended shelf life is two years.

AVAILABILITY – Veg Stable™ CHERRY is available year round from inventory. Advance notice for quantities above 5,000 lbs. is required.

PROCESSING SEASON - December - June

The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change based on raw material variations.

Appendix 5. Lemon Powder (Veg Stable Lemon 520) Product Specification

FLORIDA FOOD PRODUCTS, INC.

Product Specifications and Information

PRODUCT NAME - VEG STABLE™ LEMON 520

USES -Beverages, seasonings, snack foods, dressings, dips, sauces, bakery items, poultry and seafood marinades, health foods and baby foods.

DESCRIPTION - VEG STABLE™ LEMON 520 is dried lemon juice concentrate with organic evaporated cane juice and silicon dioxide. Proprietary drying technologies developed by Florida Food Products yields superior fresh flavor characteristics and improved solubility.

GENERAL SPECIFICATIONS	VEG STABLE™ LEMON 520
APPEARANCE	Light tan free flowing powder
TOTAL DISSOLVED SOLIDS	3% maximum
pH @ 4.5% solution	2.3-2.9
ACIDITY as CITRIC ACID	min 30 gm/100gm
TOTAL PLATE COUNT	3,000 cfu/gm max
YEAST AND MOLD	100 cfu/gm max
TOTAL COLIFORM	Negative
PRESERVATIVES	None

INGREDIENT LISTING - Lemon juice concentrate, organic evaporated cane juice, and silicon dioxide (prevents caking).

PACKAGING -		
	20 kg	vacuum-sealed foil bag-n-box
	Gross	21.4 kg (47.2 lbs.)
	Net	20 kg (44.1 lbs.)

SHELF STABILITY AND STORAGE CONDITIONS - If stored at or below 70 degrees F, the recommended shelf life is two years.

AVAILABILITY - VEG STABLE™ LEMON 520 is available year round from our stock inventory. The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change.

The technical information and suggestions for use contained herein are believed to be reliable, but they are not to be construed as warranties and no patent liability can be assumed. Specifications are subject to change based on raw material variations.

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Issued: 1/7/08 SP520

Appendix 6. Sea Salt (Foran 388915) Product Specification

SPECIFICATION SHEET

FORAN SPICE COMPANY

"THE TASTE OF THINGS TO COME"

Issued: 5/21/07

Reviewed:

Revised:

PRODUCT CODE: 388915 **DESCRIPTION: MEDITERRANEAN SEA SALT**

This ingredient is food grade and all shipments conform to the Federal Food, Drug and Cosmetic Act requirements.

INGREDIENT STATEMENT: Contains: sea salt.

Contains no anti-caking or free-flowing additives or conditioners. All natural product.

PHYSICAL DESCRIPTION: White, fine, free-flowing salt.

ANALYSIS:

PHYSICAL AND CHEMICAL	LIMITS (TYPICAL)
Sodium Chloride (NaCl)	98.8%
Calcium (Ca)	500ppm
Magnesium (Mg)	250ppm
Iron (Fe)	<10ppm
Sulphates (SO4)	0.25%
Water (H2O)	0.1%
Granulation	0.5mm to 1mm

RECOMMENDED STORAGE: Product should be stored in poly bags to protect from moisture, and stored in air tight, covered container to help maintain nutrient content.

PACKAGING: Plastic Containers and/or Bulk Polylined Packages for seasonings are available as requested.

QUALITY ASSURANCE: For over 50 years, Foran Spice Company has been committed to quality. This commitment is expressed in terms of multiple product and process specifications. If you have any questions or comments, please call the Quality Control Manager at 1-800-558-6030.

7616 SOUTH SIXTH STREET. OAK CREEK. WI 53154
800-558-6030 414-764-1220 FAX 414-764-8803

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