EXECUTIVE SUMMARY

A National Survey of the Nitrite/Nitrate Concentrations in Cured Meat Products and Non-meat Foods Available at Retail

(National Pork Board Project #08-124)

Drs. Jimmy T. Keeton[1], Wesley N. Osburn[2], Margaret D. Hardin[2], Nathan S. Bryan[3], Michael T. Longnecker[4]; Nutrition and Food Science Department[1], Department of Animal Science[2], Texas A&M University, College Station, TX 77843; Institute of Molecular Medicine[3], University of Texas, Houston Health Science Center, Houston, TX 77030, Department of Statistics, Texas A&M University, College Station, TX 77843.

Date Submitted: July 31, 2009

Objectives: To survey the major categories of cured meats and highly consumed, raw, nitrate rich vegetables available at retail in five geographic regions of the U.S. and analyze each for nitrite/ nitrate content. Comparisons were made with historic databases to determine if changes had occurred in nitrite/ nitrate levels in the past 12 years. Nitrate/ nitrite concentrations of drinking water in 25 U.S. cities were compiled to evaluate their potential contribution to nitrite/ nitrate load.

Conclusions: ***Cured Meat Products*** – Generally, there were no differences in cured meat nitrite levels between conventional and organic classifications, but a few organic products surveyed in certain cities were lower in nitrate content. When evaluated across five cities, nitrite contents of all conventional cured meat categories were not different and the same was true for most organic products. Nitrite/ nitrate levels in cured meat products evaluated across all metropolitan areas were not appreciably different. Overall, nitrite/ nitrate levels of fermented cooked sausage, cured dried uncooked sausage, whole-muscle dry-cured cooked, cured cooked sausage, whole-muscle brine cured cooked and whole-muscle brine cured uncooked categories averaged 0.64/ 35.66, 0.74/ 78.81, 1.95/ 67.43, 6.86/ 27.68, 7.16/ 14.81 and 7.31/ 25.57 ppm, respectively. The weighted averages for nitrite/ nitrate across all cured meat categories were 4.54 and 37.07 ppm. Nitrite values observed were consistent within each product category and not appreciably different from those previously reported by Cassens (1997a). This study's nitrite/ nitrate values were substantially lower than those reported in the NAS (1981) study as well as those from other countries.

Vegetables – Very few differences were noted in nitrite levels of conventional and organic vegetables taken from five metropolitan cities. Differences in nitrate content between conventional and organic vegetables were observed with organic vegetables being lower. Nitrate levels of conventional broccoli, cabbage, celery, lettuce and spinach were 394.38, 417.56, 1,495.48, 850.46 and 2,797.18 ppm, respectively, while their organic counterparts averaged 204.29, 551.97, 911.94, 844.06 and 1,317.73 ppm. With one exception, organic vegetables had numerically lower nitrate concentrations than conventional vegetables.

Drinking Water – All drinking water sources surveyed were within the allowable limits for nitrate/ nitrite (if reported) established by the EPA.

Overall Summary: Nitrite/ nitrate contents of U.S. cured meat products have remained low since the last national survey in 1997. It appears that the current USDA regulations and manufacturer's processing procedures are consistently controlling the levels of nitrite/ nitrate in cured meat products and continue to be effective for minimizing their contribution to the dietary nitrite/ nitrate load. Based on this survey, regional variation in the nitrate content of vegetables may need to be taken into consideration when developing predictions based on their consumption. This variation might be of sufficient magnitude to alter epidemiological predictions if not considered appropriately.

SCIENTIFIC ABSTRACT

A random survey of 467 cured meat products representing 6 major categories and 197 fresh, raw broccoli, cabbage, celery, lettuce and spinach samples were taken from retail outlets in 5 U.S. cities (Chicago, Dallas, Los Angeles, New York, Raleigh). Samples were analyzed for nitrite/ nitrate (NO_2/NO_3) content (mg/kg or ppm) using an ENO-20 HPLC System equipped with a reverse phase column as described by Bryan and Grisham (2007). The values obtained provided a benchmark for comparison to historic databases and enabled a more accurate evaluation each food's contributions to NO_2/NO_3 load in the American diet. This survey is the first to our knowledge to evaluate the NO_2/NO_3 content of organic meat product categories. NO_2/NO_3 concentrations in drinking water of 25 major U.S. cities were also compiled to provide an additional database for evaluating water's contribution to NO_2/NO_3 load. The study was analyzed as a completely randomized design with main effects of metropolitan area (MA), vegetables (V), cured meat products (MP) and product type (PT) [conventional, organic]. A log transformation of the data was performed to satisfy the conditions of homogenous variances and a normal-like distribution. Because of significant interactions displayed in the ANOVA, a more detailed examination of the mean NO_2/NO_3 concentrations was conducted using a Bonferroni multiple comparison of the least squares means. Also, a Bonferroni pair-wise comparison of the mean NO_2/NO_3 concentrations across MPs was conducted separately for each combination of V and PT and for each combination of MP and PT. Generally, there were no differences in nitrite levels between conventional and organic cured meat categories, but a few organic products surveyed in certain cities were lower in nitrate content. When evaluated across five cities, nitrite contents of all conventional cured meat categories were not different and the same was true for most organic products. NO_2/NO_3 levels in cured meat products evaluated across MPs were not appreciably different. NO_2/NO_3 levels of fermented cooked sausage, cured dried uncooked sausage, whole-muscle dry-cured cooked, cured cooked sausage, whole-muscle brine cured cooked and whole-muscle brine cured uncooked categories averaged 0.64/ 35.66, 0.74/ 78.81, 1.95/ 67.43, 6.86/ 27.68, 7.16/ 14.81 and 7.31/ 25.57 ppm, respectively. Weighted means for NO_2/NO_3 across all cured meat categories were 4.54 and 37.07 ppm. Nitrite values observed were consistent within each MP category and not appreciably different from those previously reported by Cassens (1997a). This study's NO_2/NO_3 values were substantially lower than those reported by NAS (1981) as well as those from other countries. Very few differences were noted in mean nitrite levels of conventional and organic vegetables taken from 5 MPs. Differences in nitrate content between conventional and organic vegetables were observed with organic vegetables being lower. Nitrate levels of conventional broccoli, cabbage, celery, lettuce and spinach were 394.38, 417.56, 1,495.48, 850.46 and 2,797.18 ppm, respectively, while their organic counterparts averaged 204.29, 551.97, 911.94, 844.06 and 1,317.73 ppm. With one exception, organic vegetables had numerically lower nitrate concentrations than conventional vegetables. The fact that the NO_2/NO_3 contents of vegetables are variable poses a potential dilemma for determining actual vegetable consumption (an in turn NO_2/NO_3 dietary load) of a population. Based on this survey, regional variation may need to be taken into consideration when developing predictions based on consumption of specific vegetables. This variation might be of sufficient magnitude to alter epidemiological predictions if not considered appropriately. All drinking water sources were within the allowable limits for nitrate (and nitrite if reported) established by the EPA.

INTRODUCTION

Nitrite, and in some cases nitrate, are functional food ingredients that serve as effective antimicrobials to inhibit *Clostridium botulinum* and *Listeria monocytogenes* growth, impart a distinctive cure color to meat products, provide antioxidant properties to retard lipid oxidation and extend the shelf-life of these products. Their use in meat curing can be traced to antiquity (Cassens 1995, 1997b), but it wasn't until the early 1990s that the chemistry of curing reactions involving nitrite and nitrate were elucidated. These ingredients remained unregulated in the United States until 1926 when government regulations established a maximum use level of 156 ppm (USDA, 1925; USDA, 1926). The regulations have been modified only slightly since their implementation with allowances of up to 200 ppm for immersion or pumped products and a reduction to 120 ppm in bacon with mandatory inclusion of 547 ppm ascorbate to suppress nitrosation reactions. During the 1970's, the safety of cured meats related to human health was questioned due to the potential formation of carcinogenic nitrosamines in the stomach following ingestion of nitrite. Reducing the levels nitrite and restricting the use of nitrate, which serves as a reservoir for nitrite, has reduced the potential for nitrosamine formation dramatically. However, concerns about epidemiological studies and the association of nitrite ingestion with specific types of cancer (childhood leukemia, brain cancer) have renewed concerns about the safety of this meat ingredient.

At issue is the dietary or endogenous sources of nitrite and nitrate and whether exposure to these ingredients truly poses a sufficient health risk to warrant their removal or restriction from the food supply, and particularly from cured meats. Truly, pure nitrites are toxic compounds with an estimated lethal dose of ~1 g (14 mg/kg body weight) or 2-9 g for a 60 kg adult, respectively (Corre and Breimer, 1979). Estimates of toxic nitrite dosages range from 1-8.3 mg $NaNO_2$/kg body weight (Gangolli et al. 1994). The lowest acute oral lethal dose of nitrite has been reported to vary from 33-250 mg/kg body weight which might be applied to children or the elderly (Schuddeboom 1993). Estimates of the lethal dose of KNO_3 have ranged from 4-30 g (70-500 mg/kg body weight). A realistic estimate of a lethal dose in adults is 20 g nitrate ion or 330 mg nitrate ion/kg body weight (Gangolli et al. 1994). The National Academy of Sciences (1981) concluded that 39, 34 and 16% of the dietary intake of nitrite was derived from cured meat, baked goods/ cereal and vegetables, respectively (Cassens 1997a). However, more recent reports have shown that less than 5% of the ingested nitrite and nitrate are derived from cured meat sources with the remainder coming from vegetables and saliva (Cassens 1997a, b; Archer, 2002; Milkowski, 2006; Sebranek and Bacus, 2007). In an assessment of nitrate, nitrite and *N*-nitroso compounds in the human diet, Gangolli et al. (1994) concluded that vegetables contribute over 85% of the daily dietary intake of nitrate and that endogenous synthesis is an important contributor to human's overall exposure of nitrate. Hord et al. (2009) estimated that approximately 80% of dietary nitrates are derived from vegetable consumption. Ingested nitrate is absorbed rapidly from the upper gastrointestinal tract and the majority excreted in the urine (Schuddenboom, 1993), while nitrite may react with substances in the gastrointestinal tract or be absorbed into the circulatory system where it can be oxidized to nitrate, or it can oxidize hemoglobin to methemoglobin thereby destroying its oxygen carrying capacity in the blood. Nitrate, when shunted to the circulatory system, may be excreted in the saliva where it is then reduced to nitrite by oral bacteria, and finally swallowed as nitrite. However, this route constitutes only 5% of the total ingested nitrate that is reduced to nitrite. Hord et al. (2009) [citing Lundberg et al. (1994)] stated that approximately 25% of ingested nitrate is secreted in saliva, and 20% (5-8% of the nitrate intake) is converted to nitrite by commensal bacteria on the tongue. Hord et al. (2009) states that the amount of dietary nitrite and nitrate consumed results in nitric oxide production approximately equal to endogenous sources and in turn most of the endogenous nitric oxide is converted back to nitrite and nitrate *in vivo* through stepwise oxidation. If up to 50% of the steady state concentrations of nitrite and nitrate were derived from dietary sources, the total daily nitrite exposure from saliva alone would be 75 μmol or 5.18 mg. Based on these estimates, Hord et al. (2009) concluded that the normal physiologic exposure levels of nitrite and nitrate greatly exceed concentrations considered to produce health risks.

In an initial survey by Cassens (1997a), the residual nitrite content of cured meats taken from a metropolitan supermarket was found to be 7 ppm for bacon, 6 ppm for sliced ham and 4 ppm for hot dogs. A subsequent larger survey of over 100 retail samples of cured meats from various manufacturers taken from several U.S. cities showed the overall residual nitrite mean to be ~10 ppm. This represents a considerable decrease from the 1975 report by White that found an average residual nitrite level of 52.5 ppm in cured meats. A comprehensive review conducted in Canada over the period from 1972 to 1997 reported an average nitrite value of 28 ppm in cured meat products sampled in 1996 which is slightly higher than the level reported in the U.S. during the same time period (Sen and Baddoo, 1997). Because approximately 12 years have passed since a survey of cured meat products has taken place in the U.S., we proposed to conduct a comprehensive survey across the U.S. to document the actual levels of nitrite/ nitrate in cured meat and vegetable products offered at retail, and to establish a comprehensive database for comparison to other historic surveys. In turn, this would validate the limited contribution of cured meat products to the total dietary nitrite/ nitrate load.

A recent working group from the International Agency for Research on Cancer (IARC) has classified nitrites or nitrates as an “agent that is probably carcinogenic to humans” despite previous reviews that have found inadequate evidence for the carcinogenicity of nitrites or nitrates. As a consequence, the state of California under the Proposition 65 Law may declare both nitrite and nitrate “carcinogens” since they recognize the IARC as an authoritative source for determining cancer risk in humans. This decision could have significant impact upon the meat industry as well as other segments of the food industry by requiring warning labels on all food items that contain nitrites and/or nitrates either as a food additive or that are indigenous to the food. The intake of nitrate and nitrite is quite variable among individuals due to the variation in consumption patterns (i.e. fresh vegetables, breads, cereals, tuber crops, and water) with the greatest exposure coming from vegetables and saliva. Previous studies (NAS 1981, Cassens 1997a, b; Sen and Baddoo 1997; Cassens 1995) have provided baseline levels of residual nitrite/ nitrate in meat and food products, but no comprehensive national study is available to verify or reestablish a new baseline, provide a meaningful basis for comparison, or enable the evaluation of new cured meat categories (i.e. natural, organic, no nitrite).

This survey was proposed to assess the major categories of cured meat products for their nitrite and nitrate content by randomly sampling retail outlets in five major, geographically diverse metropolitan cities across the United States. This approach provided a representative sample of the cured meat products consumed by the American public and would be one of the largest single surveys conducted of its kind. In addition to cured meats, the major non-meat food contributors (broccoli, cabbage, celery, lettuce and spinach) (Gangiolli et al., 1994; Prasad and Chetty, 2008; Santamaria, 2006; Susin et al., 2006; Tamme et al., 2006; Chung et al., 2003; Petersin and Stoltze, 1999; Santamaria, et al., 1999; NAS, 1981; Siciliano et al., 1975) to dietary nitrate/ nitrite load were sampled simultaneously from the same retail outlets and analyzed for total nitrate/ nitrite content. The data from each food source was collected in a manner that allows for comparison to historic databases. A companion survey of the potable water supplies from 25 cities located in different geographic regions of the U.S. was conducted by securing water quality analyses for nitrite/ nitrate from the EPA databank, public health departments and/or water department municipalities. It was believed that this would offer additional insight into understanding if municipal drinking water was a potential contributor to dietary sources of nitrate/ nitrite.

OBJECTIVES

The objectives of this study were to:

1. Analyze representative samples of the major cured meat product categories of for residual nitrite/ nitrate selected from retail outlets and supermarket chains in targeted geographic regions of the United States (New York City, Raleigh, NC, Chicago, IL, Dallas, TX, and Los Angeles, CA).

2. Compare the nitrite/ nitrate concentrations of the surveyed products with those of previously established baselines (NAS 1981, Cassens 1997a, etc.) to estimate the present-day level of dietary nitrite/ nitrate exposure from cured meat sources.

3. Analyze representative samples of highly consumed raw vegetables for nitrate/ nitrite content that are taken from the outlets listed in Objective 1, and determine the concentrations of nitrite/ nitrate contributed to the diet by these foods.

4. Compare the concentrations of nitrite/ nitrate found in the raw vegetables to those of previously established databases, and estimate the current level of nitrite/ nitrite exposure from cured meat and non-meat food items.

5. Compile a database of nitrite/ nitrate concentrations in potable water from 20 cities located in different geographic regions of the U.S. by securing water quality analyses for nitrite/ nitrate from the EPA databank, public health departments and/or water department municipalities.

Hypothesis

We hypothesized that the average nitrite/ nitrate levels in cured meat products in the United States had not changed or had declined since the last major survey and that they contribute minimally to the total dietary nitrite/ nitrate load for humans. Whereas, other non-meat foods such as vegetables are the major contributors to the human dietary nitrite/ nitrate load.

LITERATURE REVIEW

History – Meat Curing, Nitrate and Nitrite

The preservation of foods by the addition of salt has been practiced for more than 3,000 years (Binkerd and Kolari 1975). The early use of nitrate as a preservative more than likely dates from ancient times as an unintentional by-product of salt preservation. In a review of the history of nitrite in meat curing, Binkerd and Kolari (1975) suggest that the preservation of meat was actually first practiced in the saline deserts of Asia where desert salts contained impurities such as nitrates (potassium nitrate). Sea salt, also rich in nitrate, from the salt-rich Dead Sea was commonly used in preservation, according to Jewish history, as early as 1,600 BC and salt from salt wells was used by the Chinese by at least 1,200 BC (Binkerd and Kolari 1975).

"Wall saltpeter" (calcium nitrate), formed by nitrifying bacteria and found as an efflorescence on the walls of caves and stables, was gathered in China and India long before the Christian era (Binkerd and Kolari 1975). The Romans learned salt preservation from the Greeks and by 900 BC the curing of meat by salt and smoking was commonly used in the preservation of meat and fish. This exchange of knowledge and processes expanded into trade and exploration for salt, saltpeter and for specialized preserved products.

The use of salt and saltpeter in meat curing was common throughout the Middle Ages and the effect of saltpeter on meat color was well recognized. The "reddening effect" of nitrates in meat curing was first reported in late Roman times while the first reported references to the characteristic flavor of cured meat produced by the addition of saltpeter during meat preservation and curing were made as early as 1835 (Binkerd and Kolari 1975). In 1876, Edward Smith describes the preserving action of salt "the oldest and best known of preserving agents…its chief action appears to be due to its power of attracting moisture, and thus extracting fluid to harden the tissues". He further describes the development of a "reddish color throughout" meat preserved with saltpeter compared to preservation by salt alone where the meat loses its color. As a more scientific understanding of the curing process evolved in the late 1800s and early 1900s, the role of nitrite in the formation of the distinct cured meat flavor and color was established.

The history of the use of nitrite was not well documented until 1891, when Polenske first reported finding nitrite in cured meat and used curing pickle. He concluded, correctly that the nitrite was the result of the bacterial reduction of nitrate added to the pickle (Jones 1932; Binkerd and Kolari 1975). In 1899, Lehman and Kisskalt demonstrated that the color development in cured meats was actually due the presence of nitrite and not nitrate. Haldane in 1901 and Hoagland in 1908 further explained the exact chemical reactions involved in the development of the red color of cooked, cured meats. Hoagland described the additional breakdown of nitrite to nitrous acid and nitric oxide by bacterial and/or enzymatic action and the reaction with "haemoglobin" resulting in the subsequent formation of the distinct final color in uncooked and cooked cured meat products (Binkerd and Kolari 1975).

Following these discoveries in the later part of the 19th and early part of the 20th century, packers found that by using nitrite in place of nitrate in curing pickles they gained more control over the process with more uniform results. Up until this time, processors had limited control, if any, over the production of nitrite in a nitrate brine or pickle. Curing establishments, prior to the early 1900s, frequently used the same lot of pickle more than once, adding in more salt and nitrate to maintain the original concentration in the pickle, failing to realize that the pickle now contained residual nitrite derived from the reduction of the previous lot of nitrate. The effect was a pickle relatively rich in nitrite, as well as highly contaminated with bacteria. For products, this resulted in a wide variation in the amount of residual nitrite in these nitrate-cured meats from 2 to 960 ppm in corned beef and American hams respectively (Jones, 1933). A very beneficial result of the direct addition of small quantities of nitrite in place of nitrate was to gain strict control of the amount of nitrite in finished products than was commonly present in nitrate-cured meats (Jones, 1933). The direct addition of nitrite also shortened pickling times and resulted in a curing process that did not require the presence of reducing microorganisms thereby allowing for a process that limited the presence of bacteria that may also cause spoilage.

Work by scientists such as Polenski, Haldane and Hoagland led to the establishment of regulations in 1908 and 1925 by the United States Department of Agriculture (USDA) setting limits for the use of nitrate and nitrite in cured meats.

Cured Meat Safety

While the distinct flavor and color development of cured meats has been well documented since the 19th century, the majority of research on the antimicrobial effects of nitrite was conducted from the 1920s through the 1940s (Archer 2002). Research during this time focused on using nitrite to solve the problem of sour hams and of perishable canned hams that were being temperature abused at the retail level (Tompkin 2005). Nitrates have been shown to inhibit the growth of spoilage organisms including *Achromobacter*, *Aerobacter*, *Escherichia*, *Flavobacterium*, *Micrococcus* and *Pseudomonas* as well as pathogens such as *Listeria monocytogenes* and *Staphylococcus aureus* (Tarr 1942). However nitrite is especially important in its antimicrobial effectiveness against *Clostridium botulinum*. Evidence of the antibotulinal effects of nitrite were first presented in 1951. Prior to the use of nitrite in meat curing, botulism was a serious and life-threatening illness associated with meat and sausages. The species name of botulinum is actually derived from the Latin word for sausage, *botulus*. The antibotulinal action of nitrite involves the interaction of nitrites with other factors such as salt, pH and heat. Initial studies in the 1920s and 30s used culture media with a pH of 7.0 and it was not until the 1960's that nitrate was reported to be more effective at a more acidic pH level (Archer 2002; Tompkin 2005).

Although nitrate and nitrite have been used for centuries in the preservation of meat and meat products, the safety of nitrite-cured meats became the subject of concern during the 1970s. These concerns centered on the risks associated with the possible formation of nitrosamines in cured meats and the potential risk of residual nitrite in cured meat products. The controversy produced a tremendous amount of research in the area of nitrates, nitrites and nitrosamine compounds as well as investigation into alternatives to the current use of nitrites in foods.

In 1973, USDA established an Expert Panel on Nitrites, Nitrates, and Nitrosamines to review all aspects of curing meat products. The result in 1975 was a recommendation that the level of nitrite permitted in bacon be reduced and that maximum levels of ascorbate or erythorbate be required as nitrosamine inhibitors. The recommendations were adopted and the regulations for bacon were changed in 1978 (IFT 1987).

In 1980, The National Academy of Sciences (NAS) entered into a contract with USDA and the Food and Drug Administration (FDA) and established the Committee on Nitrate and Alternative Curing Agents in Food. The committee was charged with the task to assess the health risks associated with overall exposure to nitrate and nitrate and *N*-nitroso compounds from both natural and added nitrate and nitrite in food and to review the status of research and future prospects for developing feasible alternatives to the use of nitrite as a preservative (NAS 1981). The 1981 report, *The Health Effects of Nitrate, Nitrite, and N-Nitroso Compounds* set forth eleven recommendations, which are shortened below (NAS 1981; Cassens, 1995):

1. Nitrate is neither carcinogenic nor mutagenic. Some human population studies have indicated an association of exposure to high nitrate levels with certain cancers. Future studies were therefore recommended.
2. Nitrite does no act directly as a carcinogen in animal studies. Further testing may be warranted.
3. Most *N*-nitroso compounds are carcinogenic in laboratory animals, mutagenic in microbial and mammalian test systems, and some are teratogenic in laboratory animals. Future work should emphasize quantitative assessment of potency and outcome.
4. Because nitrate and nitrite can exert acute toxic effects and contribute to the total body burden of *N*-nitroso compounds, it was recommended that exposure to these agents be reduced. Reduction in nitrate use should not compromise protection against botulism. The use of nitrate salts in curing should be eliminated, with the exception of a few special products. Attention should be given to reducing nitrate content of vegetables and drinking water.
5. Sources of exposure to *N*-nitroso compounds in various environmental media should be determined so that it can be reduced. Analytical procedures should be improved, especially for non-volatile compounds and for both free and bound nitrite.
6. The exposure of humans to amines and nitrosamines can be reduced in some instances by modifying manufacturing practices, such as with certain pesticides and drugs.
7. Additional studies are needed to increase the understanding of the metabolism and pharmacokinetics of nitrate in humans.
8. Further study of inhibitors of nitrosation is needed.
9. Further studies should be made to determine the mechanism(s) whereby nitrite controls the outgrowth of *C. botulinum* spores, and also its effect against other spoilage and pathogenic microorganisms.
10. Although it is not possible to estimate the potential morbidity nor mortality from *C. botulinum* in the absence of nitrite as a curing agent in certain products, the prudent approach to protecting public health requires consideration of the possibility that certain preserved food items may be contaminated and may be abused.

In the 1982 report, *Alternatives to the Current Use of Nitrite in Foods*, the committee made recommendations on alternatives to the conventional use of nitrite as agents of treatment that could serve as partial or complete replacements for nitrate, and agents that block the formation of nitrosamines in products containing conventional concentrations of nitrite. The following alternatives were found by the committee to be the most promising: the combination of ascorbate, α-tocopherol, and nitrite; irradiation (with or without nitrate); lactic acid-producing organisms (with or without nitrite); potassium sorbates with low concentrations of nitrite; sodium hypophosphite (with or without nitrite); and several fumerate esters.

Following the publication of the NAS reports, a significant amount of research was initiated and some of the recommendations have been implemented by the meat industry. A suitable alternative to nitrite however has not been identified.

Natural and Organic Cured Meats

Over the past few years there has been a significant increase in the consumer demand and resulting production of “natural” and “organic” foods. For cured meat products this has presented a particular challenge since traditional curing agents, nitrate and nitrite, cannot be added to natural or organic processed meats. This provides the consumer with a preservative-free, cleaner labeled product. However, it has created some challenges for the meat industry as they develop products that have the distinctive color, flavor and texture of cured meats, that will persist throughout shelf-life and provide the same level of safety provided by traditional nitrite-cured meats.

Nitrate and Nitrite in Vegetables

Nitrates are intrinsic constituents of plants. Nitrates are produced in the soil, by microorganisms acting on manure, urine and vegetable waste, making them naturally available to growing plants (Barnum, 2003). Certain vegetables such as spinach, beets, radishes, eggplant, celery, lettuce, collards, and turnip greens contain very high concentrations of nitrates (Table 17).

In 1981, the NAS reported several factors which may affect the nitrate content of vegetables during growth (Corré and Breimer 1979; Maynar 1978; Maynard et al. 1976; NAS 1981). These include:

- Related plant strains (cultivars) systematically may differ in nitrate content.
- Different levels and timing of nitrogen fertilizer application. Nitrate accumulation increases as the amount of nitrogen fertilizer used increases and if the fertilizer is applied shortly before harvest.
- Nitrate levels tend to increase as daytime temperatures drop below an optimal temperature, thus geographical region and season of harvest affect nitrate content.
- Greenhouse plants tend to accumulate higher levels of nitrate than do plants grown outdoors perhaps because nitrogen fertilizers are used more heavily indoors.

- Plants grown in shade, at high latitudes with limited sunlight, and during drought accumulate higher levels of nitrate than do plants grown under optimal conditions of water and light supply.
- Leafy plants harvested on a sunny afternoon often contain less nitrate than those harvested in the morning or during inclement weather.
- Some plant diseases, insect damage, or exposure to herbicides, such as those used in weed control, often increase nitrate accumulation.
- Soil deficiencies, such as insufficient molybdenum or potassium, or acidic, organically rich (peat) soils lead to elevated nitrate content.

The above factors may affect nitrate levels in products by affecting one or more plant processes such as nitrogen uptake, nitrogen transport, and nitrate reduction and assimilation (NAS, 1981). Nitrate levels in vegetables can also be affected by factors such as the storage and processing. Processes such as canning and blanching can reduce the nitrate levels by 20 to 50% in some vegetables (Kilgore et al. 1963; Lee et al. 1971; Schuphan 1974).

The nitrite content of vegetables is also affected by processing and storage. Storage over time, particularly at higher temperatures, will result in an increase of nitrite due to the reduction of nitrate to nitrite by reductase enzyme present in plant tissue and by contaminating bacteria (Corré and Breimer 1979; Lin and Len 1980; Phillips 1968a, b). While the nitrate and nitrite content of vegetables varies greatly, the initial nitrate content can be modified by certain modifications in growing conditions including water source (Wolff and Wasserman 1972), soil conditions, time of harvest, plant-specific factors, and by the amount, kind and timing of nitrogen fertilization (NAS 1981).

Nitrates and Nitrites in Drinking Water

Nitrate (NO_3^-), the oxidized form of dissolved nitrogen, is the most common groundwater contaminant worldwide and is highly soluble making it easily leached from soils into the available groundwater (Rosen and Kropf 2009). Nitrate is derived from both natural and human (anthropogenic) sources and is a relatively stable form of nitrogen in oxygen-rich soils and aquifers. Nitrogen is an inert gas that makes up 78% of the atmosphere and through natural processes is converted into a variety of common bioavailable compounds, the most common being ammonia (NH_3), ammonium (NH_4^+), nitrate nitrogen (NO_3–N), nitrite (NO_2), nitrosamines or organic nitrogen (R-N_2H) (Rosen and Kropf 2009).

Natural sources of nitrate from nitrogen include fixation by lightning, bacterial conversion in plants and to a lesser extent igneous rocks, deep geothermal fluids and dissolution of some evaporite minerals. Degradation of plants can release stored nitrogen to the soil where it is converted to nitrate and incorporated into aquifers by precipitation.

The primary sources of nitrates that contaminate groundwater are derived from human activity and also includes waste from farm animals, fertilizers, manure applied to soils, human waste from septic tanks and waste water treatment systems (discharge) (Harter 2009). In the Southwestern U.S. and other agricultural areas, inorganic fertilizer and animal manure are the most common nitrate source while urban areas without proper sewer containment contribute to the nitrate levels in groundwater. Ammonia used in fertilizers my volatilize, be used by plants or may be denitrified by microbial action, thus releasing gaseous nitrogen.

The U.S. Environmental Protection Agency (EPA) established the maximum contaminant level (MCL) for nitrate-nitrogen (NO_3^-N) at 10 mg/l in 1975 to regulate nitrate levels in drinking water and protect human health (Rosen and Kropf 2009). It has been known for more than 50 years that high concentrations of nitrate (>20 mg/l as nitrogen) could cause methemoglobinemia ("blue baby disease") in infants less than six months of age and was part of the impetus for the EPA regulation. Other conditions such as hypertension, central nervous system birth defects, certain cancers, non-Hodgkins lymphoma, and diabetes have been linked to nitrate in drinking water. Having similar concerns, the World Health Organization in 1993 established the MCL for nitrate at 11.3 mg/l nitrate-nitrogen which has been the limit adopted by many other countries throughout the world. In the U.S., a survey conducted by Nolan and Stoner (2000) of 33 regional aquifers found that more than 15% of the wells drawing from the aquifers had nitrate concentrations above the EPA maximum limit of 10 mg/l nitrate-N. In other studies, nitrate was the most frequently reported groundwater contaminant in over 40 states (Fetter 1993; US EPA 1990).

Current and future treatment options to lower nitrate levels in drinking water include: 1) blending high-nitrate water with low-nitrate water; 2) ion exchange of potable water (most widely use nitrate removal method, but may contribute very low levels of nitrosamines or their precursors from the membrane resins); 3) membrane separation (reverse osmosis and electrodialysis are used in small communities, but require high energy inputs); 4) biological denitrification with selective microorganism that convert NO_3^- to N_2; and 5) chemical denitrification (under development) that reduces nitrate. Both denitrification systems require low-dissolved oxygen levels.

MATERIALS AND METHODS

Experimental Design and Sampling Scheme

A national survey of the major categories of cured meat products and the most highly consumed raw vegetables with medium to high levels of nitrate (relative to other vegetables consumed in the United States, (USDA-ERS 2009)) was conducted in five major U.S. cities in different geographic regions from September 2008 to March 2009. The purpose of the survey was to obtain a "cross-section" of highly consumed cured meat products and raw vegetables available to consumers and to analyze each for nitrite and nitrate content. Two subcategories or types of cured meat products and raw vegetables were also targeted for sampling – conventional products and those designated as organic/ natural/ no nitrite. Random samples of each product category were collected simultaneously within each city with a criterion that all meat products sampled must be purchased at least a week before the "sell-by" date printed on the package.

The major categories of cured meat products and raw vegetables (Tables 1 and 2) were collected in retail outlets and supermarket chains in Chicago, IL, Dallas, TX, Los Angeles, CA, New York City, NY and Raleigh, NC. A proportional number of cured meat samples from each category were determined based on production volume per manufacturer, consumption, unique processing characteristics (i.e. dry cure, "no nitrite", etc.) and product regionality. The sampling scheme used with the appropriate categories is given in Tables 1 and 2.

Sampling Procedures

Each city was visited once. Three cities (Dallas, Raleigh and Chicago) were surveyed from September to November 2008 and the remaining cities (New York and Los Angeles) were surveyed during February and March 2009. Retail outlets in each city were identified in advance for sample collection. Teams of graduate students and/or faculty traveled to each city and collected conventional and organic /natural/ no nitrite samples in each of the meat product and vegetable categories (Tables 1 and 2). Meat samples were collected from fresh and/or frozen retail displays, pegboard displays and/or deli service counters. All vegetable samples collected were fresh. Samples collected from Dallas were left in their original packaging, placed in plastic bags and stored in refrigerated coolers for auto transport to Texas A&M University, College Station, TX. Samples collected in Raleigh were transported to the North Carolina State University Meat Laboratory in Raleigh, NC where they were placed in styrofoam shipping containers lined with frozen chill packs and labeled for shipping. Samples collected from Chicago were placed in plastic bags in their original packaging and transported in refrigerated coolers to the University of Wisconsin Meat Laboratory in Madison, WI where they were placed in styrofoam shipping containers lined with frozen chill packs and labeled for shipment. Samples from New York were transported to Bimmy's in Long Island City where they were placed in styrofoam shipping containers lined with frozen chill packs and labeled for shipment. Samples from Los Angeles were transported to Farmer John's Quality Assurance Department where they were placed in styrofoam shipping containers lined with frozen chill packs and labeled for shipment. Samples from all cities were shipped overnight for next day arrival at the Processed Meats Research Laboratory at Texas A&M University.

Table 1. Sampling scheme by category and product type for cured meats collected in retail outlets in each of five regional cities across the United States

	Product Type	
Product Category	**Conventional**	**Natural, Organic, “No Nitrite”**
1) Cured Sausages (Cooked)		
Bologna	4	4
Frankfurters	4	4
Polish Sausage	4	4
2) Whole-Muscle Brine Cured (Cooked)		
Hams	4	4
Bacon (Precooked)	4	4
Cured Poultry	4	4
Pastrami		
Corned Beef		
3) Fermented/Acidified Sausages (Cooked)		
Pepperoni	4	4
Summer Sausage	4	4
Snack Sticks	4	4
4) Whole-Muscle Brine Cured (Uncooked)		
Bacon	4	4
	4	4
	4	4
5) Whole Muscle Dry Cured (Uncooked)		
Dry-cure Country Style Hams	4	4
Dry-cure Bacon	4	4
Prosciutto	4	4
6) Cured, Dried Sausages (Uncooked)		
German Air-Dry Sausage	4	4
Chorizo	4	4
Italian Dry Sausage	4	4

*Sample numbers = 5 Cities x 6 Product Categories x 2-3 Products Per Subcategory x 2 Product Types x 4 Samples Per Category = 480 Total Samples (467 samples were actually collected)
Six samples per subcategory were purchased; four analyzed for nitrite/ nitrate content; two samples held in reserve.
Note – Not all products were available in some categories, but similar products were collected to fill the category. For sausages, no products were selected as strictly poultry, beef or pork and could have been formulated to contain one or more species within a single product, i.e. poultry, beef and pork frankfurters.

Raw Vegetables

Based on the most current USDA-ERS Food Availability data and previous surveys comparing the nitrate and nitrite contents of raw vegetables (Gangiolli et al. 1994; Prasad and Chetty 2008; Santamaria 2006; Susin et al. 2006; Tamme et al. 2006; Chung et al. 2003; Petersin and Stoltze 1999; Santamaria et al. 1999; NAS 1981; Siciliano et al. 1975), five vegetables were selected for analysis as the most likely candidates for contributing to total dietary nitrate/ nitrite load. Samples of raw vegetables were taken at the same time and in the same retail establishment (if possible), as the meat samples. The assumption being that consumers would likely purchase these items in the same retail outlet and at the same time. The sampling scheme for the raw vegetables selected are shown in Table 2.

Table 2. Sampling scheme for vegetables collected in retail outlets in each of five cities across the United States

	Product Type	
Vegetable Product Category*	**Conventional**	**Natural, Organic**
Spinach (Nitrate ranges from previous studies - 2,508 to 4818 ppm) Retail per capita availability 2007 (1.8 lbs, 0.82 kg)	4	4
Lettuce (1,011 to 2,846 ppm) Retail per capita availability 2007 (18.8 lbs, 8.55 kg)	4	4
Cabbage (724 to 2,501 ppm) Retail per capita availability 2007 (8.0 lbs, 3.64 kg)	4	4
Celery (732 to 6,008 ppm) Retail per capita availability 2007 (5.9 lbs, 2.68 kg)	4	4
Broccoli (~783 ppm) Retail per capita availability 2007 (5.5 lbs, 2.5 kg)	4	4

*Sample numbers = 5 Cities x 5 Product Categories x 2 Product Types x 4 Samples Per Category = 200 Total Samples (197 samples were actually collected)
Six samples per subcategory were purchased; four analyzed for nitrite/ nitrate content; two samples held in reserve.
Note – Not all products were available in some categories, but attempts were made to fill the category with a similar product.

Potable Water Supply

A companion survey was performed by acquiring nitrite /nitrate concentrations of potable water supplies from 25 major cities located in different geographic regions of the U.S. by securing water quality analyses from the EPA databank, public health departments and/ or water department municipalities. The database was used to evaluate other potential sources of dietary nitrite in regions across the U.S. and estimate the municipal water supply's contribution nitrate/ nitrite intake.

Sample Receipt, Handling and Storage

Upon receipt at the Processed Meats Laboratory, all meat and vegetable samples were visually evaluated for overall condition. Any samples that were not previously packaged (deli meats) or that had lost their package integrity during shipping were vacuum packaged until analyzed. All samples were labeled, placed into cardboard storage boxes based on random sample order and immediately frozen or refrigerated. Meat samples were held under frozen storage (-15° C), thawed under refrigeration (4° C) 24 hr prior to sample preparation. Vegetable samples were held refrigerated (4°C) prior to sample preparation. Vegetable samples were prepared first for nitrate/ nitrite analysis followed by meat samples. All retention samples (extra backup samples) were placed in cardboard storage boxes and held frozen (-15° C).

Sample preparation and extraction procedures – vegetables

Vegetable samples were removed from their package and the outside leaves and/or ends of leaves and/or stems/stalks removed. Samples were rinsed in distilled, deionized water, allowed to drain and the excess water spun off using a salad spinner (10 pumps of pressure, spun 30 secs). Rinsed samples were cut into smaller pieces and weighed to amass a 200 g sample. Sample pieces were placed in a food processor and homogenized 15 s. The sides of the food processor were scraped and the sample homogenized an additional 15 s. This process was repeated until the sample was homogenized for a total of 60 s (4 iterations).

Samples for nitrite analysis

A 20 g portion of vegetable homogenate was placed in a blender with 100 mL of phosphate buffer (pH 7.4), homogenized for 5 min and three, 400 µL aliquots of the homogenate pipetted into labeled, 1.5 mL centrifuge tubes. Methanol (400 µL) was added to each tube, the samples vortexed and then centrifuged (13,000 x *g*) for 8 min. After centrifugation, the sample supernatant was collected placed in a new centrifuge tube, capped, labeled and stored at 4°C until shipped to Dr. Nathan Bryan’s laboratory for HPLC analysis.

Samples for nitrate analysis

Three additional 100 µL aliquots of phosphate buffered homogenate were collected and each diluted with 10 mL of phosphate buffer in a culture tube that was subsequently covered with Parafilm™ and vortexed (15 s). Three, 400 µL aliquots of the homogenate were pipetted into labeled, 1.5 mL centrifuge tubes. Methanol (400 µL) was added to each tube, the samples vortex and then centrifuged (13,000 x *g*) for 8 min. After centrifugation each sample supernatant was collected separately, placed in a new centrifuge tube, capped, labeled and stored at 4°C until shipped for analysis.

Sample preparation and extraction procedures – cured meat products

Meat samples were removed from their package and artificial casings or nettings removed if present. Samples were cut into small pieces and subjected to the same homogenization and dilution procedures as previously described for vegetable samples.

Samples for nitrite analysis

Three, 40 g portions of slurry from each meat sample were individually weighed into 50 mL polycarbonate centrifuge tubes and subjected to centrifugation for 5 min at 10,000 x *g* at 4°C. This enabled aggregation of the lipid fraction (top layer) and allowed easier pipetting of the homogenate (bottom layer). Samples were then subjected to the same procedures as previously described for vegetables.

Samples for nitrate analysis

Three additional 100 µL aliquots of phosphate buffered homogenate were collected and each diluted with 10 mL of phosphate buffer in a culture tube that was subsequently covered with Parafilm™ and vortexed (15 s). Three, 400 µL aliquots of the homogenate were pipetted into labeled, 1.5 mL centrifuge tubes. Samples were then subjected to the same procedures as previously described for vegetables.

Sample extract handling and shipment

All sealed sample extract tubes were held refrigerated (4°C) until packaged for shipment to Dr. Nathan Bryan at the University of Texas, Houston Health Science Center (UTH-HSC) for analyses. U-Tek freeze packs (-23°C) were placed in the bottom of an insulated foam shipping container, tube racks containing sample extracts were wrapped in Parafilm™ "M" laboratory film and the racks placed on top of the frozen packs. Additional frozen packs were placed on top of the tube racks. The box was sealed and shipped via overnight carrier to UTH-HSC to arrive by 10:00 AM the following day. All samples were shipped to UTH-HSC within 48 hours of sample extraction and preparation.

Nitrate/ Nitrite Determination – High Performance Liquid Chromatography (HPLC)

Samples were analyzed in triplicate upon the day of arrival or refrigerated until analyzed the next day. In preparation for nitrite and nitrate analysis, methanol (1:1 v/v for nitrite and 1:100 v/v for nitrate) was added to each sample, the sample tube vortexed and then centrifuged for 10 min to precipitate proteins prior to HPLC analysis of nitrite and nitrate. Complete analytical procedures have been previously described by Bryan and Grisham (2007).

A dedicated ENO-20 HPLC System (EiCom Corporation) was employed for nitrate/ nitrite analysis. This system is sensitive, selective for the measurement of nitrate and nitrite in all biological matrices and has the capacity for high throughput. The ENO-20′s high sensitivity is attained by the combination of a diazo coupling technique with the extract to be measured and separation of nitrite and then nitrate using a reverse-phase column. To separate nitrite and nitrate, the nitrate is first reduced to nitrite through a reaction with cadmium and reduced copper inside a reduction column. The two resolved peaks are then mixed with Griess reagent (dinitrogen trioxide, N_2O_3, generated from acidified nitrite that reacts with sulfanilamide) in-line to form the classical diazo compound which can be detected spectrophotometrically. This system allows for easy sample preparation, little if any cross-reactivity and high through put when coupled with an auto-sampler. The system is adaptable for a wide range of nitrite and nitrate concentrations regardless of their respective ratios and operates at a sensitivity level of 1nM × 100-µL injections for each anion with no interference from protein or other colored species.

Experimental Design – Statistical Analysis

Six categories of cured meat products and five highly consumed raw vegetables were randomly and simultaneously sampled in retail outlets in five metropolitan areas (described previously) to determine the nitrite/ nitrate content of each sample in each product category. For the purpose of analysis, the study was considered to be a completely randomized design with the following factors:

1. Metropolitan Area (MA): Chicago, Dallas, Los Angeles, New York, Raleigh
2. Vegetables (V): Broccoli, Cabbage, Celery, Lettuce, Spinach
3. Meat Products (MP): Cured Sausages, Cooked; Whole-muscle Brine Cured, Cooked; Fermented/ Acidified Sausages, Cooked; Whole-muscle Brine Cured, Uncooked; Whole-Muscle Dry-Cured, Uncooked; Cured, Dried Sausages, Uncooked
4. Product Type (PT): Conventional, Organic

From each sample, the nitrite/ nitrate concentration was determined in triplicate. These values were considered as subsamples and were used to assess the variation in the nitrite/ nitrate measurement process. The least squares means, standard errors of the estimated means, and the minimum and the maximum observed concentrations of nitrite/ nitrate were computed for each combination of the factors and are reported in the Tables under the Results and Discussion section.

To determine significant main effects and interactions of the factors, a data analysis was conducted separately for Vegetables and Meat Products and for nitrite and nitrate concentrations. This yielded four separate analyses:

1. Analysis I: Response variable: Nitrite concentration; Factors: MA; V; PT
2. Analysis II: Response variable: Nitrite concentration; Factors: MA; MP; PT
3. Analysis III: Response variable: Nitrate concentration; Factors: MA; V; PT
4. Analysis IV: Response variable: Nitrate concentration; Factors: MA; MP; PT

For each of the analyses, an examination of the residuals from the fitted models demonstrated heterogeneous variability and either heavier than normal tails or a right skewed distribution. Therefore, a log transformation of the data was performed in order to satisfy the necessary conditions for conducting an analysis of variance (ANOVA). The residuals from the models using the log transformed nitrite/ nitrate concentrations appeared to satisfy the conditions of homogenous variances and a normal-like distribution.

The results from the ANOVA are reported in Tables under the Results and Discussion section. Because of the significant interactions displayed in the ANOVA tables, a more detailed examination of the mean nitrite/ nitrate concentrations was conducted using a Bonferroni multiple comparison of the least squares means. For each combination of MA and V and each combination of MA and MP, a test of the difference in mean nitrite/ nitrate concentrations for Organic versus Conventional products was conducted. Also, a Bonferroni pair-wise comparison of the mean nitrite/ nitrate concentrations across the five metropolitan areas was conducted separately for each combination of V and PT and for each combination of MP and PT.

Analysis I - Nitrite Concentrations in Vegetables

The 3-way interaction between MA, V, and PT was not significant (p-value=0.1714). Of the three 2-way interactions, only the interaction between V and MA was significant (p-value=0.0092). Therefore, the size of the differences in the mean nitrite concentrations between the five vegetables varied across the five metropolitan areas. There was not a significant difference (p-value=0.8295) in the mean nitrite levels of conventional and organic vegetables.

Analysis II – Nitrite Concentrations in Meat Products

The 3-way interaction between MA, MP, and PT was not significant (p-value=0.0926). None of the three 2-way interactions were significant. All three of the main effects were significant: MA (p-value=0.0188), MP (p-value<0.0001), and PT (p-value=0.0021). Thus, the mean concentration of nitrite was different across the five metropolitan areas, across the six meat products, and organic differed from conventional meat products.

Analysis III – Nitrate Concentrations in Vegetables

The 3-way interaction between MA, V, and PT was significant (p-value<0.0001). Therefore, we can conclude that the size of the differences in the mean nitrate concentrations between organic and conventional vegetables will vary across the five metropolitan areas and across the five vegetables. This is reflected in the tables in the next section, where it can be observed that whether or not there is a significant difference between organic and conventional vegetables depends on the type of vegetable and the metropolitan area.

Analysis IV – Nitrate Concentrations in Meat Products

The 3-way interaction between MA, MP, and PT was significant (p-value=0.0298). Therefore, we can conclude that the size of the differences in the mean nitrate concentrations between organic and conventional meat products will vary across the five metropolitan areas and across the six categories of meat products. This is reflected in the tables in the next section, where it can be observed that whether or not there is a significant difference between organic and conventional meat products depends on the type of meat product and the metropolitan area.

RESULTS AND DISCUSSION

Cured Meat Products

Current U.S. regulations allow the use of nitrite and nitrate in meat products based upon the product category and method of curing (IFT 1987). Immersion cured, massaged or pumped products such as hams or pastrami are limited to a maximum ingoing level of sodium or potassium nitrite and sodium or potassium nitrate of 200 and 700 ppm (mg/kg), respectively, based on the raw product weight (USDA 1995). Dry-cured products, however, are allowed a maximum ingoing level of 625 and 2,187 ppm of nitrite and nitrate, respectively, since these products have longer curing times that allow for nitrite dissipation and nitrate conversion to nitrite. If a combination of nitrite and nitrate are used, the combination must not result in more than 200 ppm sodium nitrite in the finished product. Comminuted products such as frankfurters, bologna and other cured sausages are limited to a maximum ingoing level of 156 ppm of sodium or potassium nitrite based on the raw weight of the meat block. Sodium or potassium nitrate may be added to these products at 1,718 ppm regardless of the type of salt used. USDA regulations lowering the nitrite level in bacon to 120 ppm $NaNO_2$ (148 ppm KNO_2), requiring 547 ppm sodium ascorbate or erythorbate and eliminating nitrates were implemented in 1978 (IFT 1987). Bacon regulations were again changed in 1986 to give processors three alternatives that would allow lower levels of nitrite in combination with other processing procedures. Skinless bacon is required to have 120 ppm of sodium nitrite (148 ppm potassium nitrite) in combination with 547 ppm of sodium ascorbate or erythorbate to reduce the ingoing nitrite level and the potential for nitrosamine formation. Regulations allow for a ± 20% (96-144 ppm) variance from the specified concentration of nitrite at the time of injection or massaging and nitrates are not allowed in any type of bacon. Other exceptions to these regulations include reducing sodium nitrite to 100 ppm (123 ppm potassium nitrite) with an "appropriate partial quality control program" (Sebranek and Bacus 2007), or 40-80 ppm of sodium nitrite (49-99 ppm potassium nitrite) if sugar and lactic acid starter culture are included in the curing brine. Dry-cured bacon is limited to 200 ppm sodium nitrite or 246 ppm potassium nitrite.

In this study, 467 cured meat products representing six major cured meat categories and 197 samples of fresh, raw broccoli, cabbage, celery, lettuce and spinach (~40 samples each) were taken from retail outlets in five major metropolitan cities across the U.S. and analyzed for nitrite and nitrate content (ppm). Random samples representing both conventional and organic/ natural/ no nitrite (referred to as "organic" hereafter) type products were analyzed for nitrite and nitrate content to provide a benchmark for comparison to historic databases and to enable a more accurate evaluation of nitrite and nitrate contributions to the American diet from these food sources. This survey is the first to our knowledge to evaluate the nitrite and nitrite content of products classified as organic.

Comparisons between conventional and organic

Pair-wise comparisons of the nitrite and nitrate concentrations of conventional and organic meat products sampled from five cities are shown in Table 3A. In all cases except one, there were no differences in the mean nitrite levels of conventionally processed and organic products. As shown in Table 3A, significant differences in nitrite content were found between conventional and organic types only in the cured cooked sausage products category sampled in New York City. The nitrite content of cured cooked sausage was 10.31 ppm for conventional products as compared to 0.70 ppm for organic products (Table 8).

Differences in pair-wise comparisons for nitrate content between conventional and organic meat products was more apparent with significant differences noted for cured dried uncooked sausages sampled in Chicago, fermented cooked sausages in Dallas, Los Angeles and Raleigh and whole muscle dry-cured uncooked products in Raleigh (Table 3A). Cured dried uncooked sausages from Chicago labeled conventional contained 368.09 ppm nitrate versus 0.73 ppm for the organic type products (Table 5). Nitrate levels in conventional fermented cooked sausages from Dallas, Los Angeles and Raleigh samples designated conventional were 29.56, 51.17 and 40.60 ppm respectively, while organic products were 3.75, 1.31 and 9.89 ppm (Tables 6, 7, 9). Whole muscle, dry-cured uncooked conventional products from Raleigh had 114.92 ppm of nitrate while those labeled organic contained only 2.44 ppm nitrate. Thus, for these product categories, the organic labeled products contained a lesser amount of nitrate than conventionally processed products, but for most cured meat categories, there were no differences in nitrate content between conventional and organic product types.

Overall, for most cured meat product categories, there were few differences in the nitrite and nitrate concentrations between conventionally processed and organic type products. In those specific cases where differences were noted for organic products (as described above), the nitrite and nitrate contents were lower. In general, the survey results indicate that most conventional and organic products within a specific meat category might be expected to have similar nitrite and nitrate concentrations.

Comparisons between cities

A comparison of the nitrite and nitrate concentrations among cities (Table 4A) revealed no differences in nitrite content for conventionally cured meat products. However, the nitrite content of organic cured cooked sausage and organic whole-muscle brine cured uncooked products differed among four pairs of cities. Paired comparisons between cities for nitrate content indicated no differences among cities for conventional products except for the whole-muscle brine cured cooked category which was different between New York and Raleigh. Only two organic products, cured dried uncooked sausage and cured cooked sausage, differed among cities for nitrate content.

Overall, the nitrite content of conventional meat products obtained from five cities was not different within the product categories sampled. For the most part, the same was true for organic products except for two categories. Nitrite content differences between cities for organic cured cooked sausage and whole-muscle brine cured uncooked products may indicate significant differences in curing techniques being applied to organic products by the processor supplying the respective retail markets in different cities or that greater variation exists in the retention of nitrite in these products during storage or retail display as compared to conventionally processed meats. This same conclusion is likely true of the nitrate content for organic cured dried uncooked sausage and cured cooked sausage. In general, within most cured meat categories and between conventional and organic types, limited variation was noted in the nitrite and nitrate concentrations in these products.

Pooled nitrite and nitrite means of cured meat products

Table 10 presents the pooled nitrite and nitrate means of individual categories of cured meat products that are segregated into conventional and organic product types across five cities. Table 16 gives the pooled means of individual cured meat product categories across cities and product type (conventional and organic). Because very few differences were found in the nitrite and nitrate concentrations between conventional versus organic product types and only a few organic nitrate differences were noted for specific cities, Table 16 will be used to discuss nitrite and nitrate concentrations observed in the study as a whole. The values in Table 16 will also be used to make comparisons of like products contained within other data sets.

Comparisons with other databases

In the 1970s, the use of nitrite to cure meat was questioned due to the potential formation of *N*-nitrosamines and the level of residual nitrite that was being contributed to the total dietary load (Cassens 1997a). Recommendations derived from this concern and the subsequent publication of additional studies on the use of nitrite in curing led to a change in USDA regulations in 1978 and 1986 that reduced the allowable levels of nitrite and nitrate in meat products and made provision for the use of reductants such as sodium ascorbate to decrease the level of residual nitrite and reduce the potential for *N*-Nitroso compound formation (Milkowski 2006). The use of nitrate was restricted to only certain long-term cured products and stricter controls on handling of nitrites were instituted in the manufacturing process. In 1981, a comprehensive report entitled "The Health Effects of Nitrate, Nitrite and *N*-Nitroso Compounds" was published by the National Academy of Sciences (NAS 1981) to assess the human health risk of these compounds. Eleven recommendations were made to reduce the risk associated with consumption of nitrites, nitrates and *N*-nitroso compounds in cured meats. A subsequent report (NAS 1982) entitled "Alternatives to the Current Use of Nitrite in Foods" provided suggestions for reducing the nitrite and nitrate levels in cured meats and combined these reports alleviated public concern about cured meat as a human health risk (Cassens 1997a). An epidemiological report that processed meats (specifically hot dogs) caused cancer in children (Peters et al. 1994) led to additional concerns about the potential risk of *N*-nitroso compounds and the levels of nitrite in these products.

To substantiate that the levels of nitrite were lower in cured meat products since the changes instituted in USDA regulations in 1978 and 1986, a multi-city (Madison, WI, Los Angeles, CA, Denver, CO, St. Louis, MO, Tampa, FL) survey of U.S. cured meat products (~164 packages of bacon, ham bologna and wieners from major manufacturers accounting for one-third of products manufactured in the U.S.) was conducted by Cassens (1997a) to assess the levels of residual nitrite and ascorbate in these products. The overall mean residual nitrite level observed for samples was 10 ppm (0-48 ppm). In comparison, the average nitrite value was lower than those reported by White (1975) and those given in the NAS (1981) report. White (1975) reported an average nitrite value of 52.5 ppm (26.4 – 63.6 ppm range) and 235 ppm nitrate (60-800 ppm range of means in different cured products) for a broad category of U.S. cured meat products sampled from 1936 to 1972, some of which were manufactured with a combination of nitrate and nitrite. The 1997 survey of cured meats indicated that the levels of residual nitrite had been reduced by approximately 80% from the 1970's (Cassens 1997a).

Over 12 years have passed since the last national survey of cured meat products. This survey was performed to verify that the current nitrite and nitrate levels contributed by cured meats have remained low and are minor contributors to the total human dietary nitrite/ nitrate load. A comprehensive list of the nitrite and nitrate contents of specific cured meat products and raw vegetables available in the U.S. and other countries was compiled for this report and spans the period from 1926 to 2009 (Table 17A).

A summary of the mean nitrite and nitrate levels of six cured meat product categories taken from retail outlets in five major metropolitan areas and representing both conventional and organic type products are presented in Table 16. The specific products making up each category in this study and listed in Table 1 are given below.

Product Categories

1. Cured Dried Uncooked Sausage – German Air-Dried Sausage, Chorizo, Italian Dry Sausage

2. Cured Cooked Sausage – Bologna, Frankfurters, Polish Sausage

3. Fermented Cooked Sausage – Pepperoni, Summer Sausage, Snack Sticks

4. Whole-muscle Brine Cured Uncooked – Bacon

5. Whole-muscle Brine Cured Cooked – Ham, Precooked Bacon, Cured Poultry, Pastrami, Corned Beef

6. Whole-muscle Dry Cured Uncooked – Dry-Cured Country Style Ham, Dry-Cured Bacon, Prosciutto

In Table 16, the lowest nitrite levels in this study were noted for the fermented cooked sausage, cured dried uncooked sausage and whole-muscle dry-cured cooked categories averaging 0.64, 0.74 and 1.95 ppm, respectively. Slightly higher levels of nitrite were observed for cured cooked sausage, whole-muscle brine cured cooked and whole-muscle brine cured uncooked categories averaging 6.86, 7.16 and 7.31 ppm, respectively. Nitrate levels were lowest in whole-muscle brine cured cooked, whole-muscle brine cured uncooked, cured cooked sausage fermented cooked sausage averaging 14.81, 25.57, 27.68 and 35.66 ppm, respectively. Whole-muscle dry-cured uncooked and cured dried uncooked sausage had nitrate contents of 67.43 and 78.81 ppm, respectively. By comparison, these nitrite values were similar to those observed by Cassens (1997a) in two separate trials evaluating bacon (3 and 5 ppm), bologna (15 and 15 ppm), wieners (8 and 9 ppm) and ham (4 and 7 ppm), a total of 154 samples. Cassens (1997a) reported an overall mean nitrite value of approximately 10 ppm in 164 cured meat samples evaluated in three trials. The overall mean nitrite value in this study of the same product categories surveyed by Cassens (1997a) was 7.11 ppm. The mean nitrate value for the same categories was 22.69 ppm. The weighted average means for nitrite and nitrate levels in this study across all cured meat categories were 4.54 and 37.07 ppm, respectively. For comparison to the NAS (1981), nitrite and nitrate values in this study of similar product categories are presented in the following table.

Product Category	**AMIF/NPB (2009) Nitrite/ Nitrate ppm**	**NAS (1981) Table 5-1 Nitrite/ Nitrate ppm**
1) Cured, Dried Sausages (Uncooked) German Air-Dry Sausage, Chorizo, Italian Dry Sausage	0.74/ 78.81	13-17/ 78-89
2) Cured Sausages (Cooked) Bologna, Frankfurters, Polish Sausage	6.86/ 27.68	10-31/ 32-110
3) Fermented/ Acidified Sausages (Cooked) Pepperoni, Summer Sausage, Snack Sticks	0.64/ 35.66	6-17/ 78-89
4) Whole-Muscle Brine Cured (Uncooked) Bacon	7.31/ 25.57	12-42/ 33-96
5) Whole-Muscle Brine Cured (Cooked) Hams, Bacon (Precooked), Cured Poultry, Pastrami Corned Beef	7.16/ 14.81	16-37/ 140-150
6) Whole Muscle Dry-Cured (Uncooked) Dry-cure Country Style Hams, Dry-cure Bacon, Proscuitto	1.95/ 67.43	280/ 24-640

Overall, the nitrite values observed in this survey were consistent within each product category (as noted by the relatively small individual standard errors) and not appreciably different from those reported by Cassens (1997a). In comparison, the nitrite and nitrate values in this study were substantially lower than those reported in the NAS (1981) study. It appears that the current USDA regulations and manufacturer's processing procedures are consistently controlling the levels of nitrite and nitrate in cured meat products and continue to be effective for minimizing their contribution to the dietary nitrite/ nitrate load.

In other countries, the levels of nitrite and nitrate in cured meats are regulated, but vary depending upon the maximum ingoing levels allowed by each regulatory authority and the specific processing procedures followed by manufacturers. European Union rules, as specified by Directive No. 95/2/EC (Leth et al. 2008), fix the ingoing nitrite level in bacon at 150 ppm and residual amounts between 50 and 175 ppm. In Denmark, a lesser amount is allowed (60-150 ppm) in semi-preserved products and special cured hams. Directive No. 95/2/EC allows only 250 ppm residual nitrate (sodium) in salted meats, but for unheated products 150 ppm nitrite + 150 ppm nitrate are allowed. Wiltshire or dry cured bacon may have 175 ppm residual nitrite + 250 ppm residual nitrite (Honikel 2007). Table17A provides a summary of numerous studies and is presented to compare the nitrite and nitrate content of a variety of cured meat products in other countries. Examples of some nitrite and nitrite levels in different meat products from various countries are given in the following paragraph.

The maximum ingoing level of sodium nitrite permitted in Denmark is 60 ppm for most products with some specialty products allowed to have up to 150 ppm. From 1998 to 2006, the residual nitrite in Denmark sausages and salami-type products has varied between 6-20 ppm (Leth et al. 2008) as a result of the ingoing levels allowed. In a similar time frame (2000-2004), the mean nitrite concentrations of Estonian cooked sausages, smoked sausage and ham were 22-38, 14-30, and 8-29 ppm while nitrate means were 48-67, 44-102 and 33-153 ppm, respectively. In Australia, nitrites (sodium or potassium salts) are allowed at a maximum level of 125 ppm in cured, dried and slow-dried cured meat and 50 ppm in sterile and canned meat. Nitrate may be incorporated at 500 ppm in slow-dried cured meats (Hsu et al. 2009). Meat products surveyed in a Sydney market were found to have a nitrite content ranging from 3.7 to 86.7 ppm while nitrate levels ranged from 3.7 to 139.5 ppm. Gangolli et al. (1994) reported the nitrite and nitrate contents of bacon in the UK to be 24 and 43 mg, respectively, while ham levels were 26 and 22 ppm, respectively. A multi-year survey of Canadian products indicated that the overall mean residual nitrite levels in cured meats had declined over the past 20-25 years averaging 28 ppm in 1972, 44 ppm in 1983-1985, 31 ppm in 1993-1995, and 28 ppm in 1996 (Sen and Baddoo 1997). Finnish cured meat products have been observed to range from 2.3-31.6 and 19-136 ppm for nitrite and nitrate contents, respectively (Penttila et al. 1990).

Based on this brief overview of the nitrite and nitrate concentrations in cured meat products from other countries and those values reported in Table 17A, comparable U.S. products often contain lower levels of nitrite and nitrite. Some factors contributing to lower residual nitrite levels could be the use of reductants such as sodium ascorbate (erythorbate), depletion of nitrite during refrigerated storage and other factors.

Raw Vegetables

The predominant sources of nitrates and nitrites in the human diet include vegetables, a few fruits, cured meat products, some fish and dairy products and drinking water (Gangolli et al. 1994, Pennington 1998 and Hord et al. 2009). Vegetables contribute approximately 80% of the nitrates to the diet with lesser amounts contributed by some categories of cured meats. Cured meats are the primary source of nitrites with lesser amounts contributed by vegetables and fruits. Vegetables having the highest nitrate concentrations include escarole, lettuce, spinach, red beets, radishes, celery, rhubarb, parsley Swiss chard, turnip greens (1,000->2,500 ppm); mid-range vegetables include cabbage, leeks, squash, turnip (500-1,000 ppm); low-range examples are broccoli, carrots, cucumbers, cauliflower, pumpkin, egg plant, green onions, melon (200-500 ppm) and very low-range vegetables include potato, peppers, sweet potatoes, tomatoes (<200 ppm) (Pennington 1998, USDA-ERS 2006). Nitrite levels in most vegetables and fruits typically range between 1-2 ppm. Table 17B gives a summary of the nitrate and nitrite concentrations of vegetables found in the U.S. as well as other countries.

In this study, 197 random samples of fresh, raw broccoli, cabbage, celery, lettuce and spinach (~40 samples each) were collected from retail outlets in five major metropolitan cities across the U.S. and analyzed to determine nitrite and nitrate content (ppm). Random samples representing both conventional and organic type products were analyzed to provide a benchmark for comparison to other databases and to enable a more accurate evaluation of the nitrate and nitrite contributions to the American diet from more highly consumed vegetables. To our knowledge, this survey is the first to evaluate the nitrate and nitrite content of vegetables classified as organic.

Comparisons between conventional and organic

Pair-wise comparisons of the nitrate and nitrite concentrations of conventional and organic vegetables sampled from five cities are shown in Table 3B. There were no differences in the mean nitrite levels of conventional and organic products taken from five metropolitan areas. However, significant differences in pair-wise comparisons between conventional and organic vegetables for nitrate content were observed (Table 3B). Differences were noted in broccoli from Los Angeles and Raleigh, cabbage from Chicago, celery in Dallas and spinach in Dallas and Raleigh. Organic broccoli in Los Angeles had a mean nitrate level of 195.45 ppm as compared to conventional broccoli with 512.05 ppm (Table 7). Likewise, broccoli from Raleigh contained only 8.19 ppm of nitrate compared to 553.05 ppm that was conventionally grown (Table 9). Organic cabbage from Chicago (Table 5) had a nitrate level of 52.45 ppm while the conventional cabbage contained 474.93 ppm nitrate. The nitrate level of organic celery from Dallas was 390.42 ppm while its conventional counterpart had 2,052.33 ppm of nitrate (Table 6). Organic spinach from Dallas also had a lower nitrate content at 1,609.9 ppm as compared to conventional spinach with 4,923.26 ppm.

In each case where specific organic vegetables were found to be statistically different from conventional vegetables within a city, the organic classification contained less nitrate.

These lower levels could be due to the use of no or low levels of nitrate rich fertilizers. Other factors that could contribute to higher nitrate levels in conventional vegetables are the use of high nitrate fertilizers, naturally high nitrate levels in the soil or higher levels of nitrate in irrigation water (water that is naturally high in nitrates or has been exposed to agricultural runoff from high-density animal facilities such as feed lots). Thus, based on this survey, some organic vegetables were lower in nitrate content than their conventional counterparts.

Comparisons between cities

A comparison of the nitrite concentrations among cities (Table 4B) revealed few differences in nitrite content for conventionally produced vegetables. An exception to this was the nitrite content of conventionally grown spinach which differed between at least two city groups. The nitrite content of organic cabbage and spinach was more variable in samples taken from different cities. There were no significant differences in the mean nitrite levels of conventional and organic vegetables.

The size of the differences in mean nitrate concentrations between conventional and organic vegetables varied across the five metropolitan areas and across the five vegetables (Table 4B). The fact that nitrate concentrations of conventional and organic vegetables differed from city to city was likely due to a multiplicity of factors. Gangolli et al. (1994) noted that the variation in nitrate content of fresh produce is considerable and often unpredictable even under good agricultural practices since there are few regulations governing the use of nitrates in vegetable production. Other factors that contribute to nitrate variability include the cultivar used, the use and level of commercial nitrogen fertilizers, the natural nitrate content of soils, the region or country of origin, season or time of year the product was grown, cultivation practices of individual growers, time required for transport to the retail outlet, length of storage time prior to sale, day length, light intensity, green house cultivation versus open fields, soil and ambient temperature and mineral content of the soil.

Pooled nitrite and nitrite means of vegetables

Table 10 presents the nitrate and nitrite means of individual vegetables pooled across five cities, but separated into conventional and organic types. Even though a 3-way interaction was observed between the main effects, the data were pooled across cities to provide mean nitrate and nitrite values that could be compared with the values in other data bases. The nitrite content of both conventional and organic vegetables ranged between 0.11-1.20 ppm with the exception of conventionally grown spinach which contained 7.98 ppm nitrite (Table 10). The nitrate contents of conventional broccoli, cabbage, celery, lettuce and spinach were 394.38, 417.56, 1,495.48, 850.46 and 2,797.18 ppm, respectfully, while their organic counterparts averaged 204.29, 551.97, 911.94, 844.06 and 1,317.73 ppm. Only the organic cabbage had a slightly higher nitrate content than the conventional cabbage. With this one exception, organic vegetables had numerically lower nitrate concentrations than conventional vegetables.

Tables 5-9 give individual nitrate and nitrite values for vegetables surveyed in each city and segregated by product type (conventional versus organic). These tables are provided to indicate the regional variability observed in vegetable nitrate and nitrite values. Tables 11-15 provide the nitrate and nitrite values of vegetables by individual cities, but pooled across product type. Table 16 presents the means of individual vegetables pooled across cities and vegetable type (conventional and organic), but was not used for comparative purposes due to the significant 3-way interaction for the metropolitan area, vegetable and product type (conventional versus organic).

Comparisons with other databases

Siciliano et al. (1975) analyzed fresh and frozen vegetables from local U.S. supermarkets (December 1973 to January 1974) for nitrate and nitrite content and reported the following values: broccoli, 573 and 1.0 ppm, cabbage 784 and 0.5 ppm, celery 1,600 and 0.5 ppm, lettuce 1,400 and 0.4 ppm, spinach 2,140 6.1 ppm. The values from this study are somewhat comparable to the nitrate and nitrite contents of conventional vegetables observed in this survey (Table 10). For additional comparisons, the nitrate and nitrite values from other countries for the same vegetables analyzed in this study are presented in the table below. Nitrate and nitrite concentrations vary from country to country and within the same vegetable category. Thus, for determining the level of dietary nitrate and nitrite actually contributed by vegetables, the values used would need to be country specific and region specific. The fact that the nitrate and nitrite contents of vegetables are variable (as shown between conventional and organic products and from city to city in this survey) poses a potential dilemma for determining actual vegetable consumption (an in turn nitrate/ nitrite dietary load) of a population. Based on this survey, regional variation may need to be taken into consideration when developing predictions based on consumption of specific vegetables and their contribution to nitrate load. This variation might be of sufficient magnitude to alter epidemiological predictions if not considered appropriately.

	Nitrate/ Nitrite Content of Vegetables (ppm)					
US Conventional Table 10 Values	**UK** Gangolli et al. 1994	**Italy** Santamaria et al. 1999	**Denmark** Petersen and Stoltze (1999)	**Korea** Chung et al. (2003)	**Estonia** Tamme et al. (2006)	**Germany** Tamme et al. (2006)
Broccoli 394/ 0.59	1,014/ 1.5	905/ 0.57				
Cabbage 418/ 0.13	712/ 0.8	400/ 0.68	1,000/ 0.16	1,740/ 1.1	1,243/ <5	451
Celery 1,495/ 0.12	3,151/ 0.8	1,678/ 3.86			565/ <5	
Lettuce 850/ 0.59	2,330/ 0.6	1,241/14.23	2,440/ 0.20	2,430/ 0.6	2,167/ <5	1,489
Spinach 2,797/ 7.98	2,470/ 3.8	1,845/ 5.72	1,783/ 11.0	4,259/ 1.0	2,508/ <5	965

Additional nitrate and nitrite values for a variety of vegetables in the U.S. and other countries are shown in Table 17.

Drinking Water

The permissible concentration of nitrate in drinking water is 50 mg nitrate/L in the European Union and 44 mg/L in the United States (Hord 2009). The U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) or exposure level for drinking water is 10 mg/L nitrate and 1 mg/L nitrite (EPA 2006). The Joint Food and Agricultural Organization/ World Health Organization set the Acceptable Daily Intake (ADI) for nitrate ion at 3.7 mg/kg body weight and for the nitrite ion at 0.6 mg/kg body weight. The EPA has set a Reference Dose for nitrate at 1.6 mg nitrate ion/kg-day body weight and for the nitrite ion a level of 0.1 mg/kg-day body weight. Lower doses are set for infants and children due to the potential for methemoglobinemia.

A survey of the nitrate and nitrite concentrations in 25 municipal water supplies across the U.S. was conducted to determine the average concentration of nitrate/ nitrite in drinking water. EPA reports on the municipal water supply from each city were compiled and nitrate/ nitrite results are presented in Table 18. Philadelphia PA, Atlantic City, NJ and Los Angeles, CA reported the highest levels of nitrate of the 25 cities at 4.9, 4.56 and 2.2-9.2 ppm (mg/L), respectively. It is interesting to note that the highest nitrate concentrations in Los Angeles came from groundwater that was taken from wells. All drinking water sources were below the allowable limits for nitrate and nitrite (if reported) established by the EPA.

CONCLUSIONS

Cured Meats

In this study, 467 cured meat products representing six major cured meat categories and 197 samples of fresh, raw broccoli, cabbage, celery, lettuce and spinach (~40 samples each) were taken from retail outlets in five major metropolitan cities across the U.S. and analyzed for nitrite and nitrate content (ppm). Random samples representing both conventional and organic/ natural/ no nitrite (referred to as "organic") type products were analyzed for nitrite and nitrate content to provide a benchmark for comparison to historic databases and to enable a more accurate evaluation of nitrite and nitrate contributions to the American diet from these food sources. This survey is the first to our knowledge to evaluate the nitrite and nitrite content of products classified as organic.

Generally, there were no differences in nitrite levels between conventionally processed and organic cured meat product categories except for cured cooked sausage sampled in New York City. Only three organic products, cured dried uncooked sausages in Chicago, fermented cooked sausages in Dallas, Los Angeles and Raleigh and whole muscle, dry-cured uncooked products in Raleigh were lower in nitrate content. Thus, for most conventional and organic meat product categories, the nitrate and nitrite concentrations were not different.

Nitrite contents of all conventional cured meat categories across five cities were not different and the same was true for organic products except for cured cooked sausage and whole-muscle brine cure uncooked categories in certain cities. Nitrate content followed the same trend as nitrite in that there were no differences in levels of conventional cured meat products. Only small differences were noted in the nitrate levels of organic cured dried uncooked sausages and cured cooked sausage in a few cities. These small differences may have been due to different curing techniques being applied to organic products within a specific regional of the country. For the most part, nitrite and nitrate levels in cured meat products evaluated across five cities in large metropolitan areas were not appreciably different.

The lowest nitrite levels in this study were noted for the fermented cooked sausage, cured dried uncooked sausage and whole-muscle dry-cured cooked categories averaging 0.64, 0.74 and 1.95 ppm, respectively. Slightly higher levels of nitrite were observed for cured cooked sausage, whole-muscle brine cured cooked and whole-muscle brine cured uncooked categories averaging 6.86, 7.16 and 7.31 ppm, respectively. The weighted average means for nitrite and nitrate levels across all cured meat categories were 4.54 and 37.07 ppm. Overall, the nitrite values observed in this survey were consistent within each product category and not appreciably different from those previously reported by Cassens (1997a). In comparison, the nitrite and nitrate values in this study were substantially lower than those reported in the NAS (1981) study. It appears that the current USDA regulations and manufacturer's processing procedures are consistently controlling the levels of nitrite and nitrate in cured meat products and continue to be effective for minimizing their contribution to the dietary nitrite/ nitrate load. Comparisons with comparable cured meat products from other countries indicate that U.S. products often contain lower levels of nitrite and nitrite. Some factors contributing to lower residual nitrite levels could be the use of reductants such as sodium ascorbate (erythorbate), depletion of nitrite during refrigerated storage and other factors.

Vegetables

The predominant sources of nitrates and nitrites in the human diet include vegetables, a few fruits, cured meat products, some fish and dairy products and drinking water. Vegetables contribute approximately 80% of the nitrates to the diet with lesser amounts contributed by some categories of cured meats. Cured meats are the primary source of nitrites with lesser amounts contributed by vegetables and fruits.

There were no differences in the mean nitrite levels of conventional and organic products taken from five metropolitan areas. However, significant differences between conventional and organic vegetables for nitrate content were observed. Where specific organic vegetables were found to be different from conventional vegetables within a city, the organic classification contained less nitrate. These lower levels could be due to the use of no or low levels of nitrate rich fertilizers. Other factors that could contribute to higher nitrate levels in conventional vegetables are the specific cultivar used, the use of high nitrate fertilizers, naturally high nitrate levels in the soil or higher levels of nitrate in irrigation water (water that is naturally high in nitrates or has been exposed to agricultural runoff from high-density animal facilities such as feed lots). Thus, based on this survey, some organic vegetables were lower in nitrate content than their conventional counterparts.

Previous studies have noted that the variation in nitrate content of fresh produce is considerable and often unpredictable even under good agricultural practices since there are few regulations governing the use of nitrates in vegetable production. The nitrite content of both conventional and organic vegetables in this study ranged between 0.11-1.20 ppm with the exception of conventionally grown spinach which contained 7.98 ppm nitrite. The nitrate contents of conventional broccoli, cabbage, celery, lettuce and spinach were 394.38, 417.56, 1,495.48, 850.46 and 2,797.18 ppm, respectfully, while their organic counterparts averaged 204.29, 551.97, 911.94, 844.06 and 1,317.73 ppm. With only one exception, organic vegetables had numerically lower nitrate concentrations than conventional vegetables.

A review of the nitrate and nitrite concentrations from country to country and within the same vegetable category indicate a great deal of variability in these components. Thus, for determining the level of dietary nitrate and nitrite actually contributed by vegetables, the values used would need to be country specific and region specific. The fact that the nitrate and nitrite contents of vegetables are variable (as shown between conventional and organic products and from city to city in this survey) poses a potential dilemma for determining actual vegetable consumption (an in turn nitrate/ nitrite dietary load) of a population. Based on this survey, regional variation may need to be taken into consideration when developing predictions based on consumption of specific vegetables and their contribution to nitrate load. This variation might be of sufficient magnitude to alter epidemiological predictions if not considered appropriately.

Drinking Water

A survey of the nitrate and nitrite concentrations in 25 municipal water supplies across the U.S. was conducted to determine the level of nitrate (and in some cases nitrite) in drinking water. Philadelphia PA, Atlantic City, NJ and Los Angeles, CA reported the highest levels of nitrate of the 25 cities surveyed at 4.9, 4.56 and 2.2-9.2 ppm (mg/L), respectively. It is interesting to note that the highest nitrate concentrations in Los Angeles came from groundwater taken from local wells. All drinking water sources were below the allowable limits for nitrate and nitrite (if reported) established by the EPA.

RECOMMENDATIONS FOR FUTURE RESEARCH

- Determine the dietary load of nitrite and nitrate contributed by cured meat products and vegetables based on these survey results and consumption data (USDA) specific to each product

- Support additional research that clarifies the role of nitrite and nitrate intake and cardiovascular health

- Determine the levels of residual nitrite and nitrate when “organic/ natural/ no nitrite” methods of curing are employed, especially determine the efficacy for the conversion of nitrate to nitrite using plant extractives, starter cultures, sea salt, etc. as sources of nitrite and nitrate

- Conduct follow-up survey of conventional and organic cured meat products and vegetables in 5-10 years

ACKNOWLEDGEMENTS

Raleigh, NC Assistance
Dr. Dana J. Hanson
North Carolina State University
Dept of Food Science
Rm 129 Schaub Hall - Campus Box 7624
Raleigh, NC 27695-7624
Phone: (919) 515-2958
Fax: (919) 515-7124
E-mail: dana_hanson@ncsu.edu

Los Angeles, CA Assistance
Dr. Lynn R. Graves Delmore
California Polytechnic State University
11675 Halcon Road
Atascadero, CA 93422
Phone: (805) 458-2499
Fax: (805) 756-6341
E-mail: ldelmore@calpoly.edu

Mr. Mario Martinez
Farmer John
3049 E. Vernon Ave
Vernon, CA 90058-1800

Phone: (323) 583-4621
Fax: (323) 584-1617
E-mail: mmartinez@farmerjohn.com

Chicago, IL Assistance
Dr. Jeff Sindelar
University of Wisconsin
1805 Linden Dr
Meat Science and Muscle Biology Lab
Madison, WI 53706-1110
Phone: (608) 262-0555
Fax: (608) 265-3110
E-mail: jsindelar@wisc.edu

New York Assistance
Mr. Elliot Fread
Bimmy's
47-00 33rd Street
Long Island City, NY 11101

PRESENTATIONS AND PUBLICATIONS

A manuscript is in preparation for submission to a high tier scientific journal such as the Proceedings of the National Academy of Sciences, Journal of Agriculture and Food Chemistry or Journal of Food Science. An abstract and oral presentation will be prepared for presentation to a professional scientific society annual meeting and trade association meeting(s).

LITERATURE CITED

Ahn, D. U.; Maurer, A. J. 1987. Concentration of nitrate and nitrite in raw turkey breast meat and the microbial conversion of added nitrate to nitrite in tumbled turkey breast meat. *Poult. Sci.* 66:1957-1960.

Archer, D. L. 2002. Evidence that ingested nitrate and nitrite are beneficial to health. *J. Food Protect*. 65:872-875.

Barnum, D. W. 2003. Some history of nitrates. *J Chem. Ed.* 80(12):1393-1396.

Binkerd, E. F.; Kolari, O.E. 1975. The history and use of nitrate and nitrite in the curing of meat. *Food Cosmet. Toxicol.* 13:655-661.

Bryan, N. S.; Grisham, M. B. 2007. Methods to detect nitric oxide and its metabolites in biological samples. *Free Radic. Biol. Med.* 43**:**645-657.

Cassens, R. G. 1995. Use of sodium nitrite in cured meats today. *Food Technol*. 49:72-80, 115.

Cassens, R. G. 1997a. Residual nitrite in cured meat. *Food Technol*. 51:53-55.

Cassens, R. G. 1009b. Composition and safety of cured meats in the USA. *Food Chem*. 59:561-566.

Chung, S. Y.; Kim, J. S.; Kim, M.; Hong, M. K.; Lee, J. O.; Kim, C. M.; Song, I. S. 2003. Survey of nitrate and nitrite contents of vegetables grown in Korea. *Food Add. Contamin.* 20:621-628.

Corre, W. J.; Breimer, T. 1979. *Nitrate and nitrite in vegetables*. Wageningen Pudoc., Centre for Agricultural Publishing and Documentation: Wageningen, The Netherlands, 85.

Coughlin, J. R. 2006. Update on International Agency for Research on Cancer monograph on ingested nitrite and nitrate. In Proceedings of the meat industry research conference. http://www.meatscinece.orgPubs/mircarchiv/2006/default.htm. Accessed 3/7/09. October 4-5, Hollywood, FL.

Fetter, C. S. 1993. *Contaminant Hydrology*, MacMillan Publishing Company, New York, NY.

Gangolli, S. D.; van den Brandt, P. A.; Feron, V. J.; Janzowsky, C.; Koeman, J. H.; Speijers, G. J.; Spiegelhalder, B.; Walker, R.; Wishnok, J. S. 1994. Nitrate, nitrite and *N*-nitroso compounds. *Eur. J. Pharmacol., Environ. Toxicol. Pharmacol. Section.* 292:1-38.

Harder, T. 2009. Agricultural impacts on groundwater nitrate. *Hydrology* 8(4):22-23,35.

Honikel, K-O. 2008. The use and control of nitrate and nitrite for the processing of meat products. *Meat Sci.* 78:68-76.

Hord, N. G; Tang, Y.; Bryan, N. S. 2009. Food sources of nitrates and nitrites: the physiologic context for potential health benefits. *Am. J. Clin. Nutr.* 90:1-10.

Hsu, J.; Arcot, J.; Lee, N. A. 2009. Nitrate and nitrite quantification from cured meat and vegetables and their estimated dietary intake in Australians. *Food Chem.* 115:334-339.

Institute of Food Technologists. 1987. Nitrate, nitrite and nitroso compounds in foods. *Food Technol.* 41(4):127-136.

Jones, O. 1933. Nitrite in cured meats. *The Analyst.* 58, Issue 684, p. 140.

Kerr, R.H.; Marsh, T. N.; Schoeder, W. F.; Boyer, E. A. 1926. The use of sodium nitrite in the curing of meat. *J. Agric. Res.* 33:541.

Kilgore, L.; Stasch, A. R.; Barrentine, B. F. 1963. Nitrate content of beets, collards, turnip greens. *J. Am. Diet. Assoc.* 43:39-42.

Kilic, B.; Cassens, R. G.; Borchert, L. L. 2002. Effect of turkey meat, phosphate, sodium lactate, carrageenan, and konjac on residual nitrite in cured meats. *J. Food Sci.* 67:29-31.

Lee, C. Y.; Shallenberger, R. S.; Downing, D. L.; Stoewsand, G. S.; Peck, N. M. 1971. Nitrate- and nitrite-nitrogen in fresh, stored and processed table beets and spinach from different levels of field nitrogen fertilisation. *J. Sci. Food Agric.* 22:90-92.

Leth, T; Fagt, S.; Nielsen, S.; Andersen, R. 2008. Nitrite and nitrate content in meat products and estimated intake in Denmark from 1998 to 2006. *Food Add. Contamin.* 1-9 iFirst. Accessed 7/11/2009.

Lin, J.-K.; Yen, J.-Y. 1980. Changes in nitrate and nitrite contents of fresh vegetables during cultivation and post-harvest storage. *Food Cosmet. Toxicol.* 18:597-603.

Lundberg, J. O.; Feelish, M.; Björne, H.; Jansson, E. Å.; Weitzberg, E. 2006. Cardioprotective effects of vegetables: Is nitrate the answer? *Nitric Oxide.* 15:359-362.

Lundberg, J. O.; Weitzberg, E.; Lundberg, J. M.; Alving, K. 1994. Intragastric nitric oxide production in humans: measurements in expelled air. *Gut.* 35:1543-1546.

Milkowski, A. L. 2006. The controversy about sodium nitrite. Meat Industry Research Conference: American Meat Science Association, Savoy, IL. Available at: <http://www.meatscience.org/Pubs/mircarchv/2006/presentations/2006 MIRC 09 Andy Milkowski and James Coughlin.pdf> (Accessed on 10/07/2006).

National Academy of Sciences. 1981. *The health effects of nitrate, nitrite, and N-nitroso compounds*. National Academy Press: Washington, DC.

National Academy of Sciences. 1982. *Alternatives to the Current Use of Nitrite in Foods.* National Academy Press: Washington, DC.

Nolan, B. T.; Stoner, J. D. 2000. Nutrients in ground waters of the conterminous United States, 1992-1995. *Environ. Sci. Technol.* 34(7):1156-1165.

Pennington, J. A. T. 1998. Dietary exposure models for nitrates and nitrites. *Food Control*. 9(6):385-395.

Penttila, P.-L.; Rasanen, L.; Kimppa, S. 1990. Nitrate, nitrite and *N*-nitroso compounds in Finnish foods and the estimation of the dietary intakes. *Z. Lebensm Unter Forsch*. 190:336-340.

Peters, J. M.; Preston-Martin, S; London, S J.; Bowman, J. D.; Buckley, J. D.; Thomas, D. C. 1994. Processed meat and risk of childhood leukemia (California USA). *Cancer Causes and Control,* 5:195-202.

Petersen, A.; Stoltze, S. 1999. Nitrate and nitrite in vegetables on the Danish market: content and intake. *Food Add. Contamin.* 16:291-299.

Philips, W. E. J. 1968a. Changes in the nitrate and nitrite contents of fresh and processed spinach during storage. *J. Agric. Food Chem.* 16:88-91.

Philips, W. E. J. 1968b. Nitrate content of foods – Public health implications, *Can. Inst Food Technol. J.* 1:98-103.

Pierson, M. D.; Smoot, L. A. 1982. Nitrite, nitrite alternatives, and the control of *Clostridium botulinum* in cured meats. *Crit. Rev. Food Sci. Nutr.* 17:141-187.

Prasad, S.; Chetty, A. A. 2008. Nitrate-N determination in leafy vegetables: study of the effects of cooking and freezing. *Food Chem*. 106:772-780.

Reinik, M.; Tamme, T.; Roasto, M.; Juhkam, K.; Jurtsenko, S.; Tenno, T.; Kiis, A. 2005. Nitrites, nitrates and *N*-nitrosamines in Estonian cured meat products: intake by Estonian children and adolescents. *Food Add. Contamin.* 22(11):1098-1105.

Rosen, M.R. and Kropf, C. 2009. Nitrates in Southwest Groundwater. *Southwest Hydrol.* 8(4):20-21, 34.

Santamaria, P.; Elia, A.; Serio, F.; Todaro, E. 1999. A survey of nitrate and oxalate content in fresh vegetables. *J. Sci. Food Agric*. 79:1882-1888.

Santamaria, P. 2006. Review Nitrate in vegetables: toxicity, content, intake and EC regulation. *J. Sci. Food Agric*. 86:10-17.

Schuddeboom, L. J. 1993. Nitrates and nitrites in foodstuffs. Council of Europe Press, Belgium.

Schuphan, W. 1974. The significance of nitrates in food and potable waters. *Qualitas Plantarum – Plant Foods for Human Nutrition.* 24:19-36.

Sebranek, J. G.; Bacus, J. 2007. Natural and organic cured meat products: Regulatory, manufacturing, marketing, quality and safety issues. *Am. Meat Sci. Assoc. White Paper Series*. 1:1-15.

Sebranek, J. G.; Bacus, J. 2007. Cured meat products without direct addition of nitrate and nitrite: what are the issues? *Meat Sci.* 77:136-147.

Sen, N. P.; Baddoo, P. A. 1997. Trends in the levels of residual nitrite in Canadian cured meat products over the past 25 years. *J. Agric. Food Chem.* 45:4714-4718.

Siciliano, J.; Krulick, S.; Heisler, E. G.; Schwartz, J. H.; White Jr., J. W. 1975. Nitrate and nitrite content of some fresh and processed market vegetables. *J. Agric. Food Chem.* 23:461-464.

Sindelar, J. J.; Cordray, J. C.; Sebranek, J. G.; Love, J. A.; Ahn, D. U. 2007a. Effects of vegetable juice powder concentration and storage time on some chemical and sensory quality attributes of uncured, emulsified cooked sausages. *J. Food Sci.* 72:S324-332.

Sindelar, J. J.; Cordray, J. C.; Sebranek, J. G.; Love, J. A.; Ahn, D. U. 2007b. Effects of varying levels of vegetable juice powder and incubation time on color, residual nitrate and nitrite, pigment, pH, and trained sensory attributes of ready-to-eat uncured ham. *J. Food Sci.* 72:S388-395.

Smith, E. Foods. 1873. 34-38. D. Appleton and Co., New York.

Steinke, R. K. W.; Foster, E. M. 1951. Botulism toxin formation in liver sausage. *Food Res.* 16:477.

Susin, J.; Kmecl, V.; Gregorcic, A. 2006. A survey of nitrate and nitrite content of fruit and vegetables grown in Slovenia during 1996-2002. *Food Add. Contamin.* 23:385-390

Tamme, T.; Reinik, M.; Roasto, M.; Juhkam, K.; Tenno, T.; Kiis, A. 2006. Nitrates and nitrites in vegetables and vegetable-based products and their intakes by the Estonian population. *Food Add. Contamin.* 23:355-361.

Tarr, H. L. A. 1942. Action of nitrates and nitrites on bacteria. *J. Fish Res. Board Can.* 6:233-242.

Tompkin, R. B. 2005. Nitrite. In P. M. Davidson, J. N. Sofos and A. L. Branen (Eds.), Antimicrobials in Food (3rd ed.), CRC Press, Taylor & Frances Group, Boca Raton, FL.

U. S. Environmental Protection Agency. Nitrates and Nitrites. TEACH Chemical Summary. Last revised 5/22/07. Accessed at http://www.epa.gov/teach/ on 7/15/2009.

U.S. Department of Agriculture, Economic Research Service. Food Availability: Spreadsheets. Accessed 7/25/2009. http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailSpreadsheets.htm.

U. S. Department of Agriculture, Food Safety Inspection Service. 1995. Processing Inspectors' Calculations Handbook. Revised 1995. Accessed 7/26/2009. http://www.google.com/#hl=en&q=usda+Processing+Inspector%27s+Calculations+Handbook&aq=f&oq=&aqi=&fp=VEE02fthf5k

U.S. Department of Agriculture. Service and Regulatory Announcements. 1925. November (issued December 1925) Bureau of Animal Industry, U.S. Department of Agriculture, Washington, DC. p. 101-103.

U.S. Department of Agriculture. Service and Regulatory Announcements, 1926. January (issued March 1926). Bureau of Animal Industry, U.S. Department of Agriculture, Washington, DC. p. 2-3.

White Jr., J. W. 1975. Relative significance of dietary sources of nitrate and nitrite. *J. Agric. Food Chem*. 23:886-891.

Wolff, I. A.; Wasserman, A. E. 1972. Nitrates, nitrites and nitrosamines. *Science*. 177:15-19.

RESOURCE REFERENCES (Used but not cited)

A.O.A.C. 2002. *Official Methods of Analysis of AOAC International*, 17th ed.; Association of Official Analytical Chemists: Gaithersburg, MD.

Bauermann, J. F. 1979. Processing of poultry products with and without sodium nitrite. *Food Technol*. 33:42-43.

Bloukas, J. G.; Arvanitoyannis, I. S.; Siopi, A. A. 1999. Effect of natural colourants and nitrites on colour attributes of frankfurters. *Meat Sci*. 52:257-265.

Borchert, L. L.; Cassens, R. G. 1998. Chemical hazard analysis for sodium nitrite in meat curing. American Meat Institute Foundation. p. 1-7; available at http://www.ag.ohio-state.edu/~meatsci/borca2.htm.

Cassens, R. G.; Ito, T.; Lee, M.; Buege, D. 1978. The use of nitrite in meat. *Bioscience*. 28:633-637 .

Choi, K. K.; Fung, K. W. 1980. Determination of nitrate and nitrite in meat products by using a nitrate ion-selective electrode. *Analyst*. 105:241-245.

Hotchkiss, J. H.; Cassens, R. G. 1987. Nitrate, nitrite, and nitroso compounds in foods. *Food Technol*. 41:127-136.

Izumi, K.; Cassens, R. G.; Greaser, M. L. 1989. Reaction of nitrite with ascorbic acid and its significant role in nitrite-cured food. *Meat Sci*. 26:141-153.

Jimenez-Colmenero, F.; Carballo, J.; Cofrades, S. 2001. Healthier meat and meat products: their role as functional foods. *Meat Sci*. 59:5-13.

MacDougall, D. B.; Hetherington, M. J. 1992. The minimum quantity of nitrite required to satin sliced and homogenized cooked pork. *Meat Sci*. 31:201-210.

Miller, S. A. 1980. Balancing the risks regarding the use of nitrites in meats. *Food Technol*. 34:254-256.

Murai, K.; Wilkins, D. 1990. Natural red color derived from red cabbage. *Food Technol*. 44:131.

O'Boyle, A. R.; Rubin, L. J.; Diosady, L. L.; Aladin-Kassam, N.; Comer, F.; Brightwell, W. 1990. A nitrite-free curing system and its application to the production of wieners. *Food Technol*. 44:88-104.

Öztekin, N.; Nutku, M. S.; Erim, F. B. 2002. Simultaneous determination of nitrite and nitrate in meat products and vegetables by capillary electrophoresis. *Food Chem*. 76:103-106.

Pariza, M. W.; Borzelleca, J. F.; Cassens, R. G.; Filler, L. J.; Kritchevsky, D. 1997. Examination of dietary recommendations for salt-cured, smoked and nitrite-preserved foods. Council for Agricultural Science and Technology, Ames, IA. *CAST*. 8:1-8.

Cassens, R. G. 1997. Composition and safety of cured meats in the USA. *Food Chem.* 59(4):561-566.

Pérez-Olmos, R.; Herrero, R.; Lima, J. L.; Montenegro, M. C. 1997. Sequential potentiometric determination of chloride and nitrate in meat products. *Food Chem*. 59:305-311.

Pérez-Rodríguez, M. L.; Bosch-Bosch, N.; García-Mata, M. 1996. Monitoring nitrite and nitrate residues in frankfurters during processing and storage. *Meat Sci*. 44:65-73.

Rincón, F.; Martínez, B.; Delgado, J. M. 2003. Detection of factors influencing nitrite determination in meat. *Meat Sci*. 65:1421-1427.

Rubin, L. J.; Diosady, L. L.; O'Boyle, A. R. 1990. A nitrite-free meat-curing system. *Food Technol*. 44:130.

Ruiz-Capillas, C.; Aller-Guiote, P.; Jimenez-Colmenero, F. 2007. Application of flow injection analysis to determine protein-bound nitrite in meat products. *Food Chem*. 101:812-816.

Sen, N. P.; Philander, A.; Baddoo, P. A.; Seaman, S. W. 1994. Rapid and sensitive determination of nitrite in foods and biological materials by flow injection or high-performance liquid chromatography with chemiluminescence detection. *J. Chomatogr. A*. 673:77-84.

Shahidi, F.; Pegg, R. B. 1983. Nitrite-free meat. Meat Focus International. September 1-8.

Siu, D. C.; Henshall, A. 1998. Ion chromatographic determination of nitrate and nitrite in meat products. *J. Chomatogr. A*. 804:157-160.

Table 3A. ANOVA comparisons between conventional and organic mean nitrite/ nitrate levels of six cured meat categories surveyed in five U.S. cities.

City		Cured dried uncooked sausage	Cured cooked sausage	Fermented cooked sausage	Whole-muscle brine cured uncooked	Whole-muscle brine cured cooked	Whole-muscle dry-cured uncooked
Chicago	Nitrite	N[a]	N	N	N	N	N
	Nitrate	Y[b]	N	N	N	N	N
Dallas	Nitrite	N	N	N	N	N	N
	Nitrate	N	N	Y	N	N	N
Los Angeles	Nitrite	N	N	N	N	N	N
	Nitrate	Y	N	Y	N	N	N
New	Nitrite						N
York		N	Y	N	N	N	
	Nitrate	N	N	N	N	N	N
Raleigh	Nitrite	N	N	N	N	N	N
	Nitrate	N	N	Y	N	N	Y

[a] N - Indicates that there is not significant ($P>0.05$) evidence of a difference between the organic and conventional mean nitrite/ nitrate level in the product.

[b] Y - Indicates that there is significant ($P<0.05$) evidence of a difference between the organic and conventional mean nitrite/ nitrate level in the product.

Table 3B. ANOVA comparisons between conventional and organic mean nitrite/ nitrate levels of five raw vegetables surveyed in five U.S. cities

City		Broccoli	Cabbage	Celery	Lettuce	Spinach
Chicago	Nitrite	N[a]	N	N	N	N
	Nitrate	N	Y[b]	N	N	N
Dallas	Nitrite	N	N	N	N	N
	Nitrate	N	N	Y	N	Y
Los Angeles	Nitrite	N	N	N	N	N
	Nitrate	Y	N	N	N	N
New York	Nitrite	N	N	N	N	N
	Nitrate	N	N	N	N	N
Raleigh	Nitrite	N	N	N	N	N
	Nitrate	Y	N	N	N	Y

[a] N - Indicates that there is not significant ($P>0.05$) evidence of a difference between the organic and conventional mean nitrite/ nitrate level in the product.

[b] Y - Indicates that there is significant ($P<0.05$) evidence of a difference between the organic and conventional mean nitrite/ nitrate level in the product.

Table 4A. Pair-wise comparisons between cities of the mean nitrite/ nitrate levels in six cured meat categories classified as conventional or organic

Product Category		**Pairs of Cities with Different Means**[ab]	
		Nitrite	**Nitrate**
Cured dried uncooked sausage	Conventional	None	None
	Organic	None	CH-DA; CH-NY; CH-RA
Cured cooked sausage	Conventional	None	None
	Organic	CH-NY; NY-RA	LA-NY
Fermented cooked sausage	Conventional	None	None
	Organic	None	None
Whole-muscle brine cured uncooked	Conventional	None	None
	Organic	CH-DA; DA-RA	None
Whole-muscle brine cured cooked	Conventional	None	NY-RA
	Organic	None	None
Whole-muscle dry-cured uncooked	Conventional	None	None
	Organic	None	None

[a] Pairs of cities with significantly ($P<0.05$) different nitrite/ nitrate mean levels

[b] Analysis was conducted on the logarithm of the data value due to lack of normality and unequal variances

[c] CH=Chicago; DA=Dallas; LA=Los Angeles; NY=New York; RA=Raleigh

Table 4B. Pair-wise comparisons between cities of the mean nitrite/ nitrate levels in five raw vegetables classified as conventional or organic

Product Category		Pairs of Cities with Different Means[ab]	
		Nitrite	Nitrate
Broccoli	Conventional	None	None
	Organic	None	CH-RA; DA-NY; DA-RA; LA-RA; NY-RA
Cabbage	Conventional	None	None
	Organic	CH-NY; DA-NY; LA-NY; NY-RA	CH-DA; CH-LA; CH-NY
Celery	Conventional	None	CH-DA; CH-LA; CH-RA; DA-NY; LA-NY; NY-RA
	Organic	None	CH-LA; DA-LA; DA-RA;
Lettuce	Conventional	None	CH-DA;
	Organic	None	CH-DA; CH-LA; CH-NY
Spinach	Conventional	CH-DA; CH-RA;	CH-DA; DA-NY; LA-NY; NY-RA
	Organic	CH-DA; CH-RA; DA-NY; LA-RA; NY-RA	None

[a] Pairs of cities with significantly ($P<0.05$) different nitrite/ nitrate mean levels

[b] Analysis was conducted on the logarithm of the data value due to lack of normality and unequal variances

[c] CH=Chicago; DA=Dallas; LA=Los Angeles; NY=New York; RA=Raleigh

Table 5. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from Chicago

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	4	0.125	0.008	0.07	0.17	4	0.282	0.058	0.07	0.67
	Nitrate	4	271.331	89.167	60.92	822.32	4	211.598	34.591	84.43	416.86
Cabbage	Nitrite	4	0.271	0.026	0.15	0.41	4	0.104	0.016	0.03	0.2
	Nitrate	4	474.932	45.458	255.55	669.74	4	52.447	12.101	1.95	107.04
Celery	Nitrite	4	0.232	0.038	0.06	0.46	4	1.232	0.618	0.1	6.22
	Nitrate	4	229.713	19.164	147.39	358.47	4	309.572	58.315	25.6	597.28
Lettuce	Nitrite	4	0.333	0.044	0.12	0.62	4	0.119	0.021	0.05	0.27
	Nitrate	4	206.951	32.321	79.41	424.58	4	100.123	8.213	57.58	158.5
Spinach	Nitrite	4	36.388	15.209	0.04	137.2	4	4.433	1.962	0.03	16.92
	Nitrate	4	647.326	69.04	161.51	875.42	4	458.698	47.756	237.52	744.29
Cured dried uncooked sausage	Nitrite	9	1.266	0.363	0.04	6.95	4	0.392	0.084	0.06	0.91
	Nitrate	9	368.089	136.553	1.15	2288.99	4	0.728	0.207	0.14	1.89
Cured cooked sausage	Nitrite	12	10.427	1.419	0.4	29.31	5	9.995	3.412	0.78	35.39
	Nitrate	12	77.491	23.355	0.81	540.8	5	26.901	3.966	0.45	45.07
Fermented cooked sausage	Nitrite	12	0.131	0.014	0.05	0.36	4	0.057	0.011	0.02	0.13
	Nitrate	12	51.804	9.16	1.76	250.96	4	4.289	1.328	0.29	11.19
Whole-muscle brine cured uncooked	Nitrite	4	7.438	0.774	3.7	13.02	4	11.727	2.617	1.04	27.01
	Nitrate	4	15.44	2.237	3.471	24.48	4	115.627	57.032	3.94	462.05
Whole-muscle brine cured cooked	Nitrite	19	7.823	0.994	0.27	22.41	9	7.139	0.82	0.49	15.32
	Nitrate	19	17.441	2.699	0.25	107.86	9	25.99	7.186	0	142.93
Whole-muscle dry-cured uncooked	Nitrite	8	1.487	0.345	0.13	6.03	6	2.047	0.752	0.02	10
	Nitrate	8	192.547	83.856	0.39	1366.52	6	11.829	2.77	0.34	37.12

Table 6. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from Dallas

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	4	0.036	0.007	0.02	0.08	4	0.045	0.003	0.03	0.06
	Nitrate	4	356.987	49.611	164.69	664.39	4	429.917	40.417	224.85	682.65
Cabbage	Nitrite	4	0.051	0.012	0.01	0.14	4	0.061	0.008	0.01	0.11
	Nitrate	4	255.813	32.52	63.2	433.61	4	989.003	165.826	70.59	1471.85
Celery	Nitrite	4	0.043	0.004	0.02	0.07	4	0.08	0.019	0.02	0.21
	Nitrate	4	2052.329	155.474	918.43	2973.02	4	390.419	139.403	0.66	1452.8
Lettuce	Nitrite	4	0.038	0.006	0.01	0.07	4	0.023	0.006	0	0.06
	Nitrate	4	1370.362	92.836	870.21	1909.43	4	1366.702	98.456	989.04	2013.32
Spinach	Nitrite	4	0.041	0.013	0	0.14	4	0.036	0.004	0.02	0.06
	Nitrate	4	4923.295	327.147	2377.42	6473.3	4	1609.896	209.054	488.15	2940.73
Cured dried uncooked sausage	Nitrite	12	1.436	0.442	0.06	9.71	4	2.158	1.077	0.06	8.45
	Nitrate	12	23.618	2.631	0.13	54.53	3	56.847	17.007	7.08	137.45
Cured cooked sausage	Nitrite	12	4.083	0.768	0.09	15.65	6	3.368	0.722	0.23	7.16
	Nitrate	12	17.194	1.421	2.16	45.3	6	16.082	3.492	1.83	44.77
Fermented cooked sausage	Nitrite	12	0.268	0.058	0.01	1.38	7	0.08	0.015	0.02	0.28
	Nitrate	12	29.563	3.031	8.78	92.25	7	3.749	0.906	0	14.79
Whole-muscle brine cured uncooked	Nitrite	4	6.16	1.35	0.17	12.54	4	0.486	0.118	0.09	1.15
	Nitrate	4	10.678	1.124	3.96	13.59	4	19.733	3.81	6.69	39.92
Whole-muscle brine cured cooked	Nitrite	20	5.389	0.494	0.07	15.0	9	2.547	0.525	0.13	7.36
	Nitrate	20	13.921	1.205	2.58	42.16	9	10.539	2.173	0.25	41.92
Whole-muscle dry-cured uncooked	Nitrite	7	4.04	1.354	0.02	16.17	4	0.092	0.007	0.07	0.15
	Nitrate	7	27.677	5.416	0.42	70.99	4	10.734	4.224	0.37	50.07

Table 7. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from Los Angeles

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	4	0.085	0.005	0.05	0.11	4	0.048	0.002	0.04	0.06
	Nitrate	4	512.053	84.81	164.05	1140.42	4	195.451	47.291	43.56	501.38
Cabbage	Nitrite	4	0.129	0.019	0.06	0.25	4	0.07	0.004	0.05	0.1
	Nitrate	4	800.393	141.976	275.41	1831.05	4	611.53	85.288	334.99	1364.71
Celery	Nitrite	3	0.132	0.009	0.1	0.19	4	1.88	0.949	0.05	7.6
	Nitrate	4	2651.405	338.574	607.92	4268.95	4	2021.96	207.748	1195.64	3588.65
Lettuce	Nitrite	4	0.144	0.026	0.03	0.24	4	0.137	0.018	0.04	0.21
	Nitrate	4	1050.914	122.201	422.02	1495.15	4	1276.65	73.008	1028.52	1701.54
Spinach	Nitrite	4	0.431	0.109	0.03	0.87	4	0.41	0.156	0.02	1.33
	Nitrate	4	4137.799	450.526	2140.87	8000.26	4	2199.004	236.626	1074.5	3820.37
Cured dried uncooked sausage	Nitrite	8	0.221	0.048	0.03	0.69	7	0.377	0.133	0.03	1.94
	Nitrate	8	67.126	9.662	19.03	146.72	7	6.097	1.059	0.38	14.07
Cured cooked sausage	Nitrite	11	8.63	1.074	0.29	18.63	7	4.178	1.607	0.05	23.23
	Nitrate	11	12.868	1.33	4.69	28.32	7	4.113	0.893	0.46	11.89
Fermented cooked sausage	Nitrite	11	2.465	1.333	0.01	26.69	3	0.131	0.052	0.02	0.36
	Nitrate	12	51.173	10.337	13.05	319.57	3	1.313	0.279	0.45	2.42
Whole-muscle brine cured uncooked	Nitrite	4	4.711	2.081	0.17	16.76	4	3.12	0.84	0.1	6.32
	Nitrate	4	7.103	0.487	4.73	9.15	3	7.313	1.247	3.29	12.31
Whole-muscle brine cured cooked	Nitrite	19	7.842	1.046	0.07	26.71	10	6.841	1.167	0.48	22.06
	Nitrate	19	9.979	1.584	0.41	53.1	10	7.837	0.843	1.39	16.9
Whole-muscle dry-cured uncooked	Nitrite	6	1.055	0.263	0.02	3.35	6	6.083	2.629	0.04	28.87
	Nitrate	6	172.352	76.605	0.38	878.54	6	6.898	1.673	0.43	18.45

Table 8. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from New York

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	4	2.481	1.203	0.03	9.49	4	0.108	0.026	0.01	0.26
	Nitrate	4	278.467	79.997	29.27	1009.33	3	166.966	52.926	10.93	502.08
Cabbage	Nitrite	4	0.133	0.027	0.04	0.28	4	5.073	1.4	0.17	10.75
	Nitrate	4	193.053	27.697	37.32	283.21	4	898.134	191.081	3.43	2113.83
Celery	Nitrite	3	0.092	0.014	0.05	0.16	4	1.785	0.983	0.05	9.23
	Nitrate	3	87.669	16.88	19.87	157.37	4	806.46	207.615	11.24	2052.46
Lettuce	Nitrite	3	3.311	1.616	0.01	9.68	4	0.098	0.013	0.03	0.16
	Nitrate	3	567.769	92.81	321.07	969.65	4	779.475	111.09	346.63	1594.59
Spinach	Nitrite	3	0.47	0.22	0.02	1.41	4	1.117	0.326	0.21	3.09
	Nitrate	3	563.823	173.838	65.32	1545.01	4	1566.282	383.654	16.28	4089.4
Cured dried uncooked sausage	Nitrite	6	0.126	0.016	0.03	0.24	5	0.193	0.072	0.01	0.74
	Nitrate	6	38.154	6.007	2.81	71.11	5	33.261	12.29	1	123.2
Cured cooked sausage	Nitrite	12	10.313	0.895	0.33	19.3	6	0.696	0.22	0.07	2.74
	Nitrate	12	39.877	7.905	14.77	255.35	6	39.439	7.005	3.8	73.85
Fermented cooked sausage	Nitrite	8	0.088	0.008	0.04	0.18	2	0.052	0.011	0.02	0.08
	Nitrate	8	60.82	9.824	2.49	182.62	2	27.265	11.868	0.76	57.37
Whole-muscle brine cured uncooked	Nitrite	4	12.177	4.137	2.91	36.46	4	9.457	1.9	0.42	18.59
	Nitrate	4	25.479	1.281	18	32.24	4	24.644	2.91	10.83	38.7
Whole-muscle brine cured cooked	Nitrite	20	8.085	1.085	0.26	23.47	8	8.175	1.217	0.1	16.04
	Nitrate	20	24.7	1.697	0.92	47.11	8	16.896	2.56	1.14	36.93
Whole-muscle dry-cured uncooked	Nitrite	10	0.293	0.044	0.03	0.84	1	0.097	0.003	0.09	0.1
	Nitrate	9	41.078	6.622	1.71	107.35	1	1.91	0.111	1.78	2.13

Table 9. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from Raleigh

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	4	0.156	0.03	0.01	0.32	4	0.054	0.006	0.03	0.08
	Nitrate	4	553.052	27.577	374.37	680.64	4	8.186	2.286	2.57	21.97
Cabbage	Nitrite	4	0.083	0.022	0.01	0.3	4	0.078	0.02	0.02	0.2
	Nitrate	4	363.621	78.745	71.8	881.63	4	167.084	17.743	94.24	271.21
Celery	Nitrite	4	0.075	0.011	0.03	0.15	4	0.16	0.034	0.05	0.34
	Nitrate	4	2200.651	112.35	1397.33	2726.78	4	1022.518	68.705	598.11	1460.93
Lettuce	Nitrite	4	0.039	0.003	0.02	0.06	4	0.058	0.008	0.01	0.09
	Nitrate	4	985.637	185.367	449.61	2170.82	4	691.98	28.053	566.68	869.3
Spinach	Nitrite	4	0.037	0.007	0.01	0.07	4	0.022	0.007	0	0.06
	Nitrate	4	3155.293	145.314	2477.59	4168.38	4	754.773	101.112	398.5	1361.51
Cured dried uncooked sausage	Nitrite	5	0.315	0.086	0.04	0.96	4	0.102	0.033	0.01	0.29
	Nitrate	5	31.042	7.307	5.73	86.58	4	10.675	3.105	4.57	35.42
Cured cooked sausage	Nitrite	12	4.546	0.913	0.35	21.55	6	10.148	1.822	3.23	31.11
	Nitrate	12	12.117	0.551	6.71	20.67	6	8.179	1.396	1.44	21.93
Fermented cooked sausage	Nitrite	9	1.211	0.636	0	12.03	3	0.164	0.068	0	0.47
	Nitrate	8	40.599	5.486	12.89	77.89	3	9.894	4.094	0.2	30.89
Whole-muscle brine cured uncooked	Nitrite	4	3.393	0.559	0.46	6.44	3	16.844	4.304	5.49	35.95
	Nitrate	4	13.395	2.468	5.81	28.65	3	7.051	1.281	1.8	11.85
Whole-muscle brine cured cooked	Nitrite	19	8.228	1.213	0.03	27.56	8	8.202	1.522	0.23	19.81
	Nitrate	19	11.765	2.416	0.21	71.51	8	3.595	1.29	0.27	24.31
Whole-muscle dry-cured uncooked	Nitrite	8	0.897	0.147	0.08	2.62	7	2.344	1.222	0.03	17.13
	Nitrate	8	114.919	36.943	11.24	570.91	7	2.439	0.704	0.19	8.3

Table 10. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories classified as conventional or organic from all five cities

		Conventional					Organic				
Product Category		N	Mean	Std Err	Min	Max	N	Mean	Std Err	Min	Max
Broccoli	Nitrite	20	0.586	0.268	0.01	9.49	20	0.107	0.017	0.01	0.67
	Nitrate	20	394.378	34.02	29.27	1140.42	19	204.29	24.765	2.57	682.65
Cabbage	Nitrite	20	0.133	0.014	0.01	0.41	20	1.093	0.381	0.01	10.75
	Nitrate	20	417.562	43.65	37.32	1831.05	20	551.965	72.045	1.95	2113.83
Celery	Nitrite	18	0.115	0.013	0.02	0.46	20	1.027	0.307	0.02	9.23
	Nitrate	19	1495.479	160.139	19.87	4268.95	20	911.943	103.628	0.66	3588.65
Lettuce	Nitrite	19	0.592	0.265	0.01	9.68	20	0.087	0.008	0	0.27
	Nitrate	19	850.461	75.169	79.41	2170.82	20	844.062	68.254	57.58	2013.32
Spinach	Nitrite	19	7.981	3.731	0	137.2	20	1.204	0.442	0	16.92
	Nitrate	19	2797.175	265.034	65.32	8000.26	20	1317.731	127.982	16.28	4089.4
Cured dried uncooked sausage	Nitrite	40	0.818	0.164	0.03	9.71	24	0.599	0.2	0.01	8.45
	Nitrate	40	112.934	32.913	0.13	2288.99	23	18.599	4.145	0.14	137.45
Cured cooked sausage	Nitrite	59	7.582	0.504	0.09	29.31	30	5.431	0.861	0.05	35.39
	Nitrate	59	32.458	5.378	0.81	540.8	30	18.295	2.206	0.45	73.85
Fermented cooked sausage	Nitrite	52	0.834	0.309	0	26.69	19	0.094	0.015	0	0.47
	Nitrate	52	46.225	3.764	1.76	319.57	19	6.924	1.694	0	57.37
Whole-muscle brine cured uncooked	Nitrite	20	6.776	1.028	0.17	36.46	19	7.878	1.209	0.09	35.95
	Nitrate	20	14.419	1.087	3.471	32.24	18	37.95	13.585	1.8	462.05
Whole-muscle brine cured cooked	Nitrite	97	7.454	0.444	0.03	27.56	44	6.513	0.511	0.1	22.06
	Nitrate	97	15.645	0.928	0.21	107.86	44	12.979	1.746	0	142.93
Whole-muscle dry-cured uncooked	Nitrite	39	1.46	0.284	0.02	16.17	24	2.736	0.795	0.02	28.87
	Nitrate	38	106.112	23.233	0.38	1366.52	24	7.262	1.159	0.19	50.07

Table 11. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from Chicago

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	8	0.203	0.033	0.07	0.67
	Nitrate	8	241.465	47.182	60.92	822.32
Cabbage	Nitrite	8	0.191	0.023	0.03	0.41
	Nitrate	8	272.874	50.945	1.95	669.74
Celery	Nitrite	8	0.732	0.32	0.06	6.22
	Nitrate	8	269.643	31.15	25.6	597.28
Lettuce	Nitrite	8	0.226	0.033	0.05	0.62
	Nitrate	8	153.537	19.748	57.58	424.58
Spinach	Nitrite	8	20.41	8.206	0.03	137.20
	Nitrate	8	553.012	45.519	161.51	875.42
Cured dried uncooked sausage	Nitrite	13	0.997	0.26	0.04	6.95
	Nitrate	13	255.054	97.924	0.14	2288.99
Cured cooked sausage	Nitrite	17	10.3	1.398	0.40	35.39
	Nitrate	17	62.612	16.776	0.45	540.8
Fermented cooked sausage	Nitrite	16	0.113	0.012	0.02	0.36
	Nitrate	16	39.925	7.482	0.29	250.96
Whole-muscle brine cured uncooked	Nitrite	8	9.583	1.407	1.04	27.01
	Nitrate	8	65.533	29.801	3.471	462.05
Whole-muscle brine cured cooked	Nitrite	28	7.601	0.72	0.27	22.41
	Nitrate	28	20.222	2.969	0.00	142.93
Whole-muscle dry-cured uncooked	Nitrite	14	1.727	0.375	0.02	10.00
	Nitrate	14	115.096	49.503	0.34	1366.52

Table 12. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from Dallas

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	8	0.041	0.004	0.02	0.08
	Nitrate	8	393.452	32.202	164.69	682.65
Cabbage	Nitrite	8	0.056	0.007	0.01	0.14
	Nitrate	8	622.408	112.568	63.2	1471.85
Celery	Nitrite	8	0.061	0.01	0.02	0.21
	Nitrate	8	1221.374	201.118	0.66	2973.02
Lettuce	Nitrite	8	0.03	0.004	0	0.07
	Nitrate	8	1368.532	66.175	870.21	2013.32
Spinach	Nitrite	8	0.038	0.007	0	0.14
	Nitrate	8	3266.595	394.178	488.15	6473.3
Cured dried uncooked sausage	Nitrite	16	1.616	0.423	0.06	9.71
	Nitrate	15	30.264	4.352	0.13	137.45
Cured cooked sausage	Nitrite	18	3.844	0.564	0.09	15.65
	Nitrate	18	16.823	1.482	1.83	45.3
Fermented cooked sausage	Nitrite	19	0.199	0.039	0.01	1.38
	Nitrate	19	20.052	2.55	0	92.25
Whole-muscle brine cured uncooked	Nitrite	8	3.323	0.888	0.09	12.54
	Nitrate	8	15.205	2.16	3.96	39.92
Whole-muscle brine cured cooked	Nitrite	29	4.507	0.402	0.07	15
	Nitrate	29	12.871	1.076	0.25	42.16
Whole-muscle dry-cured uncooked	Nitrite	11	2.604	0.918	0.02	16.17
	Nitrate	11	21.516	3.997	0.37	70.99

Table 13. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from Los Angeles

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	8	0.067	0.005	0.04	0.11
	Nitrate	8	353.752	57.83	43.56	1140.42
Cabbage	Nitrite	8	0.1	0.011	0.05	0.25
	Nitrate	8	705.961	83.351	275.41	1831.05
Celery	Nitrite	7	1.131	0.566	0.05	7.6
	Nitrate	8	2322.997	201.675	607.92	4268.95
Lettuce	Nitrite	8	0.14	0.015	0.03	0.24
	Nitrate	8	1163.782	73.481	422.02	1701.54
Spinach	Nitrite	8	0.42	0.093	0.02	1.33
	Nitrate	8	3168.402	320.6	1074.5	8000.26
Cured dried uncooked sausage	Nitrite	15	0.294	0.067	0.03	1.94
	Nitrate	15	38.646	6.88	0.38	146.72
Cured cooked sausage	Nitrite	18	6.899	0.945	0.05	23.23
	Nitrate	18	9.399	1.054	0.46	28.32
Fermented cooked sausage	Nitrite	14	1.965	1.055	0.01	26.69
	Nitrate	15	41.201	8.777	0.45	319.57
Whole-muscle brine cured uncooked	Nitrite	8	3.915	1.11	0.1	16.76
	Nitrate	7	7.193	0.584	3.29	12.31
Whole-muscle brine cured cooked	Nitrite	29	7.497	0.792	0.07	26.71
	Nitrate	29	9.24	1.079	0.41	53.1
Whole-muscle dry-cured uncooked	Nitrite	12	3.641	1.407	0.02	28.87
	Nitrate	12	87.261	39.283	0.38	878.54

Table 14. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from New York

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	8	1.346	0.664	0.01	9.49
	Nitrate	7	230.68	51.417	10.93	1009.33
Cabbage	Nitrite	8	2.603	0.857	0.04	10.75
	Nitrate	8	545.593	119.659	3.43	2113.83
Celery	Nitrite	7	1.06	0.582	0.05	9.23
	Nitrate	7	483.004	138.786	11.24	2052.46
Lettuce	Nitrite	7	1.384	0.718	0.01	9.68
	Nitrate	7	684.207	76.081	321.07	1594.59
Spinach	Nitrite	7	0.84	0.216	0.02	3.09
	Nitrate	7	1136.657	252.479	16.28	4089.4
Cured dried uncooked sausage	Nitrite	11	0.156	0.034	0.01	0.74
	Nitrate	11	35.93	6.378	1	123.2
Cured cooked sausage	Nitrite	18	7.107	0.863	0.07	19.3
	Nitrate	18	39.731	5.724	3.8	255.35
Fermented cooked sausage	Nitrite	10	0.08	0.008	0.02	0.18
	Nitrate	10	54.109	8.503	0.76	182.62
Whole-muscle brine cured uncooked	Nitrite	8	10.817	2.244	0.42	36.46
	Nitrate	8	25.062	1.557	10.83	38.7
Whole-muscle brine cured cooked	Nitrite	28	8.111	0.845	0.1	23.47
	Nitrate	28	22.47	1.46	0.92	47.11
Whole-muscle dry-cured uncooked	Nitrite	11	0.275	0.041	0.03	0.84
	Nitrate	10	37.161	6.336	1.71	107.35

Table 15. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from Raleigh

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	8	0.105	0.018	0.01	0.32
	Nitrate	8	280.619	58.396	2.57	680.64
Cabbage	Nitrite	8	0.08	0.015	0.01	0.3
	Nitrate	8	265.353	44.474	71.8	881.63
Celery	Nitrite	8	0.118	0.019	0.03	0.34
	Nitrate	8	1611.585	138.687	598.11	2726.78
Lettuce	Nitrite	8	0.048	0.005	0.01	0.09
	Nitrate	8	838.808	96.655	449.61	2170.82
Spinach	Nitrite	8	0.03	0.005	0	0.07
	Nitrate	8	1955.033	264.821	398.5	4168.38
Cured dried uncooked sausage	Nitrite	9	0.225	0.055	0.01	0.96
	Nitrate	9	22.425	4.789	4.57	86.58
Cured cooked sausage	Nitrite	18	6.343	0.917	0.35	31.11
	Nitrate	18	10.83	0.635	1.44	21.93
Fermented cooked sausage	Nitrite	12	0.942	0.477	0	12.03
	Nitrate	11	31.963	4.766	0.2	77.89
Whole-muscle brine cured uncooked	Nitrite	7	9.158	2.343	0.46	35.95
	Nitrate	7	10.676	1.639	1.8	28.65
Whole-muscle brine cured cooked	Nitrite	27	8.22	0.959	0.03	27.56
	Nitrate	27	9.314	1.78	0.21	71.51
Whole-muscle dry-cured uncooked	Nitrite	15	1.588	0.591	0.03	17.13
	Nitrate	15	61.235	20.941	0.19	570.91

Table 16. Mean nitrite/ nitrate concentrations of raw vegetables and cured meat categories pooled across conventional and organic classifications from all five cities

Product Category		N	Mean	Std Error	Min	Max
Broccoli	Nitrite	40	0.347	0.135	0.01	9.49
	Nitrate	39	301.771	22.89	2.57	1140.42
Cabbage	Nitrite	40	0.609	0.193	0.01	10.75
	Nitrate	40	484.199	42.232	1.95	2113.83
Celery	Nitrite	38	0.595	0.166	0.02	9.23
	Nitrate	39	1196.099	97.847	0.66	4268.95
Lettuce	Nitrite	39	0.331	0.13	0	9.68
	Nitrate	39	847.206	50.469	57.58	2170.82
Spinach	Nitrite	39	4.476	1.834	0	137.2
	Nitrate	39	2038.485	159.708	16.28	8000.26
Cured dried uncooked sausage	Nitrite	64	0.737	0.127	0.01	9.71
	Nitrate	63	78.813	21.289	0.13	2288.99
Cured cooked sausage	Nitrite	89	6.862	0.446	0.05	35.39
	Nitrate	89	27.683	3.661	0.45	540.8
Fermented cooked sausage	Nitrite	71	0.635	0.227	0	26.69
	Nitrate	71	35.658	3.034	0	319.57
Whole-muscle brine cured uncooked	Nitrite	39	7.313	0.789	0.09	36.46
	Nitrate	38	25.565	6.523	1.8	462.05
Whole-muscle brine cured cooked	Nitrite	141	7.159	0.345	0.03	27.56
	Nitrate	141	14.809	0.841	0	142.93
Whole-muscle dry-cured uncooked	Nitrite	63	1.951	0.354	0.02	28.87
	Nitrate	62	67.432	14.568	0.19	1366.52

Table 17A. Mean concentrations of nitrates and nitrites in cured meat products compiled from peer-reviewed databases

Product	NO_3 Mean/Range ppm (mg/kg) [µg/g]	NO_2 Mean/Range ppm (mg/kg) [µg/g]	Reference	Year Data Collected	Country	Analytical Method
Bacon (uncooked, nitrate cured)		(140/37-430)	1	1926	USA	
Bacon (uncooked, nitrite cured)		1.3-272	2	1972	USA	
	(96/7-320)	(25/3-170)	3	1972	Canada	
	77/10-120		4	1972	England and Wales	
		(28/8-63)	5	1972	Canada	
		(35/7-68)	7	1975	Canada	
		(42/ND-88)	9	1975	Canada	
		(17/4-32)	10	1974		
		(35/7-68)	10	1976		
		(40)	11	1977	USA	
		(21)	11a	1977-78	USA	
		(12)	15	1978-79	USA	
	(43/ND-310)	(24/ND-76)	16	1985	UK	
		4,1,15	18	1996	USA	
		5±2	18	1996	USA	
		3±2	18	1996	USA	
		33.7/ND-178	19	1983-85	Canada	Colorimetric
		33.8/7-81	19	1993-95	Canada	Colorimetric
		36/5-68	19	1996	Canada	HPLC
		34/4-63	19	1996	Canada	Colorimetric
Bacon (fried)	(32/4-98)	(7/5-18)	6	1973	Canada	
Beef brisket		0-10	2	1972	USA	
Beef loaf	186/0-260		4	1972	England and Wales	
Bologna		0-185	2	1972	USA	
	(87/9-220)	(29/<0/7-150)	3	1972	Canada	
	(42/26-60)	(5/<0.7-7)	6	1973	Canada	
		(31/3-55)	12	1977-78	USA	
		15±2	18	1996	USA	
		16±3	18	1996	USA	
		65.5/ND-137	19	1983-85	Canada	
Canadian bacon		0-178	2	1972	USA Hong Kong	
		[6]	13	1980	Hong Kong	Potentiometric
		[5]	13	1980	Hong Kong	Spectrophotometric
	[203]	[6]	13	1980		Direct Potentiometric

Chicken pate	(12/6/22)	(4/ND-11)	16	1985	UK	
Chopped pork and ham	10		4	1972	England and Wales	
	(13/5-20)	(4/ND-15)	16	1985	UK	
Canned beef		[7]	13	1980	Hong Kong	Potentiometric
		[7]	13	1980	Hong Kong	Spectrophotometric
Corned beef		1-216	2	1972	USA	
	(10/4-17)	(5/2-8)	16	1985	UK	
		31.5/1-192	19	1983-85	Canada	Colorimetric
Cured beef	60/0-260		4	1972	England and Wales	
	(29/28-30)	(11/7-15)	16	1985	UK	
Cured turkey	(19/13-31)	(54/1-84)	16	1985	UK	
Ham (boiled)		11-87	2	1972	USA	
Ham (canned)		3-130	2	1972	USA	
	(140)	(99)	3	1972	Canada	
	440/20-1600		4	1972	England and Wales	
Ham (fried)		(37/4-220)	10	1974		
Hams (nitrate cured)		(280/24-640)	1	1926	USA	
Hams (nitrite cured)		0-145	2	1972	USA	
	(150/0.7-1400)	(29/<0.7-140)	3	1972	Canada	
	417/0-1080		4	1972	England and Wales	
		[20]	13	1980	Hong Kong	Potentiometric
		[21]	13	1980	Hong Kong	Spectrophotometric
	[135]	[22]	13	1980	Hong Kong	Direct Potentiometric
		(37)	14	1979-80	USA	
	(22/3-410)	(26/ND-110)	16	1985	UK	
		3,9,7	18	1996	USA	
		7±1	18	1996	USA	
		4±1	18	1996	USA	
		48.9/4-146	19	1983-85	Canada	Colorimetric
		28.6/1-61	19	1993-95	Canada	Colorimetric
		24/10-44	19	1996	Canada	HPLC
		24/9-40	19	1996	Canada	Colorimetric
	(5.37)	(11.6)	20	1998		Ion Chromatography
	(153)	(26)	21	2000	Estonia	HPLC
	(33)	(20)	21	2001	Estonia	HPLC
	(36)	(8)	21	2003	Estonia	HPLC
	(50)	(29)	21	2004	Estonia	HPLC
Ham and pork loaf	72/0-450		4	1972	England and Wales	
Leg ham (sliced)		[5]	13	1980	Hong Kong	Potentiometric
		[5]	13	1980	Hong Kong	Spectrophotometric
	[92]	[5]	13	1980	Hong Kong	Direct Potentiometric
Liver sausage	(12/7-22)	(4/ND-11)	16	1985	UK	
Liver pate	(23/18-26)	(7/3-10)	16	1985	UK	

Luncheon meat		0-180	2	1972	USA	
	[141]	[24]	13	1980	Hong Kong	Direct Potentiometric
	(21/6-59)	(24/1-130)	16	1985	UK	
Lunch meat (pork)	78/0-360		4	1972	England and Wales	
Meat loaf		18.5/2-66	19	1983-85	Canada	Colorimetric
Pepperoni		(8.2)	17	1994	Canada	Chemiluminescence
		(7.8)	17	1994	Canada	Colorimetric
		62.5/10-206	19	1983-85	Canada	Colorimetric
		35/10-58	19	1993-95	Canada	Colorimetric
		31/9-57	19	1996	Canada	HPLC
		31/10-53	19	1996	Canada	Colorimetric
Pork belly		50-100	2	1972	USA	
Pork shoulder (cured)	(9/ND-19)	(5/2-8)	16	1985	UK	
		39.2/4-122	19	1983-85	Canada	Colorimetric
Salami		(33.5)	17	1994	Canada	Chemiluminescence
		(30.7)	17	1994	Canada	Colorimetric
	(98.5)	(108)	20	1998		Ion Chromatography
Salami, European type sausages	(89/4-270)	(17/<0.7-66)	3	1972	Canada	
	(78/4-450)	(13/5-97)	19	1973	Canada	
		37.6/3-174	6	1983-85	Canada	Colorimetric
Cooked sausage	(67)	(38)	21	2000	Estonia	HPLC
	(49)	(32)	21	2001	Estonia	HPLC
	(48)	(22)	21	2003	Estonia	HPLC
	(56)	(30)	21	2004	Estonia	HPLC
Sausages and salami		30.2/4-145	19	1993-95	Canada	Colorimetric
		29/13-43	19	1996	Canada	HPLC
		26/9-37	19	1996	Canada	Colorimetric
Sausage Francis		[3]	13	1980	Hong Kong	Potentiometric
		[4]	13	1980	Hong Kong	Spectrophotometric
	[75]	[4]	13	1980	Hong Kong	Direct Potentiometric
Sausages (fermented)		(6)	11	1977	USA	
Sausage (Polish)		0-60	2	1972	USA	
Sausages (smoked and unsmoked; nitrate cured)		(190/13-940)	1	1926	USA	
Sausages (smoked and unsmoked; wieners and sausages)	(110/17-240)	(9.6/<0.7-52)	3	1972	Canada	
	185/80-300		4	1972	England and Wales	
	(102)	(30)	21	2000	Estonia	HPLC
	(64)	(27)	21	2001	Estonia	HPLC
	(48)	(17)	21	2003	Estonia	HPLC
	(22)	(14)	21	2004	Estonia	HPLC
Sausages (smoked and unsmoked; franks, hot dogs, and wieners)		0-195	2	1972	U.S.	
	(96/66-130)	(10/10-10)	6	1973	Canada	
		17.1	17	1994	Canada	Chemiluminescence

		1,4,1,9	18	1996	USA	
		9±1	18	1996	USA	
		8±3	18	1996	USA	
		60.9/1-178	19	1983-85	Canada	Colorimetric
		62.5/10-206	19	1993-95	Canada	Colorimetric
		26/10-67	19	1996	Canada	HPLC
		24/10-63	19	1996	Canada	Colorimetric
	70.62		22	2007		Flow injection (original)
	67.48-73.77		22	2007		Flow injection (modified)
Sausages (smoked and unsmoked)		(31/0-50)	8	1975		
		(24/5-43)	12	1977-78	USA	
		(19)	14	1979-80	USA	
		33.8/1-132	19	1983-85	Canada	Colorimetric
Sausages (pasteurized, canned, cured)	(16/15-18)	(6/5-7)	6	1973	Canada	
Sausages (summer)		(6/0-29)	12	1977-78	USA	
Sausages (dry; salchichón and chorizo)	7-8 (salchichón) 2-3 (chorizo)		22	2007		Flow injection (modified)
Shelf-stable (canned, cured meat)	(100/<0.7-840)	(6/<0.7-17)	3	1972	Canada	
	(26/<0.7-110)	(6/5-8)	6	1973	Canada	
		(19)	11	1977	USA	
Sliced cooked meats		31.4/6-120	19	1983-85	Canada	Colorimetric
Refrigerated (canned meats)		(44)	11	1977	USA	
Tongue	(23/ND-82)	(17/1-71)	16	1985	UK	
Vienna sausage		6-16	2	1972	USA	
White meat loaf		[5]	13	1980	Hong Kong	Potentiometric
		[5]	13	1980	Hong Kong	Spectrophotometric
	[250]	[5]	13	1980	Hong Kong	Direct Potentiometric
Uncooked cured meats (pastrami, smoked beef, spiced beef)		72.9/11-275	19	1983-85	Canada	Colorimetric
ND = Not detected						

Ref. 1 Kerr *et al*., 1926
Ref. 2 Kolari and Aunan, 1972
Ref. 3 Panalaks *et al*., 1973
Ref. 4 Fudge and Truman, 1973
Ref. 5 Sen et al., 1974
Ref. 6 Panalaks *et al*., 1974
Ref. 7 Sen *et al*., 1975
Ref. 8 Coppola, 1975
Ref. 9 Sen *et al*., 1977
Ref. 10 Greenberg, 1977
Ref. 11 American Meat Institute, 1977
Ref. 11a American Meat Institute (NAS)
Ref. 12 Buege *et al*., 1978
Ref. 13 Choi and Fung, 1980
Ref. 14 Birdsall, 1981
Ref. 15 Nelson, 1981
Ref. 16 MAFF, 1992
Ref. 17 Sen *et al*., 1994
Ref. 18 Cassens, 1997
Ref. 19 Sen and Baddoo, 1997
Ref. 20 Siu and Henshall, 1998
Ref. 21 Reinik *et al*., 2005
Ref. 22 Ruiz-Capillas, 2007

Table 17B. Mean concentrations of nitrates and nitrites in vegetables compiled from peer-reviewed databases

Product	NO_3 Mean/Range ppm (mg/kg) [µg/g]	NO_2 Mean/Range ppm (mg/kg) [µg/g]	Reference	Year Data Collected	Country	Analytical Method
Artichoke (frozen)	12	0.4	7	1975	USA	
(fresh)	(30)		12	1994-95	Italy	Ion Chromatography
Asparagus	(50)		2	1949		
(canned)	3	0.2	7	1975	USA	
(frozen)	16	0.9	7	1975	USA	
	(21/16-50)		8	1975		
	(200)		9	1979		
	(66/13-700)		10	1979		
Bean						
Dry (navy)	(68)		1	1907		
	(13/13)		8	1975		
	(9)		9	1979		
Green	(440)		1	1907		
	(250)		3	1967		
	(150)		5	1972		
(canned)	100	0.2	7	1975	USA	
	(200)		3	1967		
(frozen)	270	0.9	7	1975	USA	
	(250/200-270)		8	1975		
	(330)		9	1979		
	(430/44-1100)		10	1979		
(fresh)	(161)		12	1994-95	Italy	Ion Chromatography
	(298/82-675)	(0.2/0.16-0.3)	15	1996-2002	Slovenia	Photometric
Lima	(310)		1	1907		
	(130)		3	1967		
(frozen)	(88)		3	1967		
(frozen)	27	1.1	7	1975		
	(54/88-130)		8	1975		
	(220)		9	1979		
Beet	(2600)		1	1907		
	(1300)		2	1949		
	(1700)		3	1967		
	(600-4500)		4	1970		
	(2600)		5	1972		

	(2400)		6	1975		
(canned)	1450	1.8	7	1975	USA	
(fresh)	3010	6.0	7	1975	USA	
	(2800/1300-3000)		8	1975		
	(2700)		9	1979		
	(2100/100-8100)		10	1979		
	(1493/116-4070)		11	1993-96	Denmark	Flow injection
(fresh)	(1727)	(0.91/0-4.5)	12	1994-95	Italy	Ion Chromatography
	(1446/214-3556)		16	2003-05	Estonia	Potentiometric
Broccoli	(2,300)		2	1949		
	(400-800)		4	1970		
	(940)		6	1972		
	(550)		3	1967		
(frozen, spears)	464	1.0	7	1975	USA	
(frozen, chopped)	573	1.0	7	1975	USA	
	(780/510-2300)		8	1975		
	(1900)		9	1979		
	(700/140-1300)		10	1979		
(fresh)	(154)		12	1994-95	Italy	Ion Chromatography
(fresh, broccoli raab)	(905)		12	1994-95	Italy	Ion Chromatography
Brussels sprouts (frozen)	84	1.0	7	1975	USA	
	(118/0-170)		10	1979		
Cabbage	(200)		1	1907		
	(1200)		2	1949		
	(320)		3	1967		
	(150-1700)		4	1970		
	(720)		5	1972		
	(910)		6	1972		
	784	0.5	7	1975	USA	
	(640/310-900)		8	1975		
	(550)		9	1979		
	(400/0-2700)		10	1979		
(fresh)	(400)		12	1994-95	Italy	Ion Chromatography
(winter)	(730/29-1498)	(0.4/ND-3.6)	14	1998	Korea	Ion Chromatography
(summer)	(722/1-1788)	(0.3/ND-2.2)	14	1998	Korea	Ion Chromatography
	(881/112-1864)	(0.2/0.16-0.4)	15	1996-2002	Slovenia	Photometric
	(437/74-1138)		16	2003-05	Estonia	Potentiometric
	(1425)		17	2007	Fiji	Flow Injection
Cabbage, white (fresh)	(342/0-1240)	(0.16/0-0.99)	11	1993-96	Denmark	Flow injection
Cabbage, Chinese	(993/111-3,160)	(0.34/0-4.0)	11	1993-96	Denmark	Flow injection
	(1240/116-8050)	(0.68/0-20)	11	1993-96	Denmark	Flow injection
(winter)[1]	(1291/131-3249)	(1.0/ND[3]-2.7)	14	1998	Korea	Ion Chromatography
(summer)[2]	(2009/208-5490)	(1.7/ND-14.3)	14	1998	Korea	Ion Chromatography

	(1243/232-2236)		16	2003-05	Slovenia	Potentiometric
	(5658)		17	2007	Fiji	Flow Injection
Carrot	(66)		1	1907		
	(320)		2	1949		
	(18)		3	1967		
(frozen)	(200)		3	1967		
	(50-500)		4	1970		
	(140)		5	1972		
	(330)		6	1972		
(fresh)	72	0.6	7	1975	USA	
(frozen)	97	1.0	7	1975	USA	
(canned)	205	1.1	7	1975	USA	
	(120/18-340)		8	1975		
	(130)		9	1979		
	(280/0-2800)		10	1979		
(fresh)	(195)		12	1994-95	Italy	Ion Chromatography
(winter)	(373/6-971)	(0.5/ND-1.8)	14	1998	Korea	Ion Chromatography
(summer)	(282/1-1158)	(0.2/ND-2.9)	14	1998	Korea	Ion Chromatography
	(298/82-675)	(0.2/0.16-0.4)	15	1996-2002	Slovenia	Photometric
	(148/<30-525)		16	2003-05	Estonia	Potentiometric
Cauliflower	(230)		1	1907		
	(2000)		2	1949		
	(53)		3	1967		
	(100-1200)		4	1970		
	(1000)		6	1972		
(frozen)	250	1.1	7	1975	USA	
	(550/53-2000)		8	1975		
	(600)		9	1979		
	(420/0-4500)		10	1979		
(fresh)	(202)		12	1994-95	Italy	Ion Chromatography
	(287/104-404)		16	2003-05	Estonia	Potentiometric
Celery	(1,500)		1	1907		
	(2,200)		2	1949		
	(2,800)		3	1967		
	(50-3200)		4	1970		
	(2400)		5	1972		
	(1000)		6	1972		
(fresh)	2220/1600-2670	0.5/0.4-0.5	7	1975	USA	
	(2300/50-3200)		8	1975		
	(1800)		9	1979		
	(2300/50-5300)		10	1979		
(fresh)	(1678)		12	1994-95	Italy	Ion Chromatography
	(565/256-830)		16	2003-05	Estonia	Potentiometric

	(4706)		17	2007	Fiji	Flow Injection
Chicory (fresh)	(1452)		12	1994-95	Italy	Ion Chromatography
Corn	(37)		1	1907		
(frozen)	45	2.0	7	1975	USA	
	(45/45)		8	1975		
Cucumber	(160)		1	1907		
(fresh)	24	0.5	7	1975	USA	
	(24/24)		8	1975		
	(160)		9	1979		
	(190/17-570)		10	1979		
(fresh)	(79)		12	1994-95	Italy	Ion Chromatography
(winter)	(267/83-580)	(0.3/ND-1.4)	14	1998	Korea	Ion Chromatography
(summer)	(180/1-649)	(0.2/ND-1.5)	14	1998	Korea	Ion Chromatography
	(93/4-245)	(0.2/0.16-0.8)	15	1996-2002	Slovenia	Photometric
	(160/<30-1236)		16	2003-05	Estonia	Potentiometric
Dill	(2243)	(102)	13	2000	Turkey	Capillary electrophoresis
	(2936/2236-3267)		16	2003-05	Estonia	Potentiometric
Eggplant	(1500)		1	1907		
(fresh)	302	0.5	7	1975	USA	
	(300/300)		8	1975		
	(300)		9	1979		
	(240/180-300)		10	1979		
(fresh)	(108)		12	1994-95	Italy	Ion Chromatography
Endive (fresh)	663	0.5	7	1975	USA	
	(1400)		9	1979		
	(1300/10-3800)		10	1979		
(fresh)	(224)		12	1994-95	Italy	Ion Chromatography
Fennel (fresh)	(363)		12	1994-95	Italy	Ion Chromatography
Garlic (fresh)	(34)		12	1994-95	Italy	Ion Chromatography
(winter)	(116/3-211)	(0.4/ND-2.0)	14	1998	Korea	Ion Chromatography
(summer)	(129/1-462)	(0.1/ND-0.5)	14	1998	Korea	Ion Chromatography
Green onion (winter)	(392/10-1364)	(0.4/ND-2.9)	14	1998	Korea	Ion Chromatography
(summer)	(463/4-1676)	(0.2/ND-2.2)	14	1998	Korea	Ion Chromatography
Kale/collard /mustard	(1900)		3	1967		
	(650-4800)		4	1970		
	(1600)		7	1975		
	(1500)		3	1967		
(frozen, collard)	2450	1.7	7	1975	USA	
(canned, collard)	2640	0.2	7	1975	USA	
(frozen, kale)	2770	1.8	7	1975	USA	
(canned, kale)	1600	0.2	7	1975	USA	
(frozen, mustard)	2390	1.6	7	1975	USA	
(canned, mustard)	1360	0.3	7	1975	USA	

	(1900)		9	1979		
	(790/30-5500)		10	1979		
Leek	(440)		1	1907		
	(510/36-4500)		10	1979		
(frozen)	(308/0-2290)	(0.15/0-3.5)	11	1993-96	Denmark	Flow injection
	(130)	(96)	13	2000	Turkey	Capillary electrophoresis
Lettuce	(1700)		1	1907		
	(1100)		2	1949		
	(660)		3	1967		
	(300-6000)		4	1970		
	(750)		5	1972		
	(280)		6	1972		
(fresh/iceberg)	1200/1100-1300	0.4/0.3-0.4	7	1975	USA	
(fresh/romaine)	1400	0.4	7	1975	USA	
	(850/280-1200)		8	1975		
	(1100)		9	1979		
	(2600/90-13000)		10	1979		
(fresh, Danish)	(2603/331-7820)	(0.8/0-1.6)	11	1993-96	Denmark	Flow injection
(fresh, foreign)	(1277/10-4680)	(0.14/0-1.4)	11	1993-96	Denmark	Flow injection
(fresh)	(832)		12	1994-95	Italy	Ion Chromatography
(winter)	(1933/247-3283)	(0.6/ND-2.9)	14	1998	Korea	Ion Chromatography
(summer)	(2728/884-4488)	(0.7/ND-4.6)	14	1998	Korea	Ion Chromatography
	(1074/21-3986)	(0.2/0.16-1.4)	15	1996-2002	Slovenia	Photometric
	(2167/397-3230)		16	2003-05	Estonia	Potentiometric
	(5658)		17	2007	Fiji	Flow Injection
Melon	(38)		1	1907		
	(500)		2	1949		
	(430/430)		8	1975		
	(430)		9	1979		
	(290/40-600)		10	1979		
(fresh)	(493)		12	1994-95	Italy	Ion Chromatography
	(95/95-95)		16	2003-05	Estonia	Potentiometric
Mushroom (fresh)	63	0.8	7	1975	USA	
(canned, sliced)	6	0.2	7	1975	USA	
(canned, whole)	17	0.2	7	1975	USA	
	(110)		9	1979		
	(160/40-400)		10	1979		
Okra (canned)	2	0.2	7	1975	USA	
(frozen, whole)	74	0.7	7	1975	USA	

Onion	(230)		1	1907		
	(180)		3	1967		
	(60)		5	1972		
(frozen, chopped)	33	1.0	7	1975	USA	
(frozen, whole)	128	0.4	7	1975	USA	
	(130/62-180)		8	1975		
	(160)		9	1979		
	(200/0-2300)		10	1979		
(fresh)	(32)		12	1994-95	Italy	Ion Chromatography
(winter)	(14/4-49)	(0.3/ND-1.5)	14	1998	Korea	Ion Chromatography
(summer)	(29/1-123)	(0.2/ND-2.2)	14	1998	Korea	Ion Chromatography
	(55/30-92)		16	2003-05	Estonia	Potentiometric
Parsley	(1000)		1	1907		
	(1700)		3	1967		
	(1300)		9	1979		
	(1000/0-4100)		10	1979		
	(1204)	(94)	13	2000	Turkey	Capillary electrophoresis
	(966/674-1588)		16	2003-05	Estonia	Potentiometric
Peas	(25)		1	1907		
	(40)		3	1967		
(frozen)	(62)		3	1967		
(frozen, blackeye)	9	2.6	7	1975	USA	
(frozen, green)	20	0.7	7	1975	USA	
(canned)	6	0.4	7	1975		
	(28/20-62)		8	1975		
	(27/0-110)		10	1979		
(fresh)	(40)		12	1994-95	Italy	Ion Chromatography
Pea pods, Chinese (frozen)	13	0.6	7	1975	USA	
Pepper	(200)		3	1967		
(frozen)	(130)		3	1967		
(fresh)	62	0.4	7	1975	USA	
(frozen)	50		7	1975	USA	
	(120/50-200)		8	1975		
	(170)		9	1979		
	(120/0-350)		10	1979		
(fresh)	(87)		12	1994-95	Italy	Ion Chromatography
(winter)	(95/2-559)		14	1998	Korea	Ion Chromatography
(summer)	(65/1-225)		14	1998	Korea	Ion Chromatography

Potato, white	(77)		1	1907		
	(63)		2	1949		
	(57)		3	1967		
	(190)		5	1972		
	(120)		6	1973		
(frozen)	(130)		3	1967		
(frozen)	150	0.8	7	1975	USA	
(canned, whole)	63	0.5	7	1975	USA	
(canned, sliced)	69	0.4	7	1975	USA	
	(120/57-190)		8	1975		
	(110)		9	1979		
	(110/0-1000)		10	1979		
(fresh, Danish)	(144/7-542)	(0.6/0-2.6)	11	1993-96	Denmark	Flow injection
(fresh, foreign)	(266/52-691)	(0.80/0-2.1)	11	1993-96	Denmark	Flow injection
(fresh)	81		12	1994-95	Italy	Ion Chromatography
(winter)	(294/2-977)	(0.6/ND-2.7)	14	1998	Korea	Ion Chromatography
(summer)	(546/34-5521)	(0.3/ND-3.4)	14	1998	Korea	Ion Chromatography
	(158/2-704)	(1.2/0.16-7.6)	15	1996-2002	Slovenia	Photometric
	(94/<30-360)		16	2003-05	Estonia	Potentiometric
Potato, sweet	(66)		1	1907		
	(53)		3	1967		
	(0)		5	1972		
	(53/53)		8	1975		
	(64)		9	1979		
	(39/0-13)		10	1979		
Potato, hash brown (frozen)	37	0.7	7	1975	USA	
Pumpkin or squash	(690)		1	1907		
	(300)		3	1967		
	(400-2,00)		4	1970		
	(410/300-460)		8	1975		
	(300)		9	1979		
	(380/34-2200)		10	1979		
(winter)	(654/174-1690)	(0.6/ND-3.6)	14	1998	Korea	Ion Chromatography
(summer)	(629/182-2340)	(0.5/ND-2.7)	14	1998	Korea	Ion Chromatography
	(174/<30-445)		16	2003-05	Estonia	Potentiometric
Radish	(1800)		1	1907		
	(740)		2	1949		
	(1500)		3	1967		
	(1800)		5	1972		
(fresh)	2400	0.2	7	1975	USA	
	(1700)		9	1979		
	(1900/60-9000)		10	1979		
(winter)	(1494/789-2643)	(0.7/ND-2.5)	14	1998	Korea	Ion Chromatography

(summer)	(2108/766-4570)	(1.0/ND-3.5)	14	1998	Korea	Ion Chromatography
	(1309/670-1500)		16	2003-05	Estonia	Potentiometric
Rhubarb	(3200)		2	1949		
	(850-6500)		4	1970		
(frozen)	(390)		3	1967		
	(3200)		9	1979		
	(2100/400-5500)		10	1979		
	(201/55-376)		16	2003-05	Estonia	Potentiometric
Salad (mixed)	819	0.7	7	1975	USA	
	(259/80-474)		16	2003-05	Estonia	Potentiometric
Sauerkraut (canned)	68	0.4	7	1975	USA	
Spinach	(1900)		1	1907		
	(1600)		2	1949		
	(240)		3	1967		
(frozen)	(670)		3	1967		
	(2300-4500)		4	1970		
	(2300)		5	1972		
	(2100)		6	1972		
(fresh)	2200	0.7	7	1975	USA	
(frozen)	2140	6.1	7	1975	USA	
(canned)	573	0.7	7	1975	USA	
	(1900/240-4500)		8	1975		
	(1800)		9	1979		
	(1700/2-6700)		10	1979		
(fresh)	(1783)	(11/0-162)	11	1993-96	Denmark	Flow injection
(frozen)	(680)	(4.5/0-19)	11	1993-96	Denmark	Flow injection
(fresh)	(1845)		12	1994-95	Italy	Ion Chromatography
	(2820)	(98)	13	2000	Turkey	Capillary electrophoresis
(winter)	(3334/427-7439)	(0.5/ND-1.8)	14	1998	Korea	Ion Chromatography
(summer)	(4814/195-7793)	(1.2/ND-5.1)	14	1998	Korea	Ion Chromatography
	(2508/2508-2508)		16	2003-05	Estonia	Potentiometric
Sprouts, soybean (winter)	(63/15-193)	(0.8/ND-3.3)	14	1998	Korea	Ion Chromatography
(summer)	(52/2-158)	(0.9/ND-5.7)	14	1998	Korea	Ion Chromatography
Squash (frozen)	160	0.9	7	1975	USA	
(fresh, acorn)	34	0.4	7	1975	USA	
(fresh, butternut)	678	0.4	7	1975	USA	
(fresh, zucchini)	665	0.6	7	1975	USA	
(frozen, zucchini)	533	1.0	7	1975	USA	
(fresh)	(603)		12	1994-95	Italy	Ion Chromatography
(zucchini)	(421/330-511)		16	2003-05	Estonia	Potentiometric
Swiss chard (fresh)	(2363)		12	1994-95	Italy	Ion Chromatography
Tomato	(120)		1	1907		
	(0)		2	1949		

	(72)		3	1967		
	(89)		5	1972		
	(62/0-89)		8	1975		
	(64)		9	1979		
	(53/0-170)		10	1979		
(fresh)	(50)		12	1994-95	Italy	Ion Chromatography
	(4.3/2-12)	(0.3/0.16-1.6)	15	1996-2002	Slovenia	Photometric
Turnip	(1000)		1	1907		
	(50-3500)		4	1970		
(canned)	2230	0.1	7	1975	USA	
	(1100)		9	1979		
	(390/10-2900)		10	1979		
	(307/64-1062)		16	2003-05	Estonia	Potentiometric
Turnip greens	(2200)		7	1975		
(frozen)	(1600)		3	1967		
(frozen)	3460	4.4	7	1975	USA	
	(6600/6600)		10	1979		

[1] Winter - Vegetables were cultivated during the months of November – March.
[2] Summer – Vegetables were cultivated during the months of April – October.
[3] ND - Not detected

Ref. 1 Richardson, 1907	Ref. 7 Siciliano *et al*., 1975	Ref. 13 Öztekin *et al*., 2002
Ref. 2 Wilson, 1949	Ref. 8 White, 1975	Ref. 14 Chung *et al*., 2003
Ref. 3 Jackson *et al*., 1967	Ref. 9 FDA, 1979	Ref. 15 Sušin *et al*., 2006
Ref. 4 Lee, 1970	Ref. 10 Corré and Breimer, 1979	Ref. 16 Tamme *et al*., 2006
Ref. 5 Maynard and Barker, 1972	Ref. 11 Petersen and Stoltze, 1999	Ref. 17 Prasad and Chestty, 2008
Ref. 6 Lee et al., 1972	Ref. 12 Santamaria *et al*., 1999	

Reference List for Cured Meat Products in Table 17A

1. Kerr, R.H., T. N. Marsh, W. F. Schoeder, and E. A Boyer. 1926. The use of sodium nitrite in the curing of meat. J. Agric. Res. 33:541.

2. Kolari, O. E. and W. J. Aunan. 1972. The residual levels of nitrite in cured meat products. pp. 422-434 in Proceedings of the 18th Meeting of Meat Research Workers, University of Guelph, Ontario, Canada.

3. Panalaks, T., J. R. Iyengar, and N. P. Sen. 1973. Nitrate, nitrite, and dimethylnitrosamine in cured meat products. J. Assoc. Off. Anal. Chem. 56:621-625.

4. Fudge, R., and R. W. Truman. 1973. The nitrate and nitrite contents of meat products—A survey by Public Analysts' laboratories in South Wales and the South West of England. J. Assoc. Public Anal. 11:19-27.

5. Sen, N. P., J. R. Iyengar, B. A. Donaldson, and T. Panalaks. 1974. Effect of sodium nitrite concentration on the formation of nitrosopyrrolidine and dimethylnitrosamine in fried bacon. J. Agric. Food Chem. 22:54-541.

6. Panalaks, T., J. R. Iyengar, B. A. Donaldson, W. F. Miles, and N. P. Sen. 1974. Futher survey of cured meat products for volatile N-nitrosamines. J. Assoc. Off. Anal. Chem. 57:806-812.

7. Sen, N. P., B. A. Donaldson, and C. Charbonneau. 1975. Formation of nitrosodimethylamine from the interaction of certain pesticides and nitrite. pp. 75-79 in P. Bogovski and E. A. Walker, eds. N-Nitroso Compounds in the Environment, IARC Scientific Publication No. 9. International Agency for Research on Cancer, Lyon, France.

8. Coppola, E. D., A. F. Wickroski, and J. G. Hanna. 1976. Nitrite in meat products determined by fluorescence quenching p-amino-benzoate ion. J. Assoc. Off. Anal. Chem. 59:783-786.

9. Sen, N. P., B. A. Donaldson, S. Seaman, B. Collins, and J. Y. Iyengar. 1977. Recent nitrosamine analyses in cooked bacon. J. Inst. Can. Sci. Technol. Aliment. 10:A13-A15.

10. Greenburg, R. A. 1977. Nitrosopyrrolidine in United States cured meat products. pp. 203-210 in B. J. Tinbergen and B. Krol, eds. Proceedings of the Second International Symposium on Nitrite in Meat Products, September 7-10, 1976, Zeist, the Netherlands. Centre for Agricultural Publishing and Documentation, Wagenigen, the Netherlands.

11. American Meat Institute. 1977. Progress Report: Residual Sodium Nitrite in Cured Meat Products. Report prepared for the July 25, 1977 meeting of the USDA Expert Panel on Nitrites and Nitrosamines. American Meat Institute, Arlington, Virginia [5]

11a.American Meat Institute. 1981. Personal communication. In National Academy of Sciences. 1981. The health effects of nitrate, nitrite and n-nitroso compounds. Washington, DC, National Academy Press.

12. Buege, D. R., M. H. Lee, and R. G. Cassens. 1978. Residual nitrite levels in meat products manufactured by Wisconsin meat processors. Research Division of the College of Agricultural and Life Sciences, University of Wisconsin, Madison, Wisconsin. Available from Agricultural Bulletin Building, Madison, Wisconsin as No. A2983. [4]

13. Choi, K. K., and K. W. Fung. 1980. Determination of Nitrate and Nitrite in Meat Products by Using a Nitrate Ion-selective Electrode. Analyst. 105:241-245.

14. Birdsall, J. J. 1981. Human dietary nitrite intake; and, results of animal feeding studies of nitrite. Paper presented at the Public Meeting of the Committee on Nitrite and Alternative Curing Agents in Food, January 22, 1981, National Research Council, National Academy of Sciences, Washington, D. C. [16]

15. Nelson, M. 1981. United States Department of Agriculture. Personal communication. In National Academy of Sciences. 1981. The health effects of nitrate, nitrite and n-nitroso compounds. Washington, DC, National Academy Press.

16. MAFF. 1992. Nitrate, nitrite and N-nitroso compounds in food. Second Report, Food Surveillance Paper no. 32.

17. Sen, N. P., P. A Baddoo, and S. W. Seaman. 1994. Rapid and sensitive determination of nitrite in foods and biological materials by flow injection or high-performance liquid chromatography with chemiluminescence detection. J. Chromatography. 673:77-84.

18. Cassens, R. G. 1997. Residual nitrite in cured meat. Food Tech. 51 (2):53-55.

19. Sen, N. P. and P. A. Baddoo. 1997. Trends in the levels of residual nitrite in Canadian cured meat products over the past 25 years. J. Agric. Food Chem. 45:4714-4718.

20. Siu, D. C. and A. Henshall. 1998. Ion chromatographic determination of nitrate and nitrite in meat products. J. Chromatography. 804:157-160.

21. Reinik, M., T. Tamme, M. Roasto, K. Juhkam, S. Jurtšenko, T. Tenńo &and A. Kiis. 2005. Nitrites, nitrates and N-nitrosamines in Estonian cured meat products: Intake by Estonian children and adolescents. Food Additives and Contaminants. 22:1098-1105.

22. Ruiz-Capillas, C., P. Aller-Guiote, and F. Jimenez-Colmenero. 2007. Application of flow injection analysis to determine protein-bound nitrite in meat products. Food Chem. 101:812-816.

Reference List for Vegetables in Table 17B

1. Richardson, W. D. 1907. The occurrence of nitrates in vegetable foods, in cured meats and elsewhere. J. Am. Chem. Soc. 29:1757-1767.

2. Wilson, J. K. 1949. Nitrate in foods and its relation to health. Agron. J. 41:20-22.

3. Jackson, W. A., J. S. Steel, and V. R. Bosswell. 1967. Nitrates in edible vegetables and vegetable products. Proc. Am. Soc. Hortic. Sci. 90:349-352.

4. Lee, D. H. K. 1970. Nitrates, nitrites, and methemoglobinemia. Environ. Res. 3:484-511.

5. Maynard, D. N., and A. V. Barker, 1972. Nitrate content of vegetable crops. Hort. Science 7:224-226.

6. Lee, C. Y., G. S. Stoewsand, and D. L. Downing. 1972. Nitrate problems in foods. N. Y. Food Life Sci. Q. 5:8-9.

7. Siciliano, J., S. Krulick, E. G. Heisler, J. H. Schwartz, and J. W White, Jr. 1975. Nitrate and nitrite content of some fresh and processed market vegetables. J. Agric. Food Chem. 23:461-464.

8. White, J. W., Jr. 1975. Relative significance of dietary sources of nitrate and nitrite. J. Agric. Food Chem. 23:886-891.

9. Food and Drug Administration. 1979. Report: Nitrite Task Force. Unpublished report of the Nitrite Task Force, Bureau of Foods, Education, and Welfare, Washington, D. C. 43 pp + tables and figures.

10. Corré, W. J., and T. Breimer. 1979. Nitrate and Nitrite in Vegetables, Literature Survey No. 39. Centre for Agricultural Publishing and Documentation, Wageningen, the Netherlands. 85

11. Petersen, A., and S. Stoltze. 1999. Nitrate and nitrite in vegetables on the Danish market: content and intake. Food Additives and Contaminants. 16:291-299.

12. Santamaria, P., A. Elia, F. Serio, and E. Todaro. 1999. A survey of nitrate and oxalate content in fresh vegetables. J Sci. Food Agric. 79:1882-1888.

13. Öztekin, N., M. Said Nutku, F. Bedia Erim. 2002. Simultaneous determination of nitrite and nitrate in meat products and vegetables by capillary electrophoresis. Food Chem. 76 :103-106.

14. Chung, S. Y., J. S. Kim, M. Kim, M. K. Hong, J. O. Lee, C. M. Kim, and I. S. Song. 2003. Survey of nitrate and nitrite contents of vegetables grown in Korea. Food Additives and Contaminants. 20:621-628.

15. Sušin, J., V. Kmecl, & A. Gregorčič. 2006. A survey of nitrate and nitrite content of fruit and vegetables grown in Slovenia during 1996-2002. Food Additives and Contaminants. 23:385-390.

16. Tamme, T., M. Reinik, M. Roasto, K. Juhkam, T. Tenno, & A Kiis. 2006. Nitrates and nitrites in vegetables and vegetable-based products and their intakes by the Estonian population. Food Additives and Contaminants. 23:355-361.

17. Prasad, S., and A. A. Chetty. 2007. Nitrate-N determination in leafy vegetables: Study of the effects of cooking and freezing. Food Chem. 106:772-780.

Table 18. Nitrate and nitrite concentrations in potable water supplies from 25 cities located in different geographic regions of the United States

City (Year)	Contaminant	Average level (ppm)	Minimum Level (ppm)	Maximum Level (ppm)	MCL[a] (ppm)	MCLG[b] (ppm)	Violation (Y or N)	Possible source of Contaminant
Boston, MA (2007)	Nitrate	Detected level average: 0.17	Range of Detections: 0.02 - 0.17		10	10	N	Atmospheric deposition
	Nitrite	Detected level average: 0.01	Range of Detections: 0.005 - 0.01		1	1	N	Byproduct of water disinfection
New York City, NY(2007)	Nitrate[c]	0.30	Range: 0.2 – 0.59		10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite[c]	<0.001	ND-0.002		1	1		
Philadelphia, PA (2007)	Nitrate	Highest result: 4.9	Range of test results for the year: 0.75 – 4.9		10	10		Fertilizer runoff, sewage
	Nitrite is not reported							
Atlantic City, NJ (2006) (Nitrate/Nitrite concentration is not reported in 2007)	Nitrate	Highest level detected: 4.56	Range detected: ND to 4.56		10	10	N	Erosion of natural deposits
	Nitrite is not reported							
Washington, DC (2007)	Nitrate	Highest : 3.0	Range: 0.1 – 3.0		10	10		Runoff from fertilizer use; erosion of natural deposits
	Nitrite	Highest : 0.1	Range: ND – 0.1		1	1		
Raleigh, NC (2005)	Nitrate	0.17			10			
	Nitrite	<0.1			1			

Atlanta, GA (2007)	Nitrate as Nitrogen	Detected level: 1.0	Range of Detections: 0.27 – 1.4	10	10	N	Fertilizer runoff
	Nitrite is not reported						
Knoxville, TN (2007)	Nitrate (as Nitrogen)	Maximum level detected: 0.53		10	10	N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						
Birmingham, AL (2007)	Nitrate (as N)		Carson highest: 0.21 Pufnam highest: 0.23 Shades Mountain highest: 0.30 Western highest: 0.18	10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite (as N)		Carson highest: ND Pufnam highest: ND Shades Mountain highest: ND Western highest: ND	1	1		
Orlando, FL (2007)	Nitrate	Highest detected: ND	Range detected: ND	10	10	N	Runoff from fertilizer; erosion of natural deposits
	Nitrite is not reported						
Chicago, IL (2007)	Nitrate (as N)	Highest level detected: 0.41	Highest level detected: 0.37 - 0.41	10	10	-	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrate/Nitrite (as N)	Highest level detected: 0.42	Highest level detected: 0.37 - 0.42	10	10	-	
Detroit, MI (2007)	Nitrate	Level detected: 0.22	Range of detection: Not applicable	10	10	N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						

Cincinnati, OH (2007)	Nitrate In: 1.- Miller Water (from the Ohio River) 2.- Bolton Water 9from the Great Miami Aquifer)	Highest compliance level detected: 1.56 2.45	Range of detections: 0.66 – 1.56 0.65 – 2.45	10	10	N N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						
Minneapolis, MN (2007)	Nitrate (as N)	Level found: 0.38	Range of detections: --	10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						
Madison, WI (2007)	Nitrate		Minimum ND Maximum 3.57	10	10	N	
	Nitrite is not reported						
Memphis, TN	Nitrate	Maximum amount detected: 0.29	Minimum ND	10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						
Little Rock, AR (2006) (Nitrate/Nitrite are not reported in 2007)	Nitrate + Nitrite	Highest level detected: 0.06 (W^d) 0.07 (OP^d)	Range detected: One sample only	10	10	N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits

Oklahoma City, OK (2007)	Nitrite-Nitrate (measure as the sum of Nitrate-N and Nitrite-N)	Highest level	Hefner WTP 0.21	Draper WTP <0.01	Overholser WTP <0.01	10	10	N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
Dallas, TX (2007)	Nitrate	Average level: 0.2	Minimum level <0.02	Maximum level 2.8		10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported								
New Orleans, LA (2007)	Nitrate		Amounts detected East Bank 1.1	Amounts detected West Bank 0.9		10	10	N	Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported								
Seattle, WA (2007)	Nitrate	- Level in Cedar Water Average: 0.045 -Level in Tolt Water Average: 0.093	- Level in Cedar Water Range: one sample	- Level in Tolt Water Range: one sample		10	10	N	Erosion of natural deposits
	Nitrite is not reported								

Fresno/Sacramento CA (2007)	Nitrate	Average in: -Weymouth Plant: 0.5 -Diemer Plant: 0.5 -Jensen Plant: 0.5 -Skinner Plant: ND -Mills Plant: 0.7	Range in: -Weymouth Plant: ND - 0.8 -Diemer Plant: ND - 0.7 -Jensen Plant: ND - 0.8 -Skinner Plant: ND - 0.4 -Mills Plant: ND – 1.1	10	10		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	Nitrite is not reported						
Los Angeles, CA (2007)	Nitrate (as NO_3):	Average:	Range:	MCL or MRDL: 45	MCLG or MRDLG: 45	N	Erosion of natural deposits, runoff and leaching from fertilizer use
	-Los Angeles Filtration Plant	2.2	<2.0 – 2.9				
	-Northern Combined Wells	9.2	<2.0 – 18				
	-Southern Combined Wells	9.2	<2.0 – 18				
	-MWD Diemer Filtration Plant	2.2	<2.0 – 3.1				
	-MWD Jensen Filtration Plant -	2.7	<2.0 – 3.5				
	MWD Weymouth Filtration Plant	2.2	<2.0 – 3.5				

Los Angeles, CA (2007) (Cont…)	Nitrate + Nitrite (as N):	Average:	Range:		MCL or MRDL: 10	MCLG or MRDLG: 10	N	Erosion of natural deposits, runoff and leaching from fertilizer use
	-Los Angeles Filtration Plant	0.5	0.4 – 0.6					
	-Northern Combined Wells	2.1	<0.4 – 4.0					
	-Southern Combined Wells	2.1	<0.4 – 4.0					
	-MWD Diemer Filtration Plant	0.5	<0.4 – 0.7					
	-MWD Jensen Filtration Plant	0.6	<0.4 – 0.8					
	-MWD Weymouth Filtration Plant	0.5	<0.4 – 0.8					
Las Vegas, NE (2007)	Nitrate (as N):	Average:	Minimum	Maximum	MCL (EPA limit):	MCLG (EPA goal):		Runoff from fertilizer use; leaching from septic tanks, sewage, erosion of natural deposits
	-Alfred Merritt Smith WTF	0.56	0.53	0.60	10	10		
	-River Mountains WTF	0.60	0.54	0.67	10	10		
	Nitrite is not reported							
Denver, CO (2007)	Nitrate	Average: 0.18	Range: 0.04-0.24		MCL (EPA limit): 10	MCLG (EPA goal): 10	N	Erosion of natural deposits
	Nitrite is not reported							

[a] MCL: Maximum contaminant levels, EPA available limit.
[b] MCLG: Maximum contaminant level goal, EPA available limit.
[c] Castskill/Delaware system.
[d] W = indicates water quality monitoring results for the Wilson Plant and OP = indicates water quality monitoring results for the Ozark Point Plant