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Using irradiation to make safe food safer

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Purpose: The meat industry has invested huge sums of money in technology to make food safer. These efforts have been highly successful in many cases. Despite these efforts people are still getting sick and dying from the food they eat. Almost all food safety experts agree that irradiation is one of the most effective technologies available for reducing or eliminating harmful bacteria in most foods. Unfortunately, irradiation is being used on only a small amount of our food supply.

Main findings: The Centers for Disease Control reports that forty-eight million people fall sick every year in the USA from eating food tainted with *Salmonella, Campylobacter, E. coli*, *Vibrio* and other contaminants. In the USA, foodborne infections cause an estimated 76 million cases of illness and 323,000 hospitalizations annually. The economic burden is substantial, estimated at up to $6.7 billion annually in patient-related costs for treatment of bacterial infections alone. Five pathogens account for much of the most severe illness: *Salmonella*, *E. coli* O157 and other Shiga toxin-producing *E. coli*, *Campylobacter*, *Listeria*, and *Toxoplasma*.

The arguments presented by decision-makers opposed to irradiation are similar or identical to issues raised by opponents of pasteurization nearly a century ago. Today, nearly all our milk is pasteurized and foodborne illness from contaminated milk is virtually zero. Pasteurization is a "kill step" and so is irradiation. Today, no retailer would consider marketing unpasteurized milk, yet numerous case studies report that *Salmonella* is very prevalent on poultry and ground beef.

An overwhelming body of scientific evidence demonstrates that irradiation does not harm the nutritional value of food, nor does it make the food unsafe to eat. Just as for the pasteurization of milk, it will be most effective when irradiation is coupled with careful sanitation programs. Consumer confidence will depend on making food clean first, and then using irradiation or pasteurization to make it safe.

Direction for future research: Dr. Robert Tauxe of the US Centers for Disease Control (CDC) has calculated the benefit of irradiation to reduce food borne illness. His conclusion is that if 50% of poultry, ground beef, pork, and processed meats in the US are irradiated and that these foods are the source of 50% of foodborne *E. coli O157, Campylobacter, Salmonella, Listeria* and *Toxoplasma* infections, the potential benefit of the irradiation would be a 25% reduction in the morbidity and mortality rate caused by these infections. Food irradiation is a logical next step to reducing the burden of foodborne disease in the USA.

Key words: food irradiation; foodborne illness; *Salmonella*; *E. coli*; pasteurization

Introduction

Food safety is at the top of every food processor's list of priorities. The public demands safe food and the marketing of an unsafe product is a recipe for disaster. Recalls are expensive, damaging brand image and often resulting in litigation. A foodborne illness outbreak resulting in hospitalization or death is always a serious threat to a company's viability.

We often hear the words "We have the world's safest food supply". The food industry has invested hundreds of millions of dollars in technology to make food safer. Any claim about producing the world's safest food is open to challenge. Forty-eight million people fall sick every year in the USA from eating food tainted with *Salmonella, Campylobacter, E. coli*, *Vibrio* and other contaminants [1].

Let's look at the numbers in the USA, a country that undeniably has one of the world's safest food supplies. The USDA's Food Safety and Inspection Service (FSIS) recently posted the third quarter progress report for the calendar year 2014 on testing of selected raw meat and poultry products for pathogenic bacteria [2].

Salmonella: This report provides preliminary data from July through September 2014 on all establishments eligible for *Salmonella* testing that have completed at least two sampling verification sets since June 2006.

A total of 2,396 samples were analyzed from 171 broiler establishments showing a 4.1 percent positive rate for *Salmonella*, representing an increase from the 3.1 percent positive rate for the second quarter of 2014. For young chickens, large plants showed a 1.5 percent positive rate, small plants had a positive rate of 4.1 percent, and very small plants had a positive rate of 15 percent.

Consumer Reports' recent analysis of more than 300 raw chicken breasts purchased at stores across the USA found potentially harmful bacteria lurking in almost all of the chicken, including organic brands [3].

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For turkeys, the overall *Salmonella* positive rate in the third quarter was 1.9 percent, down from 2.7 percent in the second quarter. Large plants showed a 1.4 percent rate while small plants came in at 2.2 percent in the third quarter. For ground beef, a 3.3 percent *Salmonella* positive rate in the third quarter was comprised of a 5.6 percent rate in large plants, a 3.2 percent rate in small plants and a 2.9 percent rate in very small plants. In the second quarter the ground beef positive rate across all plant sizes was 1.5 percent.

Campylobacter: For young chickens, the third quarter *Campylobacter* positive rate was 6.9 percent, comprised of 1.3 percent in large plants, 7.9 percent in small plants and 28.3 percent in very small plants. In the second quarter, the rate across all plant sizes was 5.1 percent. For turkeys, the *Campylobacter* positive rate was 1.2 percent, comprised of 0.5 percent in large plants and 1.6 percent in small plants. In the second quarter, the rate was 3.4 percent.

Every year the CDC releases a report entitled "Incidence and Trends of Infection with Pathogens Transmitted Commonly Through Food" [4]. Let's compare the numbers for 2014 with those of 2013. The following numbers are actual laboratory confirmed cases, not estimates. *Salmonella* infections were down 9% compared to 2010-2012, but level with that from 2006-2008. The report states that this might be because of the very high number of *Salmonella enteritidis* cases associated with the egg incident in 2010 that put the number of illnesses at its highest over the last ten years.

STEC O157 and STEC non-O157 (*E. coli*) were very similar in frequency for 2014 compared to 2013 (1.15 and 1.17, respectively) and mortality was at 0.4 percent for both years. Hemolytic Uremic Syndrome associated with STEC O157 decreased by 36% compared with 2006-2008, but the actual illness rate did not decline.

Vibrio cases increased for the 8th straight year, and are most prevalent in the warmer months when the bacteria apparently reproduce more rapidly. *Vibrio* is usually associated with raw oysters and is most deadly in older men (who consume too much alcohol). *Vibrio* has nearly devastated the oyster industry but thanks to irradiation the industry will survive. *Vibrio* is the second deadliest bug after *Listeria.*

Each year the food industry invests millions of dollars in technology to eliminate deadly bacteria. The above numbers clearly show that we still have many challenges. My analysis of the numbers is that we are fighting a battle but not winning the war. When we read press releases from various meat associations, we get the idea that great progress is being made, and to some extent this is indeed true. Progress has been made, however, it seems to me that we take a step backward for every step forward. Without a "kill step" there is no net gain! Albert Einstein said "Insanity: doing the same thing over and over again and expecting different results". We can take some lessons from the dairy industry and their reluctance to routinely use pasteurization as a "kill step".

Milk pasteurization: What we need is a "kill step"

The process of heating or boiling milk for health benefits was recognized during the early 1800s and was used to reduce milk borne illness and mortality in infants in the late 1800s. As society industrialized around the turn of the 20th century, increased milk production and consumption led to outbreaks of milk-borne diseases.

Common milk borne illnesses included typhoid fever, scarlet fever, septic sore throat, diphtheria, tuberculosis, and diarrheal diseases. A century ago, milk products caused approximately 1 out of every 4 disease outbreaks due to food or water in the USA [5]. Today, far less than 1% of all food and waterborne illnesses can be traced to dairy products. In fact, dairy products cause the fewest outbreaks of all the major food categories (e.g., beef, eggs, poultry, produce, seafood) [6].This drastic improvement in the safety of milk over the last 100 years is believed to be due primarily to pasteurization, and improved sanitation and temperature control during the processing, handling, shipping and storage of fresh milk products.

Pasteurization was developed by Louis Pasteur in 1864 to improve the keeping qualities of wine. Commercial pasteurization of milk began in the late 1800s in Europe and in the early 1900s in the USA [7]. Pasteurization became mandatory for all milk sold within the city of Chicago in 1908, and in 1947 Michigan became the first state to require that all milk for sale within the state be pasteurized.

In the USA, there were vigorous objections to the widespread heat treatment of milk and the debate continued for many years, although the method was recognized by dairy processors as a way of increasing the shelf life of fluid milk. Early commercial pasteurization of milk was not generally accepted because they were concerned about consumer acceptance, but many companies had secretly adopted the process [8, 9].

Arguments against pasteurization:

- This is little more than an excuse for the sale of contaminated milk.
- Pasteurization will be used to mask low-quality foods. Better controls and inspection are what is needed.
- Pasteurization decreases the nutritional value of milk.
- It leads to formation of harmful products in milk. Possibly dangerous substances could be formed.
- This process will increase the price of the product.
- It is not necessary. We have a direct and prompt food distribution system.

The incidence of milk-borne illness declined dramatically when pasteurization was used to kill bacteria. Today foodborne illness attributed to pasteurized milk is virtually zero. Pasteurization is the "kill step" that made milk safe.

Irradiation is another "kill step"!

The use of high-energy irradiation to kill microbes in food was evaluated in the USA as early as 1921, when scientists at the United States Department of Agriculture reported that it would effectively kill trichinae in pork. Irradiation has become a standard process used to sterilize many consumer and medical products, from adhesive strips to surgical implants. Three different technologies that can be used to treat food have been developed by the sterilization industry: gamma irradiation, electron beam irradiation and x-ray irradiation. Each technology has its own advantages, of which irradiation service providers and some food processors are well aware.

Potential health benefits of irradiating meat and poultry

Dr. Robert Tauxe at the US Centers for Disease Control (CDC) has calculated the benefit that would occur if more meat were irradiated [10]. Here is what Dr. Tauxe said, "We can roughly estimate the potential benefit of irradiating meat and poultry with a simple calculation. Let us assume that 50% of poultry, ground beef, pork, and processed meats are irradiated. Let us also assume that these foods are the source of 50% of food-borne *E. coli O157, Campylobacter, Salmonella, Listeria* and *Toxoplasma* infections. The potential benefit of the irradiation would be a 25% reduction in the morbidity and mortality rate caused by these infections. With this estimate we assume that heavily contaminated meat is just as likely to be treated with irradiation as meat, which is less contaminated. This estimate does not include the impact on other known pathogens these foods may contain, such as *Yersinia enterocolitica* and those yet to be identified. This estimate also does not account for the benefits of using irradiation to treat other foods, such as fresh produce that can also be a source of infection."

Challenges facing the meat industry

Drug resistant strains of *Salmonella* represent a serious challenge to the meat industry [11]. *Salmonella typhimurium* is a drug resistant strain of *Salmonella* that is difficult to treat using most antibiotics. Outbreaks of *S. typhimurium* are becoming frequent and usually involve ground beef and ground turkey.

According to The World Health Organization: "… *Salmonella* strains which are resistant to a range of antimicrobials, including first-choice agents for the treatment of humans, have emerged and are threatening to become a serious public health problem. This resistance results from the use of antimicrobials in humans and animal husbandry. Multi-drug resistance to critically important antimicrobials is compounding the problems."

So what can be done to reduce the risk of drug resistant strains of Salmonella in raw meat and poultry products? The beef industry already employs multiple interventions for controlling *E. coli* O157:H7. Presumably, these are also effective in controlling *Salmonella*. There is, however, one major difference – *Salmonella* may be present in lymph nodes and throughout the lymphatic system [12, 13]. Therefore, there may be an additional vector of contamination different from *E. coli* O157:H7 and other STEC's that are contaminating carcasses during hide removal and evisceration during the slaughter process. Addressing *Salmonella* contamination associated with lymph nodes poses a whole new challenge.

Salmonella is more prevalent in poultry products and its elimination from raw poultry is simply not possible without a kill step such as irradiation. Larger doses of irradiation are required to completely eliminate *Salmonella* in raw meat and poultry products, however at the doses normally used we can achieve more than a 99.9 percent reduction in *Salmonella.*

Irradiated poultry has been available commercially in the past however currently no poultry processor is offering irradiated poultry. Unfortunately, there is a currently a shortage of perishable food irradiation facilities near poultry processing plants.

Why not just cook it?

There are many who say that if consumers used a meat thermometer and learned how to cook, the risk of foodborne illness from contaminated meat would practically disappear. Let's examine this theory in depth.

We know that proper cooking will inactivate strains of bacteria in ground beef and poultry. Education of consumers to reinforce appropriate cooking methods and the use of thermometers to verify cooking temperatures is vitally important in addressing the problem of harmful bacteria in general [14, 15].

"Using thermometers is the only way to really know that your food is thoroughly cooked — that it has reached a temperature to destroy any harmful bacteria that could possibly be there," says Dr. Christine Bruhn, retired director of the Center for Consumer Research at the University of California. However, Bruhn's research has shown that few consumers actually use a thermometer to check the doneness of meat, poultry and seafood, or to check the temperature in their refrigerators. "They might do it on a roast, they might do it on whole chicken," Bruhn says. "They don't do it on the smaller chicken parts, they seldom do it on burgers, and even on steaks they are relying on visual indicators. They're not really verifying the temperature on the inside."

Self-reported use of thermometers has increased from 33 percent in 1998 to 53 percent in 2010. This seems like great progress, but Bruhn warns that people may only use thermometers on large hunks of meat or poultry, such as a pot roast or the Thanksgiving turkey, and not necessarily in everyday cooking. People might also say they use thermometers even though they don't just because they know they're supposed to. According to a survey conducted by the US Food and Drug Administration, 46 percent of participants said they never use a thermometer when cooking chicken parts and 66 percent said they never use one when cooking or grilling hamburgers.

Last year, while studying various aspects of chicken preparation in consumer homes, Bruhn found that only 5 percent of participants used a thermometer without prompting from the researchers, and only about a third agreed to do so when prompted. From there, researchers found that 40 percent of the chicken in the study was undercooked, especially when it was grilled or barbecued.

According to a recent study conducted by RTI International, Tennessee State University and Kansas State University, 62 percent of consumers own a food thermometer, but less than 10 percent of them actually use it to check for doneness in all poultry.

Litigation: the cost of contaminated food

Foodborne illness outbreaks usually result in litigation. Often these cases are settled before a case goes to a jury. One well-known company settled a lawsuit for $1 million out of court. The victim had been paralyzed as a result of an *E. coli* O157:H70 tainted hamburger [16]. Several law firms specialize in foodborne illness litigation including Marler Clark, a Seattle firm that represented victims of the Jack In The Box outbreak in 1993/94 [17].

The firm Marler Clark has represented thousands of victims of *Salmonella* and other foodborne illness outbreaks and has recovered over $600 million for clients. Marler Clark is the only law firm in the nation with a practice focused exclusively on foodborne illness litigation. *Salmonella* lawyers at Marler Clark have litigated *Salmonella* cases stemming from outbreaks traced to a variety of foods, such as cantaloupe, tomatoes, ground turkey, salami, sprouts, cereal, peanut butter, and food served in restaurants. The firm has brought *Salmonella* or *E. coli O157:H7* lawsuits against such companies as Cargill, ConAgra, Peanut Corporation of America, Sheetz, Taco Bell, Subway and Wal-Mart [18].

When is a product defective?

A product is in a defective condition, meaning unreasonably dangerous to the user, when it has a propensity or tendency for causing physical harm beyond that which would be contemplated by the ordinary user, having ordinary knowledge of the product's characteristics commonly known to the foreseeable class of persons who would normally use the product [19]. With regard to the issue of 'legal cause', a defective condition is a legal cause of injury if it directly and in natural and continuous sequence produces or contributes substantially to producing such injury, so that it can reasonably be said that, except for the defective condition, the injury complained of would not have occurred. A defective condition may be a legal cause of damage even though it operates in combination with the act of another, some natural cause, or some other cause if such other cause occurs at the same time as the defective condition and if the defective condition contributes substantially to producing such damage.

Thus, in cases involving allegedly defective, unreasonably dangerous products, the manufacturer may be liable even though you may find that it exercised all reasonable care in the design, manufacture and sale of the product in question. On the other hand, any failure by the manufacturer of a product to adopt the most modern, or even a better safeguard, does not make the manufacturer legally liable to a person injured by that product. The manufacturer is not a guarantor that nobody will get hurt in using its product, and a product is not defective or unreasonably dangerous merely because it is possible to be injured while using it. There is no duty upon the manufacturer to produce a product that is 'accident-proof'. What the manufacturer is required to do is to make a product which is free from defective and unreasonably dangerous conditions. Let the jury decide!

Effect of irradiation on microbes

Except for those within food companies that are having their products irradiated on a routine basis, we haven't heard much about food irradiation over the last decade. All of a sudden, there seems to be a resurgence of press articles and even government approvals related to irradiating food. One food safety expert who formerly was a high-ranking official at FSIS recently said "It's time to take a serious look at irradiation."

The high-energy rays of irradiation directly damage the DNA of living organisms, inducing cross-linkages and other changes that make an organism unable to grow or reproduce. When these rays interact with water molecules in an organism, they generate transient free radicals that can cause additional indirect damage to DNA. An absorbed dose of irradiation energy is now measured in units called Grays, rather than an older measure called a rad. One gray equals 100 rads, and 10 kiloGray (kGy) equal 1 megarad. Complex life forms with large DNA molecules are affected by relatively low doses. Simpler organisms with smaller DNA can take progressively higher doses. Thus, a low dose of less than 1 kGy disinfects insects and parasites and inhibits plants from sprouting; a medium dose, between 1.5 and 4.5 kGy, kills most bacterial pathogens other than spores; and a higher dose of 10-45 kGy will inactivate bacterial spores and some viruses.

The actual dose required to treat food varies with the specific pathogen and the specific circumstances of the food. It generally takes a higher dose to kill the same number of organisms in frozen food than it does to kill them in refrigerated food. A D-dose is the amount of irradiation that it takes to destroy 90% of the organisms or one decimal log. Thus, a one-log kill would reduce a million bacteria to 100,000. To eliminate 99.999% of the bacteria (a so-called 5 logarithm kill) takes 5 times the irradiation dose needed for a 1 log kill and would reduce a million bacteria to ten. For example, it takes 0.2 kGy to reduce *Campylobacter* in meat by one decimal log or 1 kGy to reduce it by 5 decimal logs.

Safety of irradiation

Irradiation has been approved for use on a broad range of foods for different purposes. The use of irradiation on food was formally approved as though it were something added to food, rather than a process to which the food is subjected. This means that for meats and poultry, approval is required from both the FDA and USDA. The effect of irradiation on food itself is usually minimal at doses up to 7.5 kGy. Treated food does not become radioactive at any dose, and, in general, shelf life is prolonged because organisms that cause spoilage are reduced along with pathogens. Irradiation has been used effectively in a wide variety of meats, poultry, seafood, oysters, grains, spices and produce.

Nutritional and other chemical changes induced in food by irradiation have been studied extensively. In general, these changes are limited to modest declines in the quality and amount of a few vitamins, particularly thiamine (vitamin B1), that are not likely to change the overall adequacy of dietary intake, and to production of transient free radical oxidants, which react almost immediately in the food and do not persist. Similar oxidants are also produced by cooking, and, in any event, would be hydrolyzed immediately in the stomach if any were present. It is important to remember that the processes of cooking, such as grilling or frying, themselves induce profound chemical changes in foods, and we depend on these processes to make food edible and tasty.

The safety of consuming irradiated foods has been evaluated in large-scale trials in animals, sometimes for several generations. No ill effects were observed, and, in particular, no teratogenic effects (birth defects) were seen in mice, hamsters, rats or rabbits. Formal feeding trials were also conducted with human volunteers without ill effects, and NASA routinely uses meats irradiated at high doses in the diet of astronauts.

Hundreds of thousands of tons of food have been irradiated and consumed in the past 50 years and there have been no reports of human issues, however hundreds of thousands of people have become ill from eating regular food that has not been irradiated.

Consumer acceptance of irradiated foods

Will the public accept irradiated foods? Recent surveys have been conducted by the Food Marketing Institute and at Food-Net sites on the general population [20]. About 50% of the population is ready to buy irradiated foods, if asked. Acceptance will be greater if irradiated food is not much more expensive than non-irradiated food. The rate of acceptance can increase from 50% up to 80% to 90% if customers understand that irradiation reduces harmful bacteria in food. Similar results have been observed when test marketing irradiated products. Since 2000, irradiated ground beef has been for sale at Wegmans and from Omaha Steaks and Schwan's. The medical and public health communities have responded to this availability with enthusiasm and full support.

There has been strong acceptance of irradiated fresh produce in the USA as well as in New Zealand. The volume of irradiated produce consumed in the USA is approaching 50 million pounds and growing. Consumer acceptance of irradiated produce has been excellent and seldom if ever comes up in a conversation. Since 2000, when irradiated ground beef became available in Minnesota, the volume of irradiated ground beef has been steady with Omaha Steaks, Schwan's and Wegmans as strong proponents of irradiation [20].

The amount of irradiated oysters is rapidly growing due to the increasing prevalence of *Vibrio*, which has nearly shut down oyster production in some parts of the US East Coast. Mississippi-based companies particularly Crystal Seas and Bon Secour are irradiating oysters. Other companies will follow in their footsteps.

References

1 Consumer Reports magazine. February 2014. Dangerous contaminated chicken. Accesses on 15/6/2015.

2 USDA/FSIS, 2006-2014, Salmonella Quarterly Data. Quarterly Progress Reports on Salmonella and Campylobacter Testing of Selected Raw Meat and Poultry Products

3 Consumer Reports. The high cost of cheap chicken. January 2014.

4 US Centers for Disease Control. Incidence and trends of infection with pathogens transmitted commonly through food. Accessed on 15/6/2015 at http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6315a3.htm

5 Weisbecker A. A legal history of raw milk in the United States; published in Journal of Environmental Health; April 2007; pp. 62-63.

6 Leedom J. Comparing the food safety record of pasteurized and raw milk products. www.foodsafetynews.com/Raw milk final.pdf

7 History of pasteurization. http://wn.com/history_of_pasteurization

8 Some objections to pasteurization of milk. Journal of the American Medical Association. December 9, 1905. JAMA. 1905;XLV (24): 1802. Doi: 10.1001/jama.1905.02510240034003

9 Hall & Trout. Milk Pasteurization (1968) and Technology Review. (Dec.1997)

10 Tauxe RV. Food safety and irradiation: protecting the public from foodborne infections. Emerging Infectious Diseases 2001: 7:516-521.

11 Frieden, TR. Director, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services (HHS) Statement on Antibiotic Resistance and the Threat to Public Health before Committee on Energy and Commerce Subcommittee on Health United States House of Representatives; 28/4/2010.

12 Salmonella in cattle lymph nodes: The next food industry crisis accessed at: http://info.abcr.com/Blog/bid/321503/ on 15/6/2015.

13 Salmonella could be the beef industry's new big challenge. http://www.foodsafetynews.com/2013/08/ on 15/6/2015.

14 Bruhn CM. Thermometers crucial for food safety. http://www.foodsafetynews.com/2015/02/thermometers-crucial-for-food-safety.

15 Many U.S. consumers do not use a food thermometer when cooking poultry, despite hazardous risks. Accessed 15/6/2015 at http://www.rti.org/newsroom/news.cfm?obj=8C254104-FADA-642E-EA4A862B4634D02C

16 Stephanie Smith and Cargill Meat Solutions Corporation announce settlement of lawsuit filed by Ms. Smith in December 2009. Accessed on 15/6/2015 at http://www.cargill.com/news/releases/2010/NA3028341.jsp

17 Jack in the Box *E. coli* lawsuits. MarlerClark; http://www.marlerclark.com/case_news/view/jack-in-the-box-e-coli-outbreak-western-states

18 Food Safety in the U.S. – NY Times and Retro Report – PBS Frontline. Accessed at http://www.foodpoisonjournal.com/foodborne-illness-outbreaks/#.VX7sGaYt35I; accessed on July 15, 2015.

19 What is a defective product? Business Directory. http://www.business dictionary.com/definition/defective-product.html

20 Eustice RF and Bruhn CM. Consumer acceptance and marketing of irradiated foods. In: Food Irradiation Research and Technology. Second Edition. Edited by Fan X, Sommers CH (editors). Ames, Iowa, USA: Wiley-Blackwell; 2013 pp. 516-521.