RESEARCH REPORT

PORK SAFETY

Title: Growth of bacteria on pork carcasses and cuts following application of different chilling procedures and after being subjected to temperature abuse during distribution and by consumers.
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I. Abstract

A. This study investigated the responses of *Campylobacter jejuni, Escherichia coli* O157:H7, *Salmonella* spp., *Yersinia enterocolitica* and *Listeria monocytogenes* inoculated on fresh pork products subjected to cold (0°C) storage under vacuum and subsequent aerobic temperature abuse (15.6, 21.1 and 26.7°C for 3 or 6 h), and short-term, limited temperature abuse. Ground pork and pork loin chops samples were inoculated with mixed strain cultures of each organism and held in plastic bags at 0, 3.3, 6.7 or 10°C for 24 and 48 h or vacuum packaged and stored at 0°C for 18 days (ground pork) and 20 days (pork loin chops). Pork in vacuum packages, following storage (0°C), was repackaged into styrofoam trays simulating retail display packages. One set of samples was abused immediately following storage, while another set was held overnight (4.4°C) before temperature abuse. Duplicate samples were analyzed for aerobic plate counts, for total coliform counts and for each pathogen using two selective agar media per pathogen. *Campylobacter jejuni* counts were reduced (0.5-1.5 log CFU/g or cm^2) during vacuum storage at 0°C, while subsequent aerobic abuse counts fluctuated slightly in ground pork and increased (approximately $\leq$1.4 log CFU/cm^2) in pork chops. During short-term, limited temperature abuse, *C. jejuni* showed no major changes or minor reductions in populations, while *L. monocytogenes* showed inconsequential variation in populations. However, in vacuum packaged/retail storage, populations of *L. monocytogenes* tended to increase more in ground pork than in pork chops. Populations of *Salmonella* spp. and *Y. enterocolitica* showed slight increases (0.4-0.8 log CFU/g and 0.1-2.1 log CFU/g, respectively) in ground pork during storage at abusive temperatures, while for pork chops, populations of *Y. enterocolitica* increased 0.5-1.2 log CFU/cm^2. Populations of *E. coli* O157:H7 showed minor fluctuations in pork chops and increased by 0.6-1.4 log CFU/g in ground pork at abusive temperatures. These results further emphasize the importance of minimizing microbial contamination at the production stage as well as maintenance of proper refrigeration temperature during handling, while verifying that temperature abuse may promote proliferation of pathogens and demonstrate also the importance of consumer education in safe food handling practices. Furthermore, the results should be useful in risk assessment studies for enhancement of fresh pork safety.

II. Introduction

A. Although public awareness of food safety issues has increased, consumers continue to abuse their food (McIlveen et al., 1999; Worsfold and Griffith, 1997). Fresh meat may be exposed to improper holding temperatures during transportation, at loading and unloading points, and in coolers that are not

properly operating or insulated. Critical factors affecting the safety and shelf life of fresh pork include initial microbial loads and storage temperatures. Minimizing microbial contamination during product preparation and maintaining proper refrigeration from packing plant to home refrigerator/freezer will help prevent proliferation of pathogenic or spoilage microorganizms.

Cabedo et al. (1997) demonstrated that storage at proper temperature can retard growth or inhibit survival of *E.* coli O157:H7 on beef. Proper refrigeration temperatures extend the lag phase and minimize growth of most spoilage and pathogenic bacteria; however, some microorganisms can grow, albeit slowly, at refrigeration temperatures and mesophilic pathogens can survive under refrigeration and grow during temperature abuse of food (Marth, 1998). Psychrotrophic (growth below 5^{o}C) and mesophilic (growth at 10-45^{o}C) pathogens that can grow during extended refrigeration and temperature abuse, respectively (Marth, 1998) are food-safety concerns.

Major efforts have been made in recent years to enhance the safety of foods such as pork products. A major component of this effort to enhance food safety is development of quantitative risk assessment models (Cassin et al., 1998; Lammerding and Paoli, 1997). Such models are useful in determining risks and applicable critical control points that can be managed through the hazard analysis critical control point (HACCP) system (Buchanan and Whiting, 1998; NACMCF, 1998).

Mishandling and abuse of fresh meat, which can occur at any point in the food chain (e.g., during processing, at supermarkets/restaurants or in the home) may lead to proliferation of meatborne pathogens. Public awareness of food safety issues increased during the last decade (McIlveen et al., 1999), and incidence of foodborne disease continues to increase. Worsfold and Griffith (1997) reported that 40% of consumers subjected food to temperature abuse during transport and storage. Consumer education is a key component of pathogen reduction strategies because a significant number of foodborne illness outbreaks are caused in part by food mishandling practices (Tietjen and Fung, 1995) like inadequate cooking or prolonged cooling or thawing at room temperature. Altekruse et al. (1996) reported that one-third of study respondents reported unsafe food handling practices such as not washing their hands or not taking precautions to prevent cross-contamination from raw meat. Woodburn and Raab (1997) surveyed food preparers and found that only 60% recognized the role of thorough cooking for minimizing foodborne illness risk. Safety and shelflife of meat depend on initial microbial contamination, use of good manufacturing practices, proper packaging and appropriate storage temperature (Podolak et al., 1996; Van Netten et al., 1997). Proper refrigeration, even in vacuum packages, may not prevent growth/survival of pathogens because some are psychrotrophs (Marth, 1998), some are facultative anaerobes and some are microaerophilic.

III. Objectives

A. To examine potential changes in counts of the bacterial pathogens *Campylobacter jejuni/coli, Listeria monocytogenes, Salmonella* spp. and *Yersinia enterocolitica* inoculated onto fresh pork that is managed to

simulate temperature abuse by distributors, retailers or consumers for different lengths of time.

IV. Procedures

A. Pathogen preparation

1. Several strains of each pathogen were combined to use as the inoculum.
    a. *Listeria monocytogenes*: four strains isolated from pork variety meats, as well as LCDC 81861 and Scott A.
    b. *Salmonella*: Group B, *S. enteriditis*, two strains isolated from pork variety meats and four strains isolated from pork carcasses.
    c. *Yersinia*: one strain isolated from pork variety meats and ATCC 51871.
    d. *Campylobacter*: five strains isolated from pork variety meats.
    e. *Escherichia coli* O157:H7: strains ATCC 43895, 43888, 43889, 43890, 51657 and 51658.
2. Tryptic soy broth (10 ml) with 0.6% yeast extract (TSBYE) was inoculated with 0.1 ml of each pathogen strain and incubated at 37^{o}C for 24 h with the exception of *Campylobacter* which was incubated at 42^{o}C in a microaerophilic environment.
3. All strains of each pathogen were mixed together in a sterile container and serially diluted in 9 ml Butterfield's Phosphate Buffer to obtain the desired inoculum level.
4. These inoculi were used to inoculate the products.

B. Stage One: To determine the effects of temperature abuse on pathogen growth characteristics during simulated storage and distribution.

1. Pork center-cut loins and pork trim from several lots were shipped overnight in insulated coolers packed with artificial refrigerant. Cooler temperature was monitored during shipping and any product that underwent temperature abuse during shipping was rejected.
2. Pork loins were cut into 4 cm wide, 8 cm long, 2.5 cm thick chops and placed into individual, sterile stomacher bags. Pork trim was ground in the Colorado State University, Center for Red Meat Safety Meat Laboratory and was divided into 100 g portions in individual, sterile stomacher bags.
3. Each sample was inoculated with approximately 10^{3}- 10^{5} CFU/ml level of each of the pathogens. Each sample was inoculated with one pathogen.
4. After inoculation, bagged samples were divided appropriately among four incubators calibrated at four different temperatures (0, 3.3, 6.7 and 10^{o}C corresponding to 32, 38, 44, and 50^{o}F) and stored there for 24 or 48 h and two samples in each of the three replicates were analyzed immediately. All analyses were performed according to the prescribed procedures (see enumeration procedures below).

C. Stage Two: To determine the effects of temperature abuse following purchase at retail by consumers on pathogen growth characteristics

1. Pork center-cut loins and pork trim from several lots were shipped overnight in insulated coolers packed with artificial refrigerant. Cooler temperature was monitored during shipping and any product that underwent temperature abuse during shipping was rejected.
2. Pork loins were cut into 4 cm wide, 8 cm long, 2.5 cm thick chops and placed into individual, sterile stomacher bags. Pork trim was ground in the Colorado State University, Center for Red Meat Safety Meat Laboratory and was divided into 100 g portions in individual, sterile stomacher bags.
3. Each sample was inoculated with approximately 10^3- 10^5 CFU/ml level of each of the pathogens. Each sample was inoculated with one pathogen.
4. After inoculation, each sample was individually vacuum packaged and stored at 0^{o}C for 18 days for ground samples or 20 days for chop samples.
5. After storage, each sample was placed on a styrofoam retail tray and over-wrapped with polyvinyl chloride film. Half of these samples were placed in a 4^{o}C incubator for 24 h to simulate retail display and then divided between three incubators calibrated at three temperatures (15.6, 21.1 and 26.7^{o}C corresponding to 60,70 and 80^{o}F) and stored there for 3 or 6 h to simulate consumer handling. The other half of the samples were divided between three incubators calibrated at three temperatures (15.6, 21.1 and 26.7^{o}C corresponding to 60, 70 and 80^{o}F) for 3 and 6 h and one sample per replicate was analyzed immediately. All analyses were performed according to the prescribed procedures (see enumeration procedures below).

D. Enumeration procedures

1. General sample preparation for chops
    a. A total of 100 g of Butterfield's Phosphate Buffer was added to each sample and the samples were shaken in a 30 cm arc 30 times.
    b. Each sample was appropriately diluted in 9 ml Butterfield's Phosphate Buffer.
    c. Each sample was plated on the appropriate media by depositing 0.1 ml of three consecutive dilutions on duplicate plates and spreading the sample with a sterile, bent glass rod. Plates were then inverted and incubated at the temperature appropriate for the organism.
    d. To calculate the final result (CFU/cm^2): colony count x dilution x 100 ml (initial buffer volume added)/64 cm^2 (surface area of pork chop).
2. General sample preparation for ground pork

a. A total of 100 g of Butterfield's Phosphate Buffer was added to each sample and the samples were stomached for 2 min.
b. 10 g of each sample was transferred into 40 ml of sterile Butterfield's Phosphate Buffer and stomached for 2 min for the initial 1:10 dilution. This emulsion was appropriately diluted in 9 ml Butterfield's Phosphate Buffer.
c. Each sample was plated on the appropriate media by depositing 0.1 ml of three consecutive dilutions on duplicate plates and spreading the sample with a sterile, bent glass rod. Plates were then inverted and incubated at the temperature appropriate for the organism.
d. To calculate the final result (CFU/g): colony count x dilution.

3. *Listeria monocytogenes*
   a. Each sample was plated on tryptic soy agar (TSA)-nonselective; PALCAM agar and Modified Oxford medium (MOX) – selective; MRS agar – lactic acid bacteria count; and TCC Petrifilm™.
   b. All plates except Petrifilm™ were incubated at 25°C for 48 ± 2 h. Petrifilm™ were incubated at 37°C for 24 h.
   c. After incubation, plates were observed for typical *L. monocytogenes* colonies. Typical colonies on PALCAM were grayish white with ß-hemolysis surrounding the colony, whereas typical colonies on MOX were small, white colonies with a black halo.
4. *Salmonella* spp.
   a. Each sample was plated on tryptic soy agar (TSA)-nonselective; hektoen enteric agar (HEK) and xylose lysine Tergitol-4 agar (XLT4) – selective; MRS agar – lactic acid bacteria count; and TCC Petrifilm™.
   b. Selective agar plates were incubated at 37°C for 48 ± 2 h, Petrifilm™ at 37°C for 24 ± 2 h, and TSA and MRS agar plates were incubated at 25°C for 48 ± 2 h
   c. After incubation, plates were observed for typical *Salmonella* colonies. Typical colonies on HEK were blue-green to green colonies with or without black centers, whereas typical colonies on XLT4 were yellow to red colonies with black centers.
5. *Yersinia enterocolitica*
   a. Each sample was plated on tryptic soy agar (TSA)-nonselective; MacConkey agar (MAC) and Yersinia selective agar (CIN) – selective; MRS agar – lactic acid bacteria count; and TCC Petrifilm™.
   b. All plates except MAC and Petrifilm™ were incubated at 25°C for 48 ± 2 h, MAC plates and Petrifilm™ were incubated at 25°C for 24 ± 2 h.

c. After incubation, plates were observed for typical *Y. enterocolitica* colonies. Typical colonies on MAC are small (1-2 mm diameter), flat, colorless, or pale pink colonies, whereas typical colonies on CIN are colorless with dark pink or red centers; bile precipitate may be present.

6. *Campylobacter jejuni/coli*
   a. Each sample was plated on tryptic soy agar (TSA)-nonselective; Brucella agar (BA) and Modified Campylobacter Charcoal Differential Blood-free agar (MCCDA) – selective; MRS agar – lactic acid bacteria count; and TCC Petrifilm™.
   b. Selective agar plates were incubated in a microaerophilic environment at 42°C for 24 ± 2 h, Petrifilm™ at 37°C for 24 ± 2 h and all other plates at 25°C for 48 ± 2 h.
   c. After incubation, the plates were observed for typical *C. jejuni/coli* colonies. Typical colonies on BA were white, irregular colonies with a green halo, whereas typical colonies on MCCDA were round to irregular with smooth edges possibly showing translucent white growth to spreading, film-like transparent growth.
7. *Escherichia coli* O157:H7
   a. Each sample was plated on tryptic soy agar (TSA)-nonselective; MacConkey Sorbitol agar (SMAC) – selective; MRS agar – lactic acid bacteria count; and TCC Petrifilm™.
   b. SMAC and Petrifilm™ were incubated at 37°C for 24 ± 2 h, and all other plates were incubated at 25°C for 24 ± 2 h.
   c. After incubation, the plates were observed for typical *E. coli* O157:H7 colonies. Typical colonies on SMAC were colorless or white.

V. Results

A. Stage One: Bacterial populations on inoculated pork chops (Table 1) remained relatively constant during storage at 3.3, 6.7 or 10°C for 24 or 48 h, with the exception of populations on chops inoculated with *Salmonella* and stored for 48 h at 10°C (increase of 0.6 log CFU/cm^2) and those inoculated with *Y. enterocolitica* stored for 48 h at 6.7°C (increase of 1.1 log CFU/cm^2) or 10°C (increase of 0.5 log CFU/cm^2). Storage of inoculated ground pork for 24 h at all temperatures allowed increases from 1.3 to 2.6 log CFU/g in counts in samples inoculated with *C. jejuni* but lesser increases (0.4-1.0 log CFU/g) at 48 h (Table 2). Counts in ground pork inoculated with *Y. enterocolitica* increased (0.9 log CFU/g at 6.7°C for 24 h, 1.6 log CFU/g at 6.7°C for 48 h, 1.1 log CFU/g at 10°C for 24 h and 2.1 log CFU/g at 10°C for 48 h) in response to mild temperature abuse, while counts in ground pork inoculated with *L. monocytogenes* and *Salmonella* remained relatively constant in spite of the mild temperature abuse. Counts in ground pork inoculated with *E. coli* O157:H7 increased (especially at 48 h) when stored at 3.3 – 10°C, but this may reflect growth

of non-*E. coli* sorbitol negative bacteria. Pathogen survival and growth at 3 – 10°C was greater in ground pork (perhaps because bacteria were dispersed throughout the product) than on pork chops (where bacteria would be present only on the product surface); counts increased by 1.0 log CFU/g or more in 11 of 30 comparisons for ground pork but in only 1 of 30 comparisons for pork chops, in response to mild temperature abuse.

B. Stage Two: At 20 d storage at 0°C, counts (Table 3) on chops inoculated with *C. jejuni* or *L. monocytogenes* declined by 0.8 and 0.7 log CFU/cm^2, respectively, while chops inoculated with *E. coli* O157:H7, *Salmonella,* or *Y. enterocolitica* showed no substantial changes (0-0.4 log CFU/cm^2). Storage (20 d at 0°C), temperature/time abuse (3 or 6 h at 15.6 – 26.7°C) and simulated display (24 h at 4.4°C) did not increase counts by 1.0 log CFU/cm^2 or more in any of the treatment groups for chops inoculated with *C. jejuni, E. coli* O157:H7, *L. monocytogenes* or *Salmonella* and in 5 of 6 treatment groups for chops inoculated with *Y. enterocolitica* (the exception was an increase of 1.3 log CFU/cm^2 for chops held 3 h at 21.1°C). Storage (20 d at 0°C), temperature/time abuse (3 or 6 h at 15.6 – 26.7°C) and simulated display (24 h at 4.4°C) did not increase counts by 1.0 log CFU/cm^2 or more in any of the treatment groups for chops inoculated with *C. jejuni, E. coli* O157:H7, *L. monocytogenes* or *Salmonella* and in 4 of 6 treatment groups for chops inoculated with *Y. enterocolitica* (the exceptions were increases of 1.8 and 2.3 log CFU/cm^2 for chops held 3 h at 15.6°C or 3 h at 26.7°C, respectively). At 18 d storage at 0°C, counts (Table 4) in ground pork inoculated with *C. jejuni, E. coli* O157:H7, *L. monocytogenes* or *Salmonella* declined by 0.5 to 0.9 log CFU/g while counts in ground pork inoculated with *Y. enterocolitica* increased by 1.1 log CFU/g. Storage (18 d at 0°C) and temperature/time abuse (3 or 6 h at 15.6 – 26.7°C) with no simulated display: (a) did not increase counts by 1.0 log CFU/cm^2 or more in any of the treatment groups for chops inoculated with *C. jejuni, E. coli* O157:H7, or *L. monocytogenes*; (b) generated decreases in counts of 0.5 to 1.0 log CFU/cm^2 or more in 6 of 6 treatment groups for chops inoculated with *Y. enterocolitica*. Storage (18 d at 0°C), temperature/time abuse (3 or 6 h at 15.6 – 26.7°C) and simulated display (24 h at 4.4°C): (a) decreased counts by 1.0 log CFU/cm^2 or more on chops in 3 of 6 treatment groups for chops inoculated with *C. jejuni* and in 1 of 6 treatment groups for chops inoculated with *Salmonella*; (b) did not increase counts by 1.0 log CFU/cm^2 of more in any of the treatment groups for chops inoculated with *E. coli* O157:H7, *L. monocytogenes*, or *Y. enterocolitica*.

C. Mild temperature abuse (up to 7-10°C for as long as 24-48 h) resulted in increased pathogen populations confirming the need to minimize exposure of pork products to microbial contamination during product preparation and maintenance of proper refrigeration temperatures during transportation and storage of fresh pork as well as education of consumers with respect to safe food handling practices. The results of this study should be useful in the development of quantitative risk

assessment models which are needed for more targeted control of hazards to improve food safety.

D. Please see attached thesis for additional results and conclusions.

VI. Current abstracts, presentations, papers derived from this study.

A. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos, and G.C. Smith. 2000. Changes in pathogenic bacteria counts during limited abuse of fresh pork. International Congress of Meat Science and Technology, Buenos Aires, Argentina.

B. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos, and G.C. Smith. 2000. Bacteria pathogen changes in fresh pork after storage and consumer abuse. International Congress of Meat Science and Technology, Buenos Aires, Argentina.

C. Segomelo, K. 2000. M.S. Thesis, Department of Animal Sciences, Colorado State University, Fort Collins, Colorado.

D. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos, and G.C. Smith. 2000. Changes in inoculated bacterial pathogens on fresh pork stored at temperatures to simulate mild distribution abuse. Department of Animal Sciences Research Report, Colorado State University, Fort Collins, Colorado.

E. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos and G.C. Smith. 2000. Pathogenic bacteria populations in inoculated fresh pork after chilled storage and simulated consumer abuse. Department of Animal Sciences Research Report, Colorado State University, Fort Collins, Colorado.

F. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos, and G.C. Smith. 2000. Fate of bacterial pathogens inoculated on fresh pork during simulated temperature abuse at distribution. Poster presented at International Association of Food Protection Annual Meeting, August 8, 2000, Atlanta, Georgia.

G. Segomelo, K., M.L. Kain, K.E. Belk, G.R. Bellinger, J.A. Scanga, J.N. Sofos, and G.C. Smith. 2000. Population changes of pathogenic bacteria inoculated in fresh pork following chilled storage and simulated consumer temperature abuse. Poster presented at International Association of Food Protection Annual Meeting, August 8, 2000, Atlanta, Georgia.

H. Belk, K.E. Growth of bacteria on pork carcasses and cuts following application of different chilling procedures and after being subjected to temperature abuse during distribution and by consumers. Proceedings of the National Pork Producers Council Conference, Des Moines, Iowa.

Table 1: Mean (log CFU/cm^2/SD) bacterial counts on pork chops inoculated with *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. or *Yersinia enterocolitica* and plated on selective agar media during aerobic storage at 0, 3.3, 6.7 or 10^{o}C for 24 or 48 h.

			Bacterial Counts [log CFU/cm^2 (SD)]				
Temperature (^{o}C)	Time (h)	N	*Campylobacter jejuni* (MCCDA)	*Escherichia coli* O157:H7 (SMAC)	*Listeria monocytogenes* (PALCAM)	*Salmonella* (XLT4)	*Yersinia enterocolitica* (CIN)
(-)	0	6	4.6 (0.9)	5.3 (0.4)	4.9 (0.1)	5.1 (0.4)	4.9 (0.1)
0	24	6	4.5 (1.4)	5.2 (0.4)	4.6 (0.4)	4.6 (0.3)	4.4 (0.6)
	48	6	4.3 (1.7)	5.3 (0.0)	4.8 (0.1)	5.2 (0.6)	4.5 (0.2)
3.3	24	6	3.9 (1.8)	5.1 (0.3)	4.8 (0.2)	4.6 (0.3)	4.7 (0.4)
	48	6	4.5 (1.4)	4.9 (0.8)	4.8 (0.1)	4.7 (0.6)	4.9 (0.5)
6.7	24	6	5.2 (0.3)	5.2 (0.5)	5.0 (0.2)	4.6 (0.6)	4.5 (0.4)
	48	6	4.9 (0.6)	5.3 (0.4)	4.7 (0.4)	4.9 (0.5)	6.0 (0.6)
10	24	6	5.1 (0.2)	5.6 (0.3)	4.9 (0.1)	4.9 (0.4)	5.0 (0.7)
	48	6	4.4 (1.2)	5.6 (0.5)	5.0 (0.3)	5.7 (0.5)	5.4 (0.8)

MCCDA = Modified Campylobacter Charcoal Differential Agar; SMAC = Sorbitol MacConkey Agar; XLT4 = Xylose Lysine Tergitol 4 Agar; CIN = Yersinia Selective Agar.

Table 2: Mean (log CFU/cm^2/SD) bacterial counts in ground pork inoculated with *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. or *Yersinia enterocolitica* and plated on selective agar media during aerobic storage at 0, 3.3, 6.7 or 10^{o}C for 24 or 48 h.

			Bacterial Counts [log CFU/cm^2 (SD)]				
Temperature (^{o}C)	Time (h)	N	*Campylobacter jejuni* (MCCDA)	*Escherichia coli* O157:H7 (SMAC)	*Listeria monocytogenes* (PALCAM)	*Salmonella* (XLT4)	*Yersinia enterocolitica* (CIN)
(-)	0	6	2.1 (1.8)	5.9 (1.4)	4.4 (0.6)	4.0 (0.7)	4.1 (0.6)
0	24	6	4.4 (0.3)	6.2 (1.3)	4.4 (0.8)	3.9 (0.7)	4.3 (1.1)
	48	6	2.5 (1.2)	6.3 (1.2)	4.5 (0.8)	4.0 (0.7)	4.6 (0.5)
3.3	24	6	4.4 (0.4)	6.3 (1.3)	4.6 (0.7)	4.0 (0.7)	4.8 (1.1)
	48	6	2.5 (1.4)	6.7 (0.9)	4.3 (0.9)	4.0 (0.9)	5.3 (0.4)
6.7	24	6	3.4 (2.0)	6.6 (1.1)	4.5 (0.6)	4.1 (0.5)	5.0 (0.7)
	48	6	3.1 (1.4)	7.2 (1.2)	4.2 (1.1)	4.2 (0.8)	5.7 (0.7)
10	24	6	4.7 (0.7)	6.5 (1.5)	4.7 (0.4)	4.6 (0.4)	5.2 (1.0)
	48	6	2.6 (1.9)	7.0 (1.0)	4.3 (1.1)	4.3 (0.4)	6.2 (0.6)

MCCDA = Modified Campylobacter Charcoal Differential Agar; SMAC = Sorbitol MacConkey Agar; XLT4 = Xylose Lysine Tergitol 4 Agar; CIN = Yersinia Selective Agar.

Table 3: Mean (log CFU/cm^2/SD) bacterial counts by plating samples of pork chops inoculated with *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. or *Yersinia enterocolitica* and subjected to aerobic temperature abuse (15.6, 21.1 or 26.7^{o}C) for 3 or 6 h following 20 days of vacuum storage at 0^{o}C and display at 4.4^{o}C for 0 or 24 h.

				Bacterial Counts [log CFU/cm^2 (SD)]				
Simulated display (h at 4.4^{o}C)	Abusive temperature (^{o}C) and time (h)		N	*Campylobacter jejuni* (MCCDA)	*Escherichia coli* O157:H7 (SMAC)	*Listeria monocytogenes* (PALCAM)	*Salmonella* (XLT4)	*Yersinia enterocolitica* (CIN)
(-)	(-)	0	6	4.1 (1.8)	5.0 (1.1)	5.1 (0.1)	4.5 (1.2)	4.5 (0.4)
0	(-)	0	3	3.3 (2.1)	5.2 (0.2)	4.4 (0.3)	4.5 (0.4)	4.9 (0.8)
0	15.6	3	3	2.2 (2.3)	4.7 (0.3)	4.5 (0.3)	4.7 (0.4)	4.0 (0.3)
0	15.6	6	3	4.4 (0.4)	5.4 (0.9)	4.6 (0.6)	4.7 (0.1)	5.0 (1.5)
0	21.1	3	3	3.4 (2.2)	4.7 (0.5)	4.2 (0.4)	4.5 (0.3)	5.8 (1.6)
0	21.1	6	3	4.5 (0.3)	5.1 (0.6)	4.9 (1.4)	4.7 (0.3)	4.3 (1.0)
0	26.7	3	3	3.4 (2.2)	4.8 (0.1)	4.7 (1.2)	4.4 (0.1)	5.3 (1.3)
0	26.7	6	3	4.3 (0.3)	5.2 (0.4)	4.4 (1.3)	4.7 (0.6)	5.1 (0.5)
24	(-)	0	3	3.6 (2.4)	4.8 (0.2)	4.1 (0.4)	4.3 (0.2)	4.5 (2.2)
24	15.6	3	3	4.4 (0.4)	5.6 (0.8)	5.1 (1.3)	4.7 (0.7)	6.3 (0.6)
24	15.6	6	3	4.2 (0.3)	5.0 (0.6)	4.2 (0.2)	3.6 (0.7)	4.6 (0.6)
24	21.1	3	3	4.4 (0.3)	4.8 (0.1)	4.7 (1.0)	4.4 (0.2)	4.4 (1.1)
24	21.1	6	3	4.3 (0.3)	5.0 (0.5)	5.1 (1.5)	4.3 (0.6)	4.5 (2.0)
24	26.7	3	3	4.5 (0.2)	5.1 (0.5)	4.5 (0.8)	4.5 (0.9)	6.8 (1.4)
24	26.7	6	3	4.6 (0.4)	5.4 (1.0)	5.1 (1.2)	4.0 (0.4)	4.9 (1.7)

MCCDA = Modified Campylobacter Charcoal Differential Agar; SMAC = Sorbitol MacConkey Agar; XLT4 = Xylose Lysine Tergitol 4 Agar; CIN = Yersinia Selective Agar.

Table 4: Mean (log CFU/cm^2/SD) bacterial counts by plating samples of ground pork inoculated with *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. or *Yersinia enterocolitica* and subjected to aerobic temperature abuse (15.6, 21.1 or 26.7°C) for 3 or 6 h following 18 days of vacuum storage at 0°C and display at 4.4°C for 0 or 24 h.

				Bacterial Counts [log CFU/cm^2 (SD)]				
Simulated display (h at 4.4°C)	Abusive temperature (°C) and time (h)		N	*Campylobacter jejuni* (MCCDA)	*Escherichia coli* O157:H7 (SMAC)	*Listeria monocytogenes* (PALCAM)	*Salmonella* (XLT4)	*Yersinia enterocolitica* (CIN)
(-)	(-)	0	6	5.1 (0.3)	4.8 (0.5)	4.8 (0.8)	4.6 (0.6)	4.4 (0.6)
0	(-)	0	3	4.5 (0.3)	4.2 (0.4)	4.3 (0.7)	3.7 (0.5)	5.5 (1.1)
0	15.6	3	3	4.6 (0.4)	4.6 (1.0)	4.4 (0.8)	3.7 (0.7)	5.3 (1.4)
0	15.6	6	3	4.0 (0.9)	4.4 (0.8)	4.6 (1.0)	3.6 (0.5)	5.5 (1.0)
0	21.1	3	3	4.6 (0.5)	4.5 (0.9)	4.4 (1.0)	3.9 (0.4)	5.5 (1.0)
0	21.1	6	3	3.9 (0.8)	4.5 (0.6)	4.6 (1.0)	3.7 (0.5)	5.7 (1.1)
0	26.7	3	3	4.4 (0.3)	4.6 (1.1)	5.0 (1.2)	3.8 (0.6)	5.4 (1.4)
0	26.7	6	3	3.9 (1.4)	4.9 (0.9)	4.8 (1.2)	4.1 (0.6)	6.1 (1.1)
24	(-)	0	3	3.1 (1.8)	4.2 (0.5)	4.7 (1.1)	3.8 (0.5)	5.7 (1.1)
24	15.6	3	3	4.0 (1.3)	4.9 (0.9)	4.8 (0.4)	3.9 (0.6)	5.8 (0.8)
24	15.6	6	3	4.7 (0.5)	4.8 (1.2)	4.7 (0.9)	3.6 (0.6)	5.9 (0.5)
24	21.1	3	3	4.5 (0.1)	4.6 (0.8)	4.9 (1.3)	3.8 (0.5)	5.6 (1.0)
24	21.1	6	3	4.1 (0.4)	5.4 (1.0)	5.3 (0.7)	3.8 (0.6)	6.3 (0.7)
24	26.7	3	3	4.5 (0.6)	5.3 (0.6)	5.1 (0.6)	3.8 (0.4)	5.9 (0.9)
24	26.7	6	3	3.7 (0.6)	5.6 (0.8)	5.5 (0.7)	4.3 (0.9)	6.5 (0.5)

MCCDA = Modified Campylobacter Charcoal Differential Agar; SMAC = Sorbitol MacConkey Agar; XLT4 = Xylose Lysine Tergitol 4 Agar; CIN = Yersinia Selective Agar.

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