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A preliminary investigation on the effects of a hot water-shrink tunnel and chill tank following vacuum packaging on commercial pork quality and bacteria growth

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Abstract

This research focused on establishing the effects of a hot water-shrink tunnel and chill tank following vacuum packaging on pork quality and bacteria growth. These preliminary results showed advantages in water-holding capacity (as assessed with purge loss), yet minimal effects on bacterial growth of pork products when using a hot water-shrink tunnel and chill tank following vacuum packaging.

Keywords: pork quality; packaging; chill tank; shrink tunnel; meat safety

For Review Only

INTRODUCTION

Assurance of quality and food safety are great concerns to the pork industry, particularly in a competitive and quality-driven marketplace, such as the export marketplace. The Canadian pork industry relies on a strong export marketplace and currently exports over two times the amount of pork that is domestically consumed on a yearly basis (Agriculture and Agri-Food Canada, 2017). Many interventions play key roles during pork production and processing to ensure food safety and quality are consistently maintained at a high level. One area that has readily accepted and adopted new technologies is packaging. Vacuum packaging techniques have been established to maintain the safety and quality of pork products during extended storage periods at refrigeration temperatures (Jeremiah et al., 1995; Cayuela et al., 2004; Yingyuad et al., 2006). Innovative procedures are often used to accompany vacuum processing, two of which with significance in the commercial setting are the use of a hot water-shrink tunnel and chill tank. While implemented in the commercial industry, there remains no research publically available on the effects and the magnitude of these effects on pork quality with the use of hot water-shrink tunnel and chill tank following vacuum packaging. It was hypothesized the use of a hot water-shrink tunnel and chill tank following vacuum packaging would improve pork quality (namely purge loss, color, and firmness of fresh pork products) and help control bacteria growth associated with extended periods of storage up to 28 days at refrigerated temperatures. Thus, the objective of this research was to analyze the effect of a hot water-shrink tunnel and chill tank following vacuum packaging on pork quality and bacteria growth when evaluated in three pork products (loin, tenderloin, and shoulder butts).

MATERIALS AND METHODS

Sample Collection

Three subprimal pork products – pork loin (whole, boneless; NAMP #413), pork tenderloin (NAMP #415), and pork shoulder butt (cellar trimmed; NAMP#407) were collected in a commercial pork plant and evaluated for this study (NAMP, 2014). For each product, 4 packages were selected for each treatment for a given replication (4 total replications). Each package contained one entire product, with the exception of the tenderloins, which contained 2 entire products, yet one tenderloin in each package was randomly selected for all safety and quality analyses. Products were randomly selected from the commercial pork fabrication line and were 24-h to 48-h postmortem when collected. While the products were selected at random, products for each replication were collected at the same time, which would reduce variability associated with day of manufacture. The first treatment group was vacuum packaged in Cryovac shrink vacuum bags (Sealed Air Corporation, Charlotte, NC, USA) and sent through the hot water-shrink tunnel (manufactured by Cryovac Inc.; Elmwood Park, New Jersey, USA) and chill tank (manufactured by CMP Charlottetown Metal Products; Charlottetown, Prince Edward Island, Canada). The product was sent to the shrink tunnel with a hot water bath system at 84°C for approximately 10 seconds to shrink the packaging to the product. After this step, products were sent to the chill tank for 2.5 min at 0.4°C in order for the product to be chilled rapidly. Both of these technologies were assessed using existing equipment in the commercial pork facility where this study was conducted. Immediately following this process, samples were collected and packaged in boxes containing four pieces of each product (loins, tenderloins, and shoulder butts). The second treatment group was vacuum packaged in the same Cryovac shrink vacuum bags (Sealed Air Corporation, Charlotte, NC, USA) as used in the first treatment group and boxed

without passing through the hot water-shrink tunnel and chill tank. The same number of products as in the first treatment group were placed in a refrigerated room for designated storage periods of 7-d, 14-d, 21-d, and 28-d. The room temperature was recorded on a weekly basis with temperatures between -2°C and 2°C.

Analysis of Safety and Quality

Samples (one package of each product per box stored for each replication) were collected and evaluated for quality and bacteria colony count at 7-d, 14-d, 21-d, and 28-d after packaging. Visual color scores (1 = pale pinkish gray to white, 2 = grayish pink, 3 = reddish pink, 4 = dark reddish pink, 5 = purplish red, 6 = dark purplish red; National Pork Producers Council, NPPC, 1999), marbling (1 through 10 corresponding to intramuscular lipid content, National Pork Producers Council, NPPC, 1999) and firmness (1 = soft, surface distorts easily, 2 = firm, surface tends to hold shape, 3 = very firm, surface was very smooth with no distortion of shape; National Pork Producers Council, NPPC, 1999) were assessed by trained personnel on each product and recorded in whole numbers. Color, marbling, firmness was measured along the ventral side of the loins, the dorsal side (non-silver skin side) of the tenderloins, and lean side of the shoulder butts. pH was obtained by inserting a portable meat pH meter (Hanna Instruments; Laval, Quebec, Canada) into each of the products at a common location throughout the study (midpoint of the ventral side of the loins, midpoint of the dorsal side of the tenderloins, and the center point of the lean side of the shoulder butts). The pH meter was calibrated at 4°C after test buffer solutions were stored at 4°C and meat temperature was tested prior to evaluation and the pH meter was adjusted accordingly. Off-odor of the raw meat samples was observed by study personnel; however, no rancid or pungent odors were detected. Weight of packaged products, non-packaged products, and packaging were measured and purge loss was calculated as the

difference in weights of the products after subtracting the weight of the packaging from the packaged products.

All tools used to collect samples were washed and sanitized (dipped in methyl alcohol, and dried with a portable propane burner) before use and between use for bacteria testing. A 15 to 25 g cube of each sample was collected for the preparation of the dilution used for bacteria testing. Dilutions were prepared with buffered peptone water (Biokar Diagnostics; Beauvais, France), which contained the 10 g peptone, 5 g sodium chloride, 3.56 g disodium phosphate, and 1.50 g monopotassium phosphate per liter of media. A dilumat machine (Dilumat 3 MK2; AES Laboratories, Marcy-l'Étoile, France) and a stomacher (Easymix; AES Laboratories) were used to prepare a dilution of the samples. Plated dilutions were at a ratio of 1:10 for total coliform colony count and at 1:1000 for total aerobic colony count. This homogenized dilution was plated to determine total coliform count and total aerobic count using 3M bacteria Petrifilms (3M; St. Paul, Minnesota, USA). The total coliform count was determined according to a slightly modified version of the AOAC International method 990.12 (AOAC, 2005a) and the total aerobic count was determined according to a slightly modified version of the AOAC International method 991.14 (AOAC, 2005b). After 24 and 48 h of incubation at 37°C in a Thermo Scientific Heratherm Incubator (Thermo Fisher Scientific Inc., Göteborg, Sweden), testing was conducted for total coliform colony counts and total aerobic colony counts, respectively. Bacteria count was expressed as a $\log_{10}$ transformation according to instructions from the manufacturer of the Petrifilms.

Data Analysis

The study was replicated in its entirety four times. All the information collected was analyzed with the MIXED procedure of SAS as repeated measures over time to account for

storage day with fixed effects of treatment, day, and their interaction. Least square means were separated using a probability of difference (PDIF) statement in the MIXED procedure of SAS. Statistical differences were detected for treatment effects at individual days of storage using the slice option. The same statistical model was used for each of the three products (pork loin, pork tenderloin, and pork shoulder butt) evaluated. Normality of residuals were tested using the UNIVARIATE procedure of SAS. Effects were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Loin Quality

Loin quality parameters (Table 1) are within the range of parameters previously reported for commercial pork (Arkfeld et al., 2016). Loin quality parameters were not different ($P > 0.13$) among treatment (shrink tunnel vs. control), with the exception of purge loss. There was not a significant interaction ($P = 0.67$) between treatment and storage time for purge loss. There was a significant main effect ($P = 0.03$) of treatment for purge loss, with loins treated with the shrink tunnel and chill tank having less purge loss. As expected there was an effect of storage day on purge loss ($P = 0.01$), with greater purge loss present after 21 and 28 days of storage when compared with after 7 and 14 days of storage. Huff-Lonergan and Lonergan (2005) described the mechanisms associated with water-holding capacity of meat, and as the storage time of meat is extended – greater degradation of cytoskeletal proteins by proteinases plays a role in water-holding capacity and the loss of purge. Total aerobic bacteria count was not different ($P = 0.61$) with or without the use of the shrink tunnel and chill tank. Blixt and Borch (2002) evaluated shelf life of vacuum-packaged pork and reported total aerobic bacteria count was greater after 3 and 4 weeks of storage when compared to after 1 or 2 weeks of storage. Yet, in the current

study, there was not an effect of storage time for total aerobic bacteria count. For the majority of samples collected (all but two samples), there were non-detectable levels of total coliform bacteria present.

Tenderloin Quality

Tenderloin quality parameters was reported in Table 2. Tenderloin quality parameters were not different ($P > 0.09$) among treatment (shrink tunnel and chill tank) for any parameters measured in this study. There was a main effect of storage day ($P = 0.04$) on purge loss, with greater ($P < 0.04$) purge loss in tenderloins after 28 days of storage when compared with after 7, 14, and 21 days of storage. Total aerobic bacteria count was not different ($P = 0.85$) with or without the use of the shrink tunnel and chill tank, on any of the different storage days evaluated ($P = 0.12$), or for the interaction of treatment and storage day ($P = 0.72$). For all the samples collected in this study, there were non-detectable levels of total coliform bacteria present. Limited research is available characterizing the quality and effect of storage on tenderloin quality and bacteria count; to date this is the only study to provide this information. Further research is warranted to set the baseline levels of quality of the pork tenderloin.

Shoulder Butt Quality

Shoulder butt quality parameters reported (Table 3) are within the range of parameters previously reported for commercial pork (Tavárez et al., 2012). Shoulder butt quality parameters were not different ($P > 0.18$) among treatment (shrink tunnel and chill tank) for any parameters measured in this study. There was an interaction between treatment and storage day ($P = 0.05$) for color; as shoulder butt tended to become darker with extended storage when no shrink tunnel or chill tank was used, and shoulder butts tended to become lighter with extended storage when shrink tunnel and chill tank was used. There was an effect of storage day ($P = 0.04$) on purge

loss, with greater ($P < 0.03$) purge loss in shoulder butts after 28 days of storage when compared with after 7, and 14 days of storage. Total aerobic bacteria count was not different ($P = 0.68$) with or without the use of the shrink tunnel and chill tank, on any of the different storage days evaluated ($P = 0.23$), or for the interaction of treatment and storage day ($P = 0.84$). For the majority of samples collected in this study (all but one sample), there were non-detectable levels of total coliform bacteria present. Limited research is available characterizing the quality and effect of storage on shoulder butt quality and bacteria count. Further research is warranted to set the baseline levels of quality for the pork shoulder butts.

Conclusions

The current study has shown the effects of utilizing a hot water-shrink tunnel and chill tank system following vacuum packaging for three popular products in the commercial pork industry. The advantages observed in this study were improvement in water-holding capacity of meat products stored for extended periods of time (greater than 21 days after packaging). The results of this study indicated that there were no differences in bacteria growth with or without the use of the shrink tunnel and chill tank. Unfavorable commercial processing facility conditions (i.e. greater storage temperature, greater bacteria count present before packaging, poorer pork quality) may have greater detrimental effects on quality and bacteria growth; and thus, the use of a hot water-shrink tunnel and chill tank system could provide added benefits beyond those observed in this study. This preliminary study provides evidence that greater research in this area could be beneficial for the pork industry.

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TABLES

Table 1. The effect of a shrink tunnel and chill tank following vacuum packaging on commercial quality and bacteria growth for **pork loins**.

	No shrink tunnel or chill tank				Shrink tunnel and chill tank				SEM	<i>P</i> - values		
	D 7	D 14	D 21	D 28	D 7	D 14	D 21	D 28		Trt	Day	Trt × Day
Pork Quality Measurements												
pH	5.53	5.80	5.62	5.67	5.51	5.55	5.56	5.79	0.07	0.29	0.02	0.07
NPPC color ^a , 1 to 6	1.75	2.75	2.00	2.00	2.25	2.50	2.00	2.25	0.20	0.52	0.01	0.21
NPPC marbling ^b , 1 to 10	1.25	2.00	1.75	1.50	1.75	2.25	1.75	2.00	0.27	0.14	0.15	0.74
NPPC firmness ^c , 1 to 3	1.50	2.00	2.00	2.00	2.00	2.25	2.25	2.25	0.31	0.32	0.39	0.95
Purge loss, %	1.72	1.74	2.98	2.75	0.75	1.02	2.38	1.22	0.45	0.03	0.01	0.67
Bacterial Count Measurements ^d												
Total aerobic count, log CFU/g	2.96	2.81	3.01	4.51	2.24	2.12	3.74	2.56	1.54	0.72	0.61	0.61
Total coliform count, log CFU/g	ND	0.25	ND	ND	ND	ND	0.25	ND	0.13	1.00	0.58	0.29

^aMeasured based on a 6-point scale where 1 indicated pale pinkish gray to white, 2 indicated grayish pink, 3 indicated reddish pink, 4 indicated dark reddish pink, 5 indicated purplish red, and 6 indicated dark purplish red (NPPC, 1999).

^bMeasured based on a 10-point scale where estimated scores correspond with intramuscular lipid content (NPPC, 1999).

^cMeasured based on the 3-point scale where 1 indicated soft, surface distorts easily, 2 indicated firm, surface tends to hold shape, and 3 indicated very firm, surface was very smooth with no distortion of shape (NPPC, 1999).

^dND = non-detectable.

Table 2. The effect of a shrink tunnel and chill tank following vacuum packaging on commercial quality and bacteria growth for **pork tenderloins**.

	No shrink tunnel or chill tank				Shrink tunnel and chill tank				SEM	<i>P</i> - values		
	D 7	D 14	D 21	D 28	D 7	D 14	D 21	D 28		Trt	Day	Trt × Day
Pork Quality Measurements												
pH	5.67	5.74	5.67	5.67	5.70	5.79	5.80	5.80	0.07	0.09	0.68	0.83
NPPC color ^a , 1 to 6	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.75	0.09	0.33	0.42	0.42
NPPC marbling ^b , 1 to 10	1.00	1.25	1.00	1.25	1.25	1.25	1.00	1.00	0.18	1.00	0.54	0.54
NPPC firmness ^c , 1 to 3	2.00	2.25	2.00	2.25	2.25	2.25	2.25	2.00	0.38	0.82	0.98	0.90
Purge loss, %	0.60	0.73	1.27	1.53	0.63	0.45	0.24	1.75	0.38	0.34	0.04	0.40
Bacterial Count Measurements ^d												
Total aerobic count, log CFU/g	3.12	4.12	4.31	3.94	1.49	4.26	4.36	3.93	1.55	0.85	0.12	0.72
Total coliform count, log CFU/g	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-

^aMeasured based on a 6-point scale where 1 indicated pale pinkish gray to white, 2 indicated grayish pink, 3 indicated reddish pink, 4 indicated dark reddish pink, 5 indicated purplish red, and 6 indicated dark purplish red (NPPC, 1999).

^bMeasured based on a 10-point scale where estimated scores correspond with intramuscular lipid content (NPPC, 1999).

^cMeasured based on the 3-point scale where 1 indicated soft, surface distorts easily, 2 indicated firm, surface tends to hold shape, and 3 indicated very firm, surface was very smooth with no distortion of shape (NPPC, 1999).

^dND = non-detectable.

Table 3. The effect of a shrink tunnel and chill tank following vacuum packaging on commercial quality and bacteria growth for **pork shoulder butts (cellar trimmed)**.

	No shrink tunnel or chill tank				Shrink tunnel and chill tank				SEM	<i>P</i> - values		
	D 7	D 14	D 21	D 28	D 7	D 14	D 21	D 28		Trt	Day	Trt × Day
Pork Quality Measurements												
pH	5.70	5.91	5.81	5.81	5.78	5.92	5.86	5.90	0.11	0.59	0.28	0.96
NPPC color ^a , 1 to 6	2.25	2.75	3.00	3.25	3.50	3.00	3.00	3.00	0.27	0.18	0.74	0.05
NPPC marbling ^b , 1 to 10	1.75	2.75	2.25	2.50	2.00	2.75	2.50	2.25	0.38	0.86	0.10	0.85
NPPC firmness ^c , 1 to 3	2.25	2.25	2.25	2.50	2.50	2.50	2.50	2.75	0.27	0.42	0.48	1.00
Purge loss, %	1.13	2.12	3.20	4.85	1.05	1.27	1.64	3.55	1.25	0.45	0.04	0.90
Bacterial Count Measurements ^d												
Total aerobic count, log CFU/g	2.90	4.70	4.16	4.45	2.39	3.98	3.93	2.77	1.52	0.68	0.23	0.84
Total coliform count, log CFU/g	ND	ND	ND	0.25	ND	ND	ND	ND	0.09	0.33	0.42	0.42

^aMeasured based on a 6-point scale where 1 indicated pale pinkish gray to white, 2 indicated grayish pink, 3 indicated reddish pink, 4 indicated dark reddish pink, 5 indicated purplish red, and 6 indicated dark purplish red (NPPC, 1999).

^bMeasured based on a 10-point scale where estimated scores correspond with intramuscular lipid content (NPPC, 1999).

^cMeasured based on the 3-point scale where 1 indicated soft, surface distorts easily, 2 indicated firm, surface tends to hold shape, and 3 indicated very firm, surface was very smooth with no distortion of shape (NPPC, 1999).

^dND = non-detectable.