

NEW INTERVENTIONS AND VALIDATION FOR THE CONTROL OF PATHOGENS IN THE PROCESSING OF JERKY

J.A. Boles, K.I. Neary and K. Clawson

Montana State University, Bozeman, MT 59717

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Introduction

Jerky is a common ready to eat product that can be purchased at just about any gas station, grocery store and small processing facility in the United States. Many small and very small plants manufacture jerky. It is important that these small and very small plants be able to validate that the product they manufacture is safe and free from pathogens. Many of the small processors use smokehouses with minimal controls, especially for humidity which are similar to home dehydrators. Faith et al. (1998) evaluated ground and formed jerky that had been dried using processes that were similar to home style dehydrators. They reported that viability of bacteria was reduced as the drying temperature increased and drying time increased. In the past, control of pathogens for jerky was due to reduced water activity. Control of most bacteria occurs at water activities below 0.90 (Jay, 1986). Calicioglu et al. (2003a) reported a 5 log reduction in *Escherichia coli* O157:H7 inoculated post-drying after 7 days of storage. The water activity of the jerky post-drying was between 0.564 and 0.696. Water activity below 0.85 has been used in other countries to establish safety of jerky (Agriculture and Agri-Food Canada, NZFSA). New guidelines from the USDA suggest lowering water activity to 0.80 to control *Salmonella* and *E. coli* O157:H7 along with processing with high humidity at the first of the manufacturing process.

Listeria monocytogenes has been a new problem that most small processors are now dealing with on ready to eat products. *Listeria* is normally a problem because of post processing contamination. Calicioglu et al. (2002) reported that *Listeria* numbers were reduced during the drying process and that the use of acid marinades helped increase this reduction. Työppönen et al (2003) observed that traditional processing procedures for dried, and fermented and dried sausages were not sufficient to prevent the survival of *Listeria monocytogenes* and *Escherichia coli* O157:H7. Therefore it is important to determine the effect of different water activities on the survivability of select pathogens. With the uncertainty of survival of different pathogens in dried products, it is important for processors to validate the process they are using to manufacture jerky that is being labeled shelf stable.

Objectives

1. Determine the survivability of *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes* on whole muscle jerky dried without humidity and stored in a vacuum package.

2. Determine the survivability of *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes* on whole muscle jerky dried with smokehouse dampers closed for the first hour of processing.
3. Determine the survivability of *Listeria monocytogenes* inoculated post processing on jerky treated with a sodium lactate or hot water dip.

Methodology

Processing affect on microbial survival

Beef (*semimembranosus* muscle) was purchased from a small commercial facility for the manufacture of jerky. Meat was tempered at 4°C for 24 h and sliced 6 mm thick. A formulation containing beef (89.58% w/w), soy sauce (5% w/w), dextrose (2% w/w), salt (1.8% w/w), garlic powder (0.5% w/w), black pepper (0.5% w/w), onion powder (0.4% w/w), Cure #1 (0.18% w/w) and sodium erythorbate (0.04% w/w) was used to marinate the jerky. Marination was conducted for 20 min in a vacuum tumbler. After marination, each slice was inoculated by dipping in a cocktail of pathogens (*Salmonella* (4 strains *S. typhimurium* 04121V and 0363V, *S. abatebua* 0817V and *S. choleraesuis* 0902V from Fisher Scientific, Denver, CO) , 3×10^6 ; *Listeria monocytogenes* (4 strains FSL J1-110, FSL C1-115, FSL J2-064, and FSL J2-054 from Martin Weidman, Cornell University) 6.25×10^7 and *E. coli* O157:H7 (one strain 0617V, Fisher Scientific, Denver, CO) 3.3×10^7). Three raw slices were tested to determine inoculation level. Jerky was placed on racks and dried in an ALKAR smokehouse (Alkar Smokehouses, Lodi WI) at 60°C with dampers open and fans running at maximum for the whole drying cycle. To evaluate how early damper closure affected survivability dampers were closed for the first hour of processing. Samples were taken at 1, 3, 6, 9, and 12 hours of drying to give three slices of jerky for each of five storage periods (0, 3, 6, 9, or 12 weeks). Samples from 0 and 1 hour of drying were not stored. Each sample was tested for microorganism survival utilizing selective media. Internal temperature and water activity was also determined. Internal temperature was determined using hypodermic thermocouples (Omega Scientific, Tarzana, CA) inserted into 6 slices in each of three different full smokehouse loads. Water activity was determined with a Series 3 Decagon Aqualab water activity meter (Aqualab, Pullman, WA) on two different samples from each jerky slice at each drying and storage period. Three jerky slices from different places in the smokehouse were analyzed at each storage time for bacterial survival and water activity.

Post-processing contamination of Listeria monocytogenes

Beef (*semimembranosus* muscle) was purchased from a small commercial facility for the manufacture of jerky. Meat was tempered at 4°C for 24 h and sliced 6 mm thick. A formulation containing beef (89.58% w/w), soy sauce (5% w/w), dextrose (2% w/w), salt (1.8% w/w), garlic powder (0.5% w/w), black pepper (0.5% w/w), onion powder (0.4% w/w), Cure #1 (0.18% w/w) and sodium erythorbate (0.04% w/w) was used to marinate

the jerky. Marination was conducted in for 20 min in a vacuum tumbler. Jerky was placed on racks and dried in an ALKAR smokehouse (Alkar Smokehouses, Lodi WI) at 60°C with dampers open and fans running at maximum for the whole drying cycle. After drying for 3, 6, 9 or 12 hours slices (30 at each time period) were removed from the smokehouse and dipped in a cocktail of *Listeria monocytogenes* (5.5×10^5 , 4 strains FSL J1-110, FSL C1-115, FSL J2-064, and FSL J2-054 from Martin Weidman, Cornell University) and allowed to dry for 30 minutes. Samples were then either vacuum packaged (10 slices per drying time) and labeled for storage vacuum packaged (10 slices per drying time) and dipped in 72°C water for 20 s or dipped in 2% sodium lactate and allowed to dry for 30 minutes before vacuum packaging. Samples were stored for 0, 3, 6, 9 or 12 weeks at 21°C.

Microbial analysis

Ten grams of jerky slice per drying time were aseptically transferred into sterile plastic bags (Fisher Scientific, Denver, CO). A 90-mL aliquot of 0.1% sterile peptone buffer (Difco) was added to each sample bag prior to pummeling with a stomacher for 2 min at room temperature. Serial decimal dilutions were made and pour-plated onto each of duplicate plates of each agar medium. Three different jerky slices per drying time were analyzed at each storage period for processing affects and two slices per drying time per treatment were analyzed for post-processing contamination with *Listeria monocytogenes*. Bacteria were enumerated using tryptic soy agar (Difco) plus 0.1% sodium pyruvate (TSAP, total plate count), PALCAM agar (Difco) (*Listeria monocytogenes*), xylose-lysine-tergitol 4 agar (Difco) (XLT4, *Salmonella*), MacConkey sorbitol agar (Difco) (SMAC, *E. coli*) and modified eosin methylene blue agar (Difco) (MEMB, *E. coli*). PALCAM and half of the TSAP plates were incubated at 30°C while the other plates were incubated at 35°C. The minimum detection limit was 10 CFU/g. All counts were econverted to log CFU/g. When numbers of the pathogen decreased to <10 CFU/g by direct plating, the presence/absence of the pathogen was determined by enrichment as described by Calicioglu et al. (2003a, b) for *Listeria* and *Salmonella*.

Data were analyzed using the GLM procedure of SAS. The absence of pathogens on selective agar was scored as 9 cfu for statistical analysis if there were no colonies on a plate. LSMEANS was used to separate means.

Results & Discussion

Processing effect on microbial survival

The internal temperature of jerky slices was similar to the smokehouse temperature after three hours of drying (Fig. 1). Calicioglu and co-workers (2003b) reported that the internal temperature of jerky slices were similar to the dehydrator temperature after 6 hours of drying. The difference between these two reports is probably due to increased air flow and better temperature control in the smokehouse used in this study when

compared to the home dehydrator used by Calicioglu et al. (2003b). This variation between temperatures also suggests that under drying conditions with no humidity added that the processor will need to establish what the internal temperature of a jerky slice is going to be under the specific conditions of their smokehouse.

The total number of colony forming units declined as drying time increased (Fig. 2). The total number of *E. coli*, *Salmonella* and *Listeria* also significantly declined as drying time increased. Drying of jerky resulted in a 2 log reduction of *Listeria* after 6 hours of drying which increased to a 3 log reduction after 12 hours. Drying of jerky slices inoculated with *E. coli* O157:H7 resulted in a 3 log reduction after 3 hours of drying and a 4 log reduction after 12 hours. Drying of jerky slices inoculated with *Salmonella* resulted in a 2 log reduction in 3 hours with an increase to 3 log reduction after 6 and 12 hours of drying. Albright et al. (2002) reported 2.1 – 2.5 log reductions of *E. coli* on jerky that had been processed in home type dehydrators at 62.5°C. These reductions are similar to what was seen in this study. Even after 12 h of drying reduction in pathogens had not reached the 5-log reduction and all drying times had surviving bacteria. The largest reduction in pathogen load happened within the first 3 hours of processing. There was not a drying by storage time interaction.

After vacuum storage for three weeks there was no *Listeria* or *E. coli* recovered from the jerky strips (Fig. 3). Furthermore after enrichment there was no *Listeria* or *E. coli* resuscitated. *Salmonella* however did survive storage up to 3 and 6 weeks of storage but was reduced to below detectable limit after 9 and 12 weeks of storage (Fig. 3). *Salmonella* was recovered after enrichment, but in very low numbers (5 CFU). Survivors of all bacteria tested were most often found when the integrity of the vacuum package was compromised. Faith et al. (1997) reported a reduction in *E. coli* in pepperoni stored under vacuum at room temperatures. They reported a 1-log reduction after 7 days of storage, 3.6-log reduction after 28 days (4 weeks) of storage that increased to approximately 5-log reduction (below detection limit) after 60 days of storage (8.5 weeks of storage). Additionally, Ihnot et al. (1998) reported that storage under vacuum at ambient temperatures was more severe on *Salmonella typhimurium* DT104 than refrigerated storage in pepperoni. Data reported herein suggests that a 5-log reduction can be achieved with drying and 6 weeks of vacuum storage. However, Calicioglu et al (2003b) reported surviving *Salmonella* on jerky after 60 days of aerobic storage. Information reported herein along with data reported in the literature suggests that *Salmonella* is more resistant to the drying and storage conditions than are *Listeria* or *E. coli*.

Water activity was reduced as the drying time increased (Table 1) however at all drying times it was low for jerky products. The water activity of jerky slices was reduced from 0.961 to 0.589 within 3 hours. This is much less than that reported by Calicioglu et al (2003b) who reported a reduction in water activity from 0.961 to 0.898 after 4 h of drying at 60°C and Albright et al (2002) who reported a reduction in water activity from 0.93 to 0.90 at 62.5°C in 4 h. Both researchers used home dehydrators for their drying. The Alkar smokehouse used in this study resulted in a much more rapid drop of water activity than that seen in other reported studies utilizing home-style dehydrators. There is a major

difference between drying rates of home dehydrators and smokehouses that are used by meat processors. It is important to recognize the difference and evaluate the processes accordingly. Storage had a significant affect on water activity but the differences were not consistent over time and reflect differences in individual slices analyzed along with differences due to drying.

Table 1 Effect of drying and storage on the water activity of jerky

	Water activity	SEM
Drying Time (hrs)		
0	0.961 ^a	0.012
1	0.843 ^b	0.012
3	0.569 ^c	0.012
6	0.464 ^d	0.012
9	0.373 ^e	0.012
12	0.373 ^e	0.012
Storage (weeks)		
0	0.445 ^a	0.008
3	0.413 ^b	0.008
6	0.396 ^b	0.008
9	0.462 ^a	0.008
12	0.393 ^b	0.008

A significant damper by drying time interaction was observed for bacteria grown on MEMB ($P = 0.01$) and XLT4 ($P = 0.0006$). Closing of the dampers for the first hour of processing resulted in a small significant decrease in *E. coli* and *Salmonella* survival that carried over to all successive times of drying except for 12 hours of drying (Fig. 4). The reduction was approximately 0.4 of a log for all *E. coli* and *Salmonella* with a greater reduction in total aerobic plate counts (0.7 log; Fig. 5). *Salmonella* was more susceptible to the increased moisture during that first hour of drying than were *Listeria* and *E. coli*. There was a significant interaction between having the dampers open for the first one hour of processing and storage time for survival of *Salmonella*. This is a result of the decreased number of pathogens surviving on the jerky prior to being placed into storage. No matter the processing scheme, after 3 to 6 weeks of vacuum packaged storage the number of pathogens were below the detectable limit and there were few being resuscitated.

Post-processing contamination of Listeria monocytogenes

Inoculation of dried jerky by dipping in a solution containing 5.5×10^5 *Listeria monocytogenes* resulted in 2.95×10^4 per g on the jerky slices. Initially dipping the vacuum package in 72°C water for 20 s had a small but significant ($P = 0.002$) affect on *Listeria* numbers on jerky. A 0.42-log reduction was achieved when compared with no treatment. Dipping in sodium lactate did not significantly affect the numbers of *Listeria* on jerky when compared to the control. There was no treatment by drying interaction ($P = 0.89$) but a significant treatment by storage interaction ($P = 0.0008$) was observed. Dipping of packaged jerky in 72°C water for 20 sec resulted in a significantly lower number of *Listeria* surviving after 0 storage than no treatment and sodium lactate dip.

After 3 weeks of storage water dip was similar to control but had significantly fewer *Listeria* surviving than sodium lactate dipped slices. After 6 weeks of vacuum storage the control and water dip had below detectable limits of *Listeria* surviving. Similarly, Calicioglu et al (2003c) reported that *Listeria* and total bacterial populations decreased or were below detection limit after 28 days of vacuum packaged storage.

Water activity of jerky was significantly affected by treatment ($P < 0.0001$) with jerky strips dipped in sodium lactate having a slightly higher water activity than either no treatment or water dipping. As expected water activity was reduced ($P < 0.0001$) during drying and was significantly different at each drying time evaluated. Storage had a significant affect on water activity but the differences were not consistent over time and reflect differences in individual slices analyzed along with differences due to drying.

Table 2 Effect of treatment, drying and storage on the water activity of jerky post-processing inoculated with *Listeria monocytogenes*

	Water activity	SEM
Treatment		
None	0.603 ^b	0.006
Sodium lactate	0.639 ^a	0.006
Water	0.593 ^b	0.006
Drying Time (hrs)		
3	0.739 ^a	0.007
6	0.646 ^b	0.007
9	0.571 ^c	0.007
12	0.488 ^d	0.007
Storage (weeks)		
0	0.695 ^a	0.008
3	0.584 ^b	0.008
6	0.612 ^c	0.008
9	0.613 ^c	0.008
12	0.551 ^d	0.008

Conclusions

Drying procedures currently used by most small processors will reduce the number of pathogens on the jerky however drying does not reduce the number enough to meet the 5-log reduction USDA desires. Use of sodium lactate dip (2%) is not as affective as a 20 s hot water dip or no treatment in decreasing post-processing inoculated *Listeria monocytogenes* on jerky. Drying and storing in a vacuum package does result in reduction of pathogens to below the detectable limit. The cause of the reduction of pathogens in storage is not clear. Some will be due to the lowered water activity but some may be due to pathogens being injured during drying and not being able to adapt to the vacuum packaged atmosphere. As long as the water activity of jerky is below 0.70 pathogens will not survive vacuum packaged storage at ambient temperature beyond 6

weeks. More research is needed to determine how high the water activity can be when vacuum packaged storage is still effective at reducing microbial numbers.

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Figure 1 Internal temperature of jerky slices during drying at 60°C.

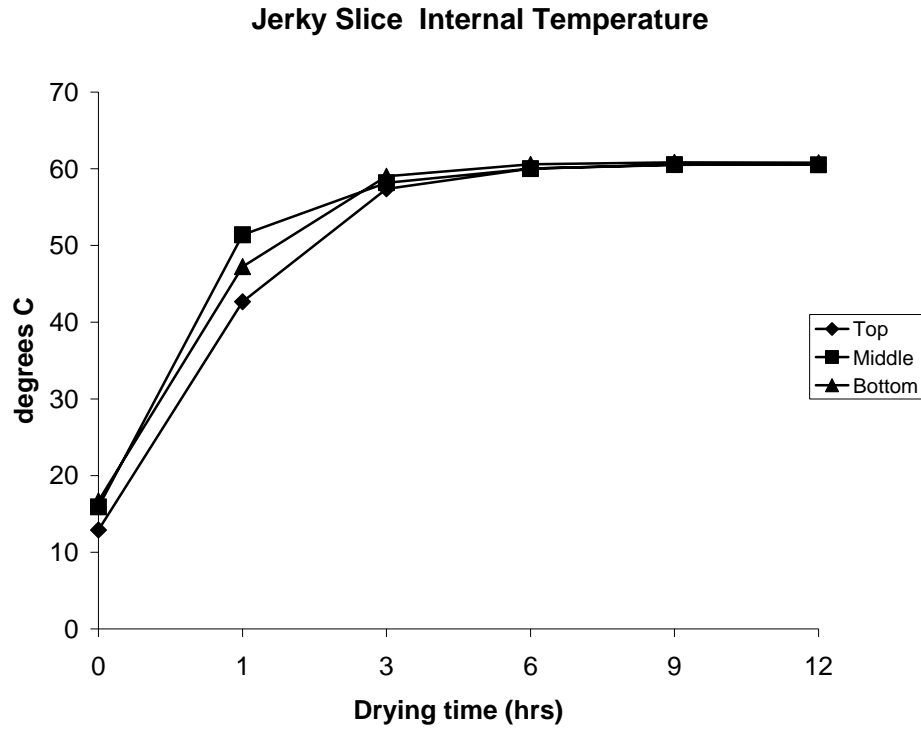


Figure 2 Effect of drying at 60°C on the survival of *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes*.

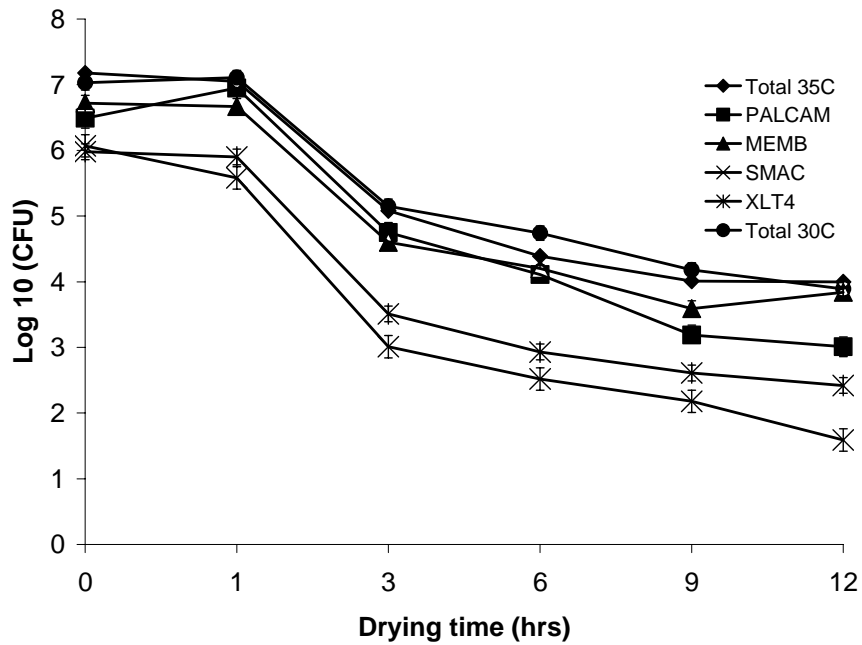


Figure 3 Effect of storage on the survival of *E. coli* O157:H7, *Salmonella spp.* and *Listeria monocytogenes*.

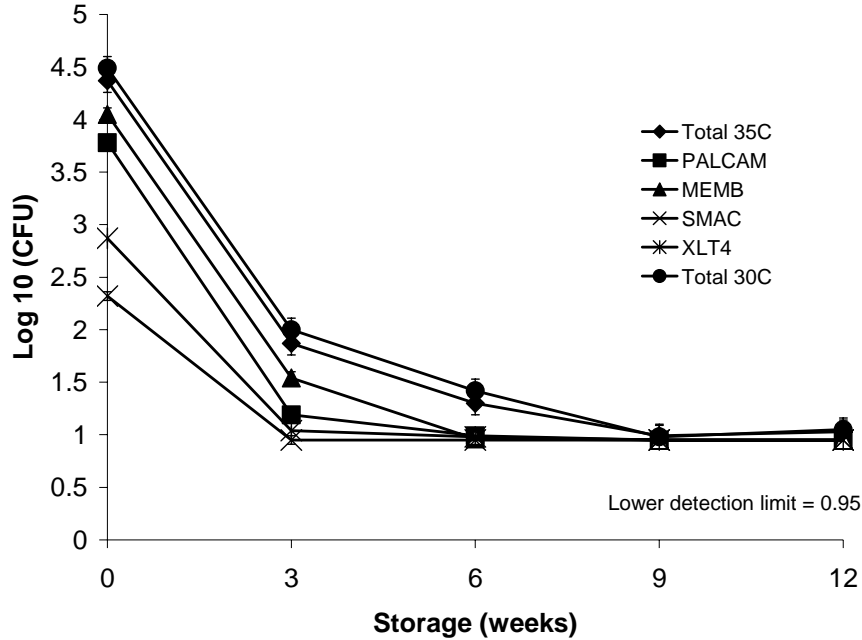


Figure 4 Effect of closing of smokehouse dampers for one hour followed by normal drying on the survival of *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes* (LM). Graphs a and b indicates survival of *E. coli* O157:H7 on jerky recovered on MEMB (a) and SMAC (b). Graph c indicates survival of LM on jerky recovered on PALCAM and graph d indicates survival of *Salmonella* spp. on jerky recovered on XLT4.

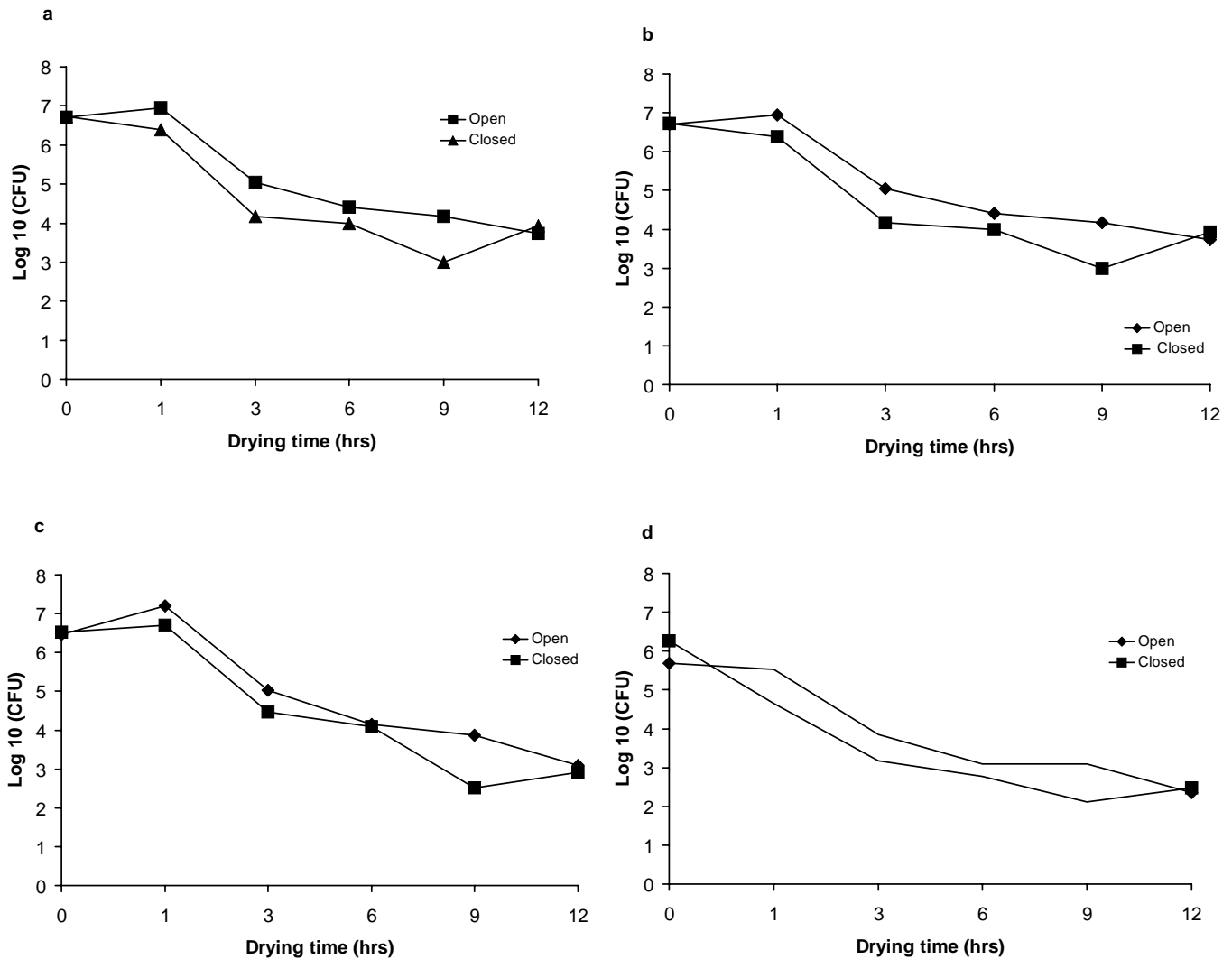


Figure 5 Effect of closing of smokehouse dampers for one hour followed by normal drying on the survival of bacteria (APC) on beef jerky

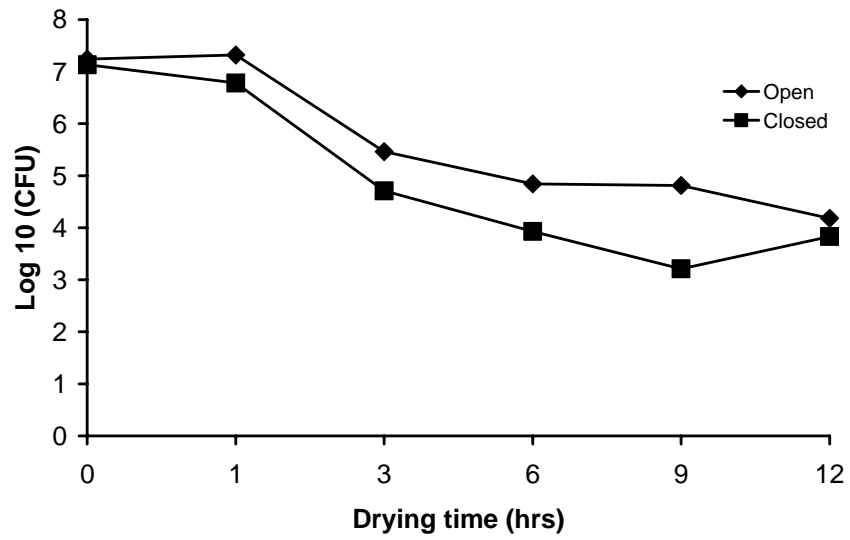
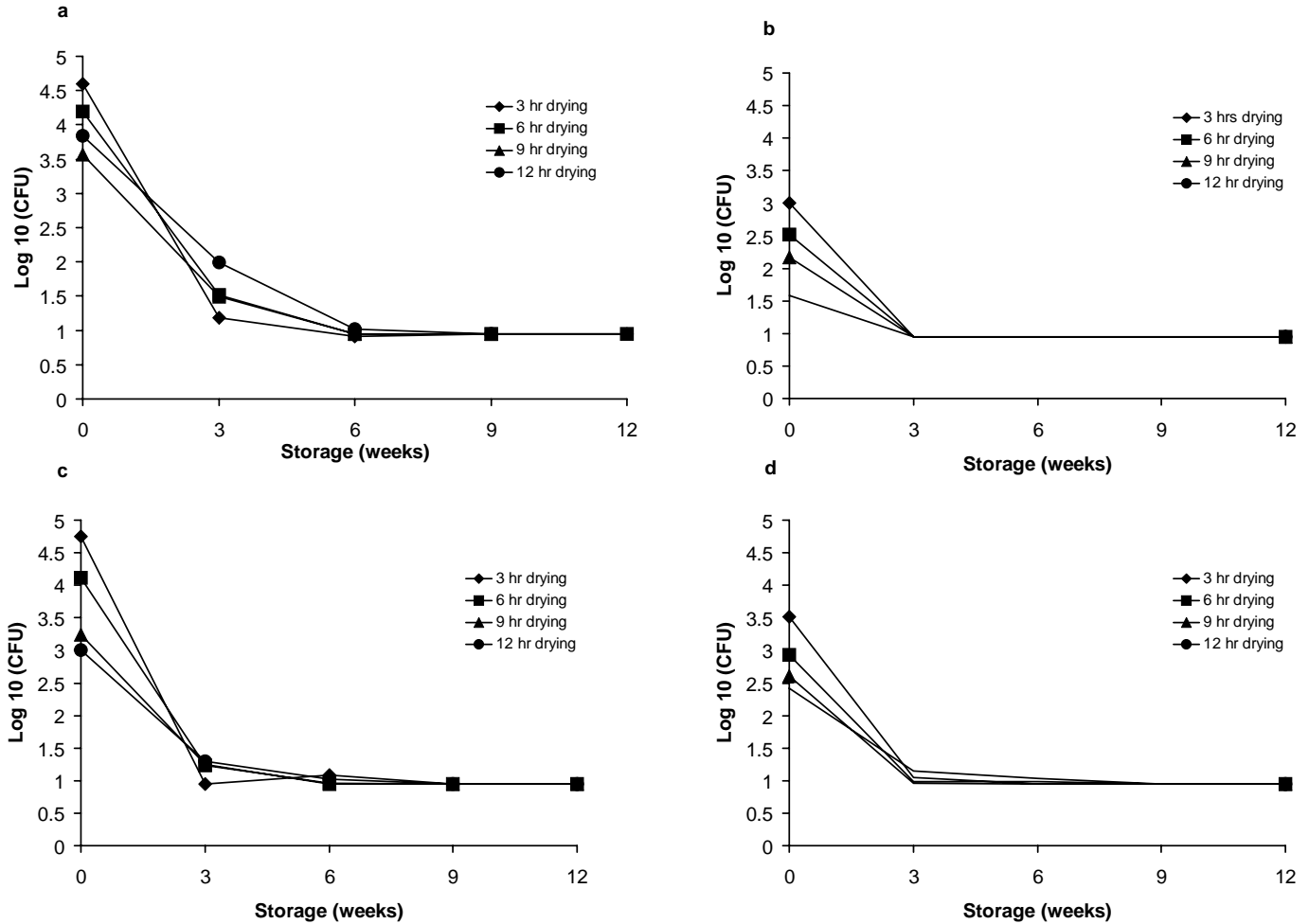


Figure 6 Interactive effects of drying and storage time on the survival of *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes* (LM). Graphs a and b indicate survival of *E. coli* O157:H7 on jerky recovered on MEMB (a) and SMAC (b). Graph c indicates survival of LM on jerky recovered on PALCAM and graph d indicates survival of *Salmonella* spp. on jerky recovered on XLT4.



Lower detection limit = 0.95

Figure 7 Interactive effects of drying and storage on the survival of bacteria (APC) on beef jerky

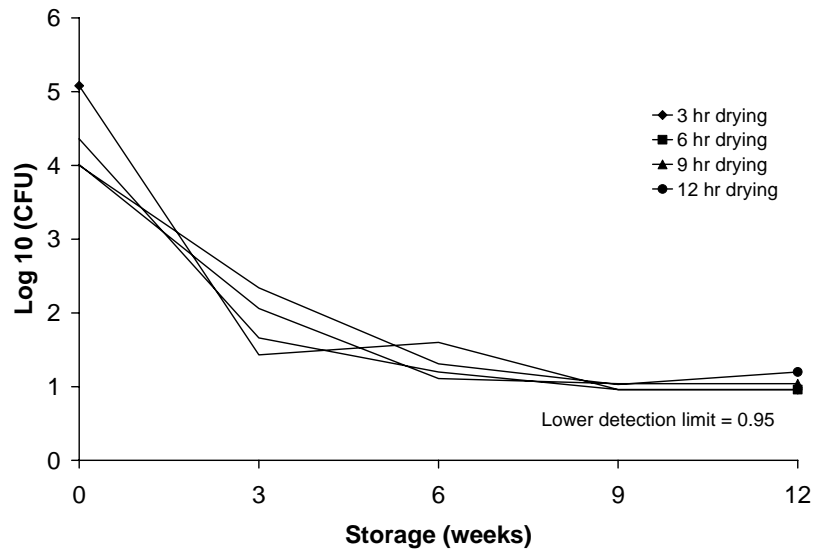


Figure 8 Effect of storage and sodium lactate or water dip on the survival of post-processing inoculated *Listeria monocytogenes* on jerky.

