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Influence of hot-processing and electrical stimulation on the bacteriology and retail case-life of vacuum packaged lamb

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Carcasses from 48 wether lambs 6 to 9 months of age were utilized to evaluate the effects of hot-processing and electrical stimulation on bacterial numbers and types of bacteria on lamb cuts, following vacuum packaged storage and during simulated retail display. Carcasses were subdivided into groups of 16. One subgroup was processed conventionally or chilled for 24 h at 1°C. Another subgroup was electrically stimulated (20; 2 s pulses interspersed with 1 s resting intervals; 550 V, AC, 50–60 cycles/s) at approximately 45 min *post mortem* and then chilled conventionally at 1°C until 24 h *post mortem*. The final subgroup was treated identically to the subgroup receiving electrical stimulation, but was hot-boned immediately following stimulation, vacuum packaged, and chilled at 1°C until 24 h *post mortem*. At 24 h *post mortem* the racks from conventional and electrically stimulated carcasses were removed and vacuum packaged. All vacuum packaged racks were then randomly allocated to four post mortem storage intervals (0, 14, 28 and 42 days) within processing treatments, so that four racks from each processing treatment were evaluated at each storage interval. Following storage for the designated intervals, racks were fabricated into chops. The two centre chops from each rack were placed into styrofoam trays, overwrapped with oxygen permeable film and displayed under simulated retail conditions for 5 days. Racks were sampled for bacteriological analyses before and immediately after storage and chops were sampled before and after 5 days of simulated retail display. Four bacterial groups were enumerated (psychrotrophs, pseudomonads, lactics and *Brochothrix thermosphacta*). Processing treatments were not found to have any consistent effects upon bacterial populations except for the absence of *B. thermosphacta* on hot-boned and electrically stimulated racks. Neither storage time nor processing treatment produced a significant effect on retail case-life. Consequently, lamb carcasses can be processed using electrical stimulation and hot-boning alone or in combination to increase processing efficiency; and cuts can be stored in vacuum for up to 42 days without reducing the case-life of retail cuts below an acceptable level of 2 to 3 days. © 1997 Published by Elsevier Science Ltd on behalf of the Canadian Institute of Food Science and Technology

INTRODUCTION

In North America the areas of intense lamb production and slaughter are remote from major areas of lamb consumption. In addition, the market for lamb is considerably smaller than for other red meats. Consequently, control of bacterial contamination and growth and extension of product storage life are particularly important. Preservative packaging has proven to be effective in extending the storage life of lamb (Smith *et al.*, 1983; Eustace, 1984; Shay and Egan, 1990). After 4 to 9 weeks of primal cut storage in vacuum a retail case-life of 2 to 4 days has been reported for lamb chops (Gill and Penney, 1985).

Accelerated processing (hot-boning, electrical stimulation) has been proposed as a practicable means of

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reducing labour and energy costs (Kotula and Emswiler-Rose, 1981). Despite the economic benefits, the bacteriological consequences of these innovative processing strategies must be evaluated, particularly if they are to receive regulatory approval in North American plants.

There are few known comprehensive studies of the qualitative and quantitative changes in the bacteriology of lamb during extended periods of vacuum storage after hot-boning and electrical stimulation. Although it has been reported the numbers of bacteria initially recovered from hot-boned cuts were significantly higher in comparison to conventionally boned product (Stern, 1980). The present study was undertaken to provide more data on the effects of hot-processing and electrical stimulation on bacterial numbers and types associated with lamb cuts following vacuum packaged storage and simulated retail display. Treatment effects were examined on psychrotrophic bacteria or organisms capable of growing at refrigeration temperatures with the potential of producing spoilage, pseudomonads or the group of organisms which normally produce spoilage under aerobic conditions, *Brochothrix thermosphacta* which is an organism capable of growing and producing spoilage of vacuum packaged cuts, stored at temperatures above 0°C, and lactic acid bacteria or the group of organisms which dominate the flora on anaerobically stored meat with the potential to produce spoilage.

MATERIALS AND METHODS

Wethers (48) 6 to 9 months of age were slaughtered at the Lacombe Meat Research Centre and subdivided into groups of 16 and subjected to one of the following three post mortem processing treatments: (1) Conventional (C)—carcasses were chilled for 24 h at 1°C; (2) electrical stimulation (ES)—carcasses were electrically stimulated (550 V, AC, 50–60 cycles/s, using 20 pulses of 2 s duration, interspersed with 1 s resting intervals) followed by conventional chilling 24 h at 1°C; or (3) electrical stimulation, hot-processing (ES/HB)—carcasses were electrically stimulated as above, and then immediately hot-processed (hot-boned, HB), prior to chilling at 1°C.

Following each processing treatment the racks were vacuum packaged and randomly assigned to four storage intervals at 1°C (0, 14, 28 and 42 days). This temperature was selected since it is a temperature that can currently be attained in commercial chillers. Consequently, four boneless racks were evaluated for each processing treatment at each storage interval (the '0' storage interval was after 24 h of chilling of carcasses or cuts at 1°C). All racks were sampled to ascertain bacterial numbers immediately before and following storage. After microbiological sampling, two chops were cut from the centre of each rack, overwrapped with an oxygen permeable film (Vitafilm Choice Wrap, Huntsman Corp., Toronto, ON) and displayed under simulated retail conditions for 5 days in a horizontal Hussmann retail display case (model: M1-12, Hill Refrigeration of Canada, Barrie, ON, model: LPM12T) under 750 lux of incandescent and fluorescent lighting for 12 h/day (Greer *et al.*, 1993). The retail cabinet was set to maintain a mean meat surface temperature of 7°C which approximated temperatures recorded during surveys of commercial, retail outlets (Greer *et al.*, 1994).

Microbiological sampling consisted of swabbing an area of 4 cm^2 on each of the anterior and posterior ends and a 10 cm^2 area on the lean and fat surfaces of each boneless rack. In total an area of 28 cm^2 was sampled on each rack and swabs were pooled. Boneless rib chops were sampled after 0 and 5 days of retail display, by swabbing a surface area of 4 cm^2. Following microbiological sampling, swabs were immersed in 0.1% peptone water and the pooled samples were diluted to differentiate and enumerate specific groups of bacteria, aliquots were plated and incubated using the media and cultural conditions shown in Table 1 (Greer *et al.*, 1993). Bacterial numbers were converted to common logarithms prior to data analysis and expressed as log colony forming units per cm^2 ($\log_{10}$ cfu cm^{-2}). The minimum limits for the sensitivity of the bacteriological methods were $\log_{10}$ 0.55 cfu cm^2 for racks and $\log_{10}$ 1.40 cfu cm^2 for chops.

Retail case-life of chops was based upon subjective evaluation of the appearance, by a 5-member, trained sensory panel. Retail case-life was arbitrarily defined as the time in days for a sample to reach a value of 3.5 on a 7-point hedonic scale (1 = extremely undesirable; 7 = extremely desirable).

Data were analyzed using the general linear model of SAS (1985) and a model with processing treatment and

Table 1. Media and cultural conditions[a]

Medium	Incubation	Bacterial group
PCA (Difco)	10 days, 7°C	Psychrotrophs
CFC	2 days, 25°C	Pseudomonads
MRS (Difco)	4 days, 25°C (anaerobic)	Presumptive Lactic Acid Bacteria
STAA	2 days, 25°C	*Brochothrix thermosphacta*

[a]Greer *et al.* (1993).
PCA: Place Count Agar. CFC: Cephaloridine–fucidin–cetrimide. MRS: de Man, Rogosa, Sharpe. STAA: Streptomycin sulfate–thallous acetate–actidione.

storage time as the main effects in the main plot of a split-plot design and display time as the main effect in the subplot.

RESULTS

The effects of processing treatment and storage time on bacterial growth on lamb racks are shown in Figs 1–4. At the onset of vacuum storage (time 0) the number of total psychrotrophic bacteria (Fig. 1), pseudomonads (Fig. 2), *B. thermosphacta* (Fig. 3) and lactic acid bacteria (Fig. 4) were unaffected by processing treatment ($p > 0.05$). The one exception was a significant increase ($p \leq 0.05$) in the numbers of bacteria with time of vacuum storage for all processing treatments (Figs 1–4). In the case of lamb racks from hot-boned and electrically stimulated lamb carcasses (Fig. 3), no *B. thermosphacta* growth was detected over the 42 days in vacuum. In all other instances, bacterial numbers increased at similar rates irrespective of the processing treatment.

The initial numbers of bacteria recovered from cut lamb chops were compared for each vacuum storage time and carcass processing treatment (Figs 5–8). For all storage times, no pseudomonads (Fig. 6) or *B. thermosphacta* (Fig. 7) could be detected on the freshly cut surfaces of chops. The total psychrotrophic population (Fig. 5) and presumptive lactic acid bacteria (Fig. 8) found initially on the surface of cut chops increased during the time of rack storage in vacuum from 14 to 42 days. The numbers of bacteria found were unaffected by carcass processing treatment ($p > 0.05$).

The effect of processing and vacuum storage on the retail case-life of lamb chops as determined by the acceptability of appearance is shown in Table 2. Analysis of variance showed no significant effects ($p > 0.05$) of storage time or processing method on case-life and no significant ($p > 0.05$) storage × processing interaction was observed.

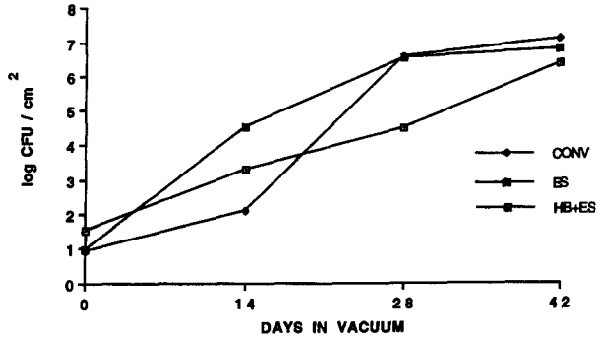

Fig. 1. Effects of processing treatment and storage time on the psychrotrophic bacteria on vacuum packaged lamb racks. Conventional, cold-boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of four racks at each vacuum storage interval for each treatment.

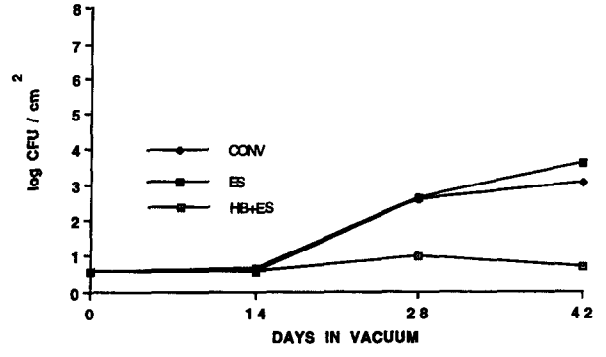

Fig. 3. Effects of processing treatment and storage time on *Brochothrix thermosphacta* on vacuum packaged lamb racks. Conventional, cold-boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of four racks at each vacuum storage interval for each treatment.

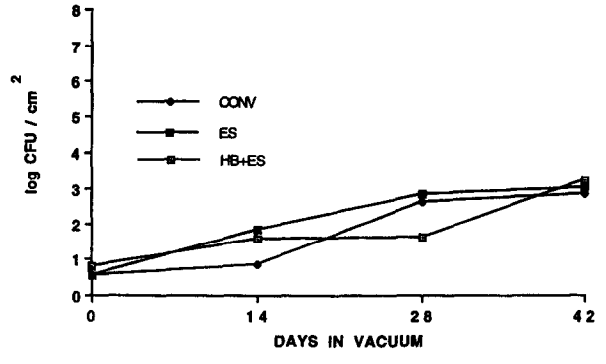

Fig. 2. Effects of processing treatment and storage time on pseudomonads on vacuum packaged lamb racks. Conventional, cold-boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of four racks at each vacuum storage interval for each treatment.

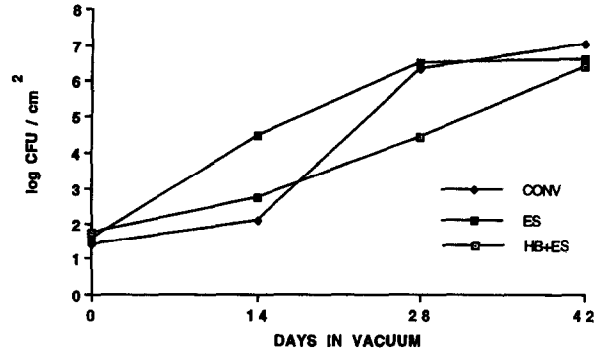

Fig. 4. Effects of processing treatment and storage time on the lactic acid bacteria on vacuum packaged lamb racks. Conventional, cold- boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of four racks at each vacuum storage interval for each treatment.

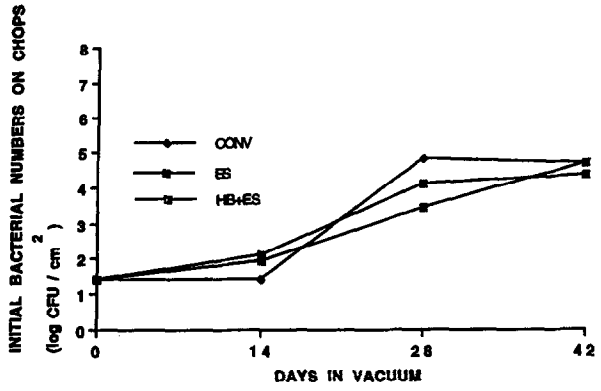

Fig. 5. Effects of processing treatment and storage time on the initial numbers of psychrotrophic bacteria on lamb chops. Conventional, cold-boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of eight chops at each vacuum storage interval for each treatment.

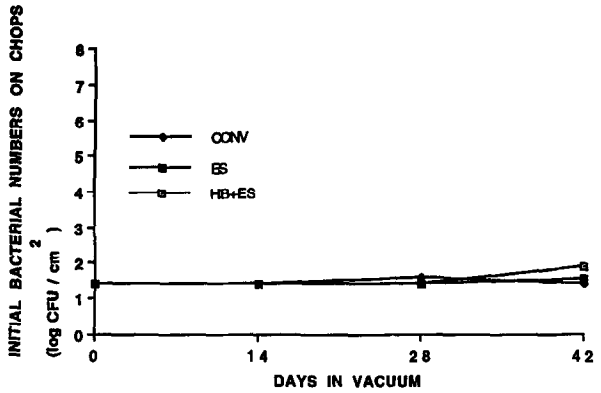

Fig. 6. Effects of processing treatment and storage time on the initial numbers of pseudomonads on lamb chops. Conventional, cold- boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of eight chops at each vacuum storage interval for each treatment.

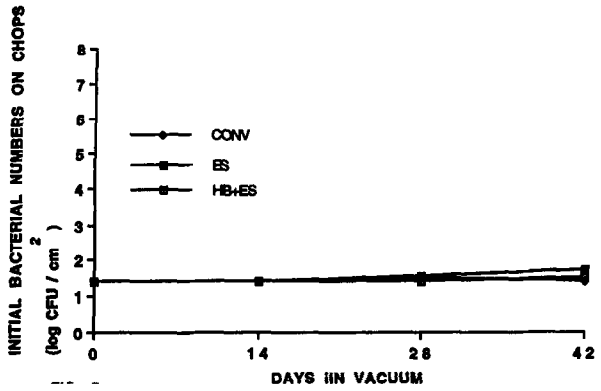

Fig. 7. Effects of processing treatment and storage time on the initial numbers of *Brochrothrix thermosphacta* on lamb chops. Conventional, cold-boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of eight chops at each vacuum storage interval for each treatment.

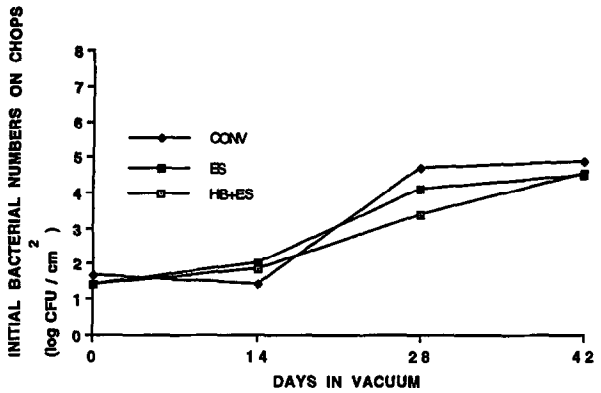

Fig. 8. Effects of processing treatment and storage time on the initial numbers of lactic acid bacteria on lamb chops. Conventional, cold- boning (CONV), electrical stimulation (ES) and hot-boning plus electrical stimulation (HB + ES) are compared. Data are the means of eight chops at each storage interval for each treatment.

DISCUSSION

Data concerning the microbiology of hot-boned and electrostimulated meat have been summarized for beef, pork and lamb (Kotula, 1981). On the basis of these comparisons it was concluded that neither hot-boning nor electrical stimulation would be expected to produce increases in microbial populations in the resultant meat. In fact, there is evidence to suggest a benefit of hot-boning beef carcasses was a delay in the onset of retail steak discolouration (Berry and Kotula, 1982). In accordance with these views the results of the present study have shown that meat from hot-boned and electrostimulated lamb carcasses can be stored in vacuum for up to 42 days without significant effects upon total psychrotrophs, pseudomonads, *B. thermosphacta* or lactic acid bacteria in relation to cold-boning. Furthermore, the initial levels of all bacteria examined were similar on chops derived from cold-boned or hot-boned primals and there were no processing treatment differences in the colour case-life of chops.

There was an interesting exception. *B. thermosphacta* was unable to grow on primals from hot-boned and electrically stimulated carcasses but could proliferate during the storage of vacuum packaged primals derived from conventionally boned or electrostimulated carcasses. This may be attributable to the lack of fat cover on hot boned racks. That is, *B. thermosphacta* has been found not to grow anaerobically on lean meat when the pH is below 5.8 (Grau, 1983). It is also conceivable that *B. thermosphacta* may have been absent from the initial flora contaminating the hot-boned lamb racks.

Table 2. Effects of processing and vacuum storage on the retail case-life of lamb chops

Vacuum storage (days)[a]	Retail case-life (days)[a]		
	Conventional	ES	Hot-boned + ES
0	3.32 ± 0.47	2.37 ± 0.22	4.16 ± 0.16[b]
14	4.21 ± 0.34	3.23 ± 0.34	4.34 ± 0.25
28	3.73 ± 0.39	3.31 ± 0.43	3.42 ± 0.20
42	2.82 ± 0.45	3.33 ± 0.27	2.40 ± 0.18

[a]Storage of racks derived from carcasses subjected to hot-boning and electrical stimulation (ES), conventional processing and ES at 1°C.
[b]Mean and standard error of the mean for eight lamb chops.

It was noteworthy that the initial numbers of psychrotrophic bacteria recovered from the surface of cut lamb chops were predominantly lactic acid bacteria and reflected the increase in the number of lactic acid bacteria on the rack surfaces during vacuum storage. A linear relationship has also been observed between the time of pork loin storage in CO_2 and the initial numbers of lactic acid bacteria on chops (Greer *et al.*, 1993) which suggests a transfer of this bacterial group from the loin to the chop surface during cutting.

Another important aspect of the current work was the observation that accelerated processing was not detrimental to the retail case-life of rib chops. Thus, the case-life of rib chops derived from carcasses processed by any treatment was similar, and 2 to 3 days could be achieved following 42 days of primal storage in vacuum. However, there have been data to show even short periods of vacuum packaged storage were detrimental to retail case-life (Fredholm, 1963; Jeremiah, 1971; Jeremiah *et al.*, 1972*a,b,c*; Reagan *et al.*, 1971). Considerable improvement has occurred in both packaging equipment and materials during the past 2.5 decades. Consequently, more recent results tend to support the present findings, since a case-life of 2 days has been observed after nine weeks of primal cut storage (Gill and Penny, 1985).

There are also some limited findings on the effects of electrical stimulation and hot-boning on lamb bacteriology and storage life. Electrical stimulation was without effect on the spoilage flora of lamb (Gill, 1980). In a more comprehensive investigation, Stern (1980) determined the effect of hot-boning and electrical stimulation on the microbiology of lamb cuts. In contrast to the results reported herein, it was found hot-boned cuts had, initially, higher numbers of bacteria than cold-boned cuts. This was attributed to the increased handling of the hot-boned product. However, the actual magnitude of the treatment differences was such that it would be difficult to support this view.

In conclusion, lamb carcass processing can be accelerated using electrical stimulation and hot-boning to increase processing efficiency without concern for the case-life of retail cuts even after 42 days of primal storage at 1°C in vacuum.

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