SHELF-LIFE EXTENSION OF AUSTRALIAN EXPORT CHILLED BEEF – A STUDY IN THE CHINESE SUPPLY CHAIN

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I. INTRODUCTION

A shelf-life of 11-weeks (77-days) is the accepted limit for vacuum packaged chilled beef (VPCB) in many export markets. Recent studies show a much longer shelf-life is achievable (>20 weeks) under ideal temperature conditions (-1 ºC).[1] Microbiological counts, such as lactic acid bacteria (LAB) or aerobic plate counts (APC), underpin traditional shelf-life limits (normally >6-7 $\log_{10}$ CFU cm^2), but they do not always correspond with the sensory characteristics or eating quality. A prediction model developed by the University of Tasmania (UTas), uses initial microbial counts and the temperature-time history to estimate remaining shelf-life; 174-days may be achievable for VPCB at -0.5 ºC. Maintaining ideal temperatures throughout the cold-supply chain is challenging, and few studies incorporate the temperature variations that exist in the real-world supply, especially into rapidly emerging markets such as China. Typical temperature deviations that occur in VPCB throughout the cold-supply chain from the processing plant in Australia, during shipping and within the Chinese distribution network were investigated. Total volatile basic nitrogen (TVB-N) a meat freshness parameter recognized by Chinese authorities was also investigated as an objective marker of VPCB shelf-life.[2]

II. MATERIALS AND METHODS

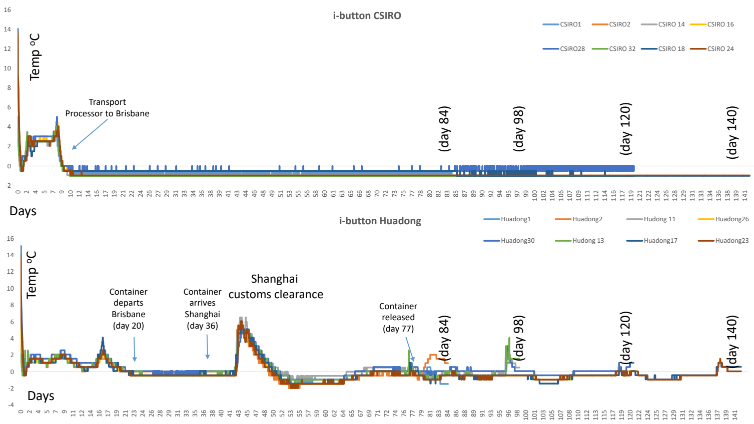
The project was in collaboration with Shandong Agricultural University (SDAU), China. Striploins (*Longissimus lumborum, LL*) from pasture-fed Santa Brahman cross-steers (n=40) were vacuum packaged in Cryovac polymer (oxygen transmission; 30 cc/m^2/ 24 h/@ 23 ºC). *LL* were distributed equally into cartons with temperature loggers (i-buttons) for shipment to three destinations in China. VPCB was shipped under normal commercial arrangements to Shanghai International Port (16-days) and was retained (~40 days) at customs. Control *LL* were also stored under ideal conditions (-1 °C) in Brisbane. Chinese *LL* (n=10 per destination and time point) were transported by road to SDAU at 84, 98, 120 and 140-days for analysis. Meat quality (pH, L* a* b* tristimulus color), APC and LAB counts and sensory assessment of packs were performed simultaneously in China and Australia using standardized methods.[1] The time-temperature deviation (ΔTT) was calculated for each pack. TVB-N was measured using the official method described in the National Standard of the People's Republic of China (GB 2707-2016). Initial micro counts and temperature data for the VPCB were used as input into the UTas model to predict shelf life. Statistical differences between VPCB parameters at different time points and destinations were estimated using REML and correlations and linear regression models were performed using standard procedures in GenStat (16th Ed.).

III. RESULTS AND DISCUSSION

Prior to export, initial microbial counts were within specification for export VPCB; APC and LAB were 2.25 and 2.05 $\log_{10}$ CFU/cm^2 respectively, with no *E. coli* or coliforms detected.

Time temperature trajectories for VPCB are shown (Fig. 1) for control and typical Chinese exported samples. Prior to export, the VPCB spent ~20-days between 0 ºC and 2 ºC and during shipping the temperature was maintained below 0 ºC. Significant ΔTT occurred at customs for all VPCB in China, where temperatures rose to > 3-4 ºC for 5 days. Good temperature control at or below 0 ºC was achieved during storage at the

Figure 1: i-button temperature log histories for VPCB stored at -1 °C, control conditions (top) and Chinese export conditions (bottom).



distribution center and during road transport in China. Control VPCB samples were maintained at -1 ºC during storage, except for some initial deviations during road transportation. Overall, the ΔTT was higher in the Chinese VPCB compared to CSIRO. At the first time point (84-days) microbial counts were ~6 $\log_{10}$ CFU/cm^2 in all packs, close to traditional shelf-life limits, yet sensory assessment of the open packs or post bloom visualization did not indicate spoilage. The pH generally increased but APC and LAB plateaued in VPCB during storage. Pack "freshness "and post-bloom "freshness" deceased in the control VPCB, however in the Chinese samples there was little evidence of a decrease in these parameters over time, except at 140-days. Notably, spoilage odor attributes; "rotten sulfur", "cheesy" and "fruity" did not increase with time, although these attributes were positively associated with ΔTT. Nearly all of the VPCB sensory attributes were correlated with the ΔTT ($p < 0.001$), whereas the APC and LAB were only weakly correlated. Open pack freshness odor ($r = -0.56$, $p < 0.001$) and post bloom freshness smell ($r = -0.65$, $p < 0.001$) were negatively correlated with ΔTT. TVB-N increased over time, and was lower (4.8-7.7 mg/100g) in the control VPCB samples compared to the Chinese (14.8 – 20.6 mg/ 100g). The TVB-N was strongly correlated with ΔTT (0.81, $p < 0.001$) and the sensory attributes; "open freshness" ($r = -0.68$, $p < 0.001$) and "post-bloom freshness" ($r = -0.78$, $p < 0.001$), suggesting TVB-N is an appropriate shelf-life indicator in extended shelf-life VPCB. Most of the Chinese VPCB slightly exceeded the official TVB-N limit of 15 mg/100 g, despite the fact that there was no obvious deterioration in sensory attributes. Some groups have suggested that a TVB-N limit of 20 mg/100 g is more appropriate for beef, in agreement with our findings[3]. This was in accordance with the UTas model which predicted the control VPCB could reach a 180-day shelf life and nearly all of the Chinese samples would achieve 140-days.

IV. CONCLUSION

The cold supply chain was generally robust for the export of VPCB in Australia and China, although critical steps were highlighted where temperature optimization should be considered. TVB-N was a good objective marker of VPCB shelf-life; a limit of 20 mg/100g is recommended. Eating quality studies of VPCB should be conducted using Chinese and Australian consumers. Optimal temperature conditions for the transport of VPCB is critical for both consumer safety and the overall consumer experience of eating beef, and may also help mitigate imminent global food shortages.[4]

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