Final report

The effect of lairage duration on carcase quality, yield and microbiological status of feedlot cattle

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Abstract

The objective of this project was to measure the effect of the duration of time feedlot cattle spend at an abattoir prior to processing, also known as duration of lairage, on carcase yield and quality, animal welfare, and food safety parameters. Fourteen replicates including 2,226 steers were used to compare three durations of lairage including short (4 hours at abattoir), mid (16.5 hours) and long (26.5 hours).

There was a significant hot carcass weight benefit for short duration lairage as compared to mid or long duration lairage. There were animal welfare benefits of reduced dehydration and improved liver glycogen levels for reduced duration lairage. The duration of lairage had no impact on meat quality or food safety parameters.

This large-scale study demonstrated that short-duration lairage is possible on a continuous basis in a commercial environment. The feedlot, transport, and abattoir teams collaborated to implement the practice of short-duration lairage through commitment, communication, and excellent logistical management. Through adoption of short-duration lairage practices, the red meat industry can benefit from increased productivity, profitability, sustainability and animal welfare.

In addition to the R&D results presented as part of this final report, a review and impact assessment was undertaken by two independent agribusiness consultants (Beattie Consulting Services and Richmond Hill Agribusiness). A review of the impact of MLA research, stakeholder engagement process to assess current usage of short duration lairage, requirements for effective use of short duration lairage, and potential and actual challenges associated with adoption of the practice was conducted.

Executive summary

Background

This project measured the effect of lairage duration on hot carcase weight and dressing percentage, meat quality, animal welfare, and food safety parameters of feedlot cattle. This project provides critical results for key stakeholders in the red meat industry including feedlots, transport companies, on-plant veterinarians, government regulators, lairage and logistics coordinators, and abattoirs to evaluate the practice of short-duration lairage. The results of this study provide scientific evaluation of the practice of short-duration lairage to clearly quantify the benefits and risks of this practice.

Objectives

This project determined the effect of lairage duration on carcase yield including hot carcase weight, dressing percentage, and liver and muscle glycogen levels. This projected determined the effect of lairage duration on animal welfare through measurement of hydration status, liver and muscle glycogen levels, ultimate pH, and meat colour. This project determined the effect of lairage duration on food safety parameters. The results of this project have been communicated to stakeholders through publications and presentations and on-going communications and adoption activities will be the focus of MLA moving forward.

Methodology

A single-blinded randomized complete block design was used to compare three durations of lairage including short (4 hours), mid (16.5 hours), and long (26.5 hours) duration. Specifically, this project was completed in 14 replicates including 2,226 individual animals.

Results

Reduced lairage duration is possible in a large-scale commercial feedlot and abattoir environment. Short duration lairage yielded a 7.4 kg advantage ($P \leq 0.05$) in hot carcase weight as compared to mid-duration lairage. Short duration lairage yielded a 6.2 kg advantage ($P \leq 0.05$) in hot carcase weight as compared to long-duration lairage. The duration of lairage had a significant ($P \leq 0.05$) effect on packed cell volume, meaning that cattle exposed to longer duration of lairage were more dehydrated as compared to cattle exposed to shorter duration lairage. The duration of lairage had a significant ($P \leq 0.05$) effect on levels of glycogen in the liver, meaning that cattle exposed to longer duration of lairage mobilized glycogen reserves in their livers to maintain blood glucose status. Total microbiological counts (standard plate counts, coliform counts, *E.coli* counts, and *Salmonella* spp. detection) and the proportion of carcasses with microbiological contamination were not affected by duration of lairage ($P > 0.05$). There was no effect of lairage duration on meat quality or food safety parameters.

Benefits to industry

This project demonstrated that reduced lairage duration provided a significant benefit in the profitability across the supply chain and improved sustainability by increasing the hot carcass weight per individual animal. Additionally, this project demonstrated the clear animal welfare benefits associated with implementing short duration lairage.

Future research and recommendations

Future work should focus on opportunities to simplify the logistical challenges associated with implementing short duration lairage in a commercial environment including electronic submission of regulatory paperwork such as National Vendor Declarations, transport scheduling, ante-mortem inspection scheduling, and improving coat cleanliness prior to abattoir arrival to reduce washing intervals required prior to slaughter during winter conditions.

Review and impact assessment

The results from B.FLT.4017 (this project) and the previous pilot study (B.FLT.4002) have demonstrated that large economic benefits can be achieved from use of short duration lairage of four hours or less. Considering previous MLA research, the value of an additional 5.7 kg HSCW was estimated at $35/head using five-year average historical prices. Extrapolation of this estimated benefit across the average number of grain fed cattle processed over the past 5 years represents the potential for an additional $97 million worth of HSCW from grain fed cattle in Australia annually.

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1. Background

The period of time and location where cattle are housed between arrival at an abattoir and slaughter is termed 'lairage'. Cattle are held in lairage to rest following transportation, to accumulate in numbers to facilitate a consistent supply of cattle to the slaughter floor during business hours, to reduce the volume of contents in the gastrointestinal tract prior to slaughter, and to allow scheduling of slaughter times for specific vendors and cattle types for more efficient chilling and boning room schedules (Jacob, 2009). Lairage is also a critical control point for food safety and animal welfare, as it provides an area for ante-mortem inspection by on-plant veterinarians to ensure the cattle are free from clinical signs of disease and any potential contamination that could affect the slaughtered carcase (Grandin et al., 2020; AMPC, 2019).

In Australian abattoirs, cattle have access to water during lairage . Rarely are cattle provided access to feed during lairage. The facilities in lairage are diverse and may include compacted earth or concrete floors, shaded or unshaded pens, and wooden or metal fences. The duration of time feedlot cattle spend in lairage in Australian conditions is highly variable and can range between 2-36 hours, but more commonly ranges between 12-24 hours (Ferguson et al., 2007). Feedlot cattle are commonly transported from the feedlot to the abattoir the day prior to slaughter and hence spend overnight in lairage on the day prior to slaughter. This practice results in a period of time off feed that often exceeds 12 hours prior to slaughter. Interestingly, this practice has been largely eliminated in the USA following the 1991 US Beef Quality Audit that 'rough handling and holding cattle overnight or over the weekend causes about 20% percent of dark-cutters (NCBA, 1992). However, the duration of lairage for feedlot cattle in Australia has largely remained un-changed over the past 30 years and the practice of overnight lairage of feedlot cattle is still widely accepted in Australia.

Transportation, handling, and lairage of cattle prior to slaughter can be stressful and contribute to the depletion of muscle glycogen (Giannetto et al., 2011, Romero et al., 2013). It is possible that by investigating strategies to minimise stress, such shorter lairage duration, that carcase weight and meat quality can be optimised. In a recent review of welfare of fed cattle in US abattoir industry, it was acknowledged that little research has been conducted on lairage duration, partly due to an processing industry perception that cattle condition does not deteriorate in lairage (Edwards-Callaway and Calvo-Lorenzo, 2020).

Australian literature on lairage duration of feedlot cattle reports varying results. Ferguson et al. (2007) compared 3 vs. 18 h lairage in a study involving 196 steers transported 150 km to slaughter in Autumn. Cattle from the 3 h lairage treatment had a 15.3 kg advantage in bled body weight ($P < 0.05$), although the difference in hot carcase weight (1.3 kg) was not statistically significant. No difference in muscle glycogen, ultimate pH or ingesta contamination was reported. The authors concluded that differences in bled body weight were due to digestive tract fill differences with shorter durations of fasting.

A larger study involving 400 grain-fed heifers in summer reported a 2.4 kg advantage in hot carcase weight, a 0.5% advantage in dressing percentage, and 0.15% higher muscle glycogen levels for heifers slaughtered in the morning, compared those slaughtered in the afternoon. (George and George, 2018). Heifers that were shipped and slaughtered in the morning the same day (1.7 h lairage) yielded carcasses that were numerically 3.9 kg heavier than cattle shipped in the morning and slaughtered that afternoon (7.2 h lairage), 3.0 kg heavier than cattle shipped the previous afternoon and slaughtered the following morning (13.3 h lairage), and 3.8 kg heavier than cattle shipped the previous afternoon and slaughtered the following afternoon (19.5 h lairage). This study recommended that time off feed prior to slaughter be reduced to less than 4 hours, lairage duration be reduced to less than 3 hours, and chilling duration increased to a minimum of 18 hours to reduce the incidence of dark-cutting in Australian feedlot heifers with an average hot carcase weight of 225-325 kg. However, the authors hypothesized the effect of lairage duration on meat colour was merely a small part of a much larger and more significant issue around time to grading standards at abattoirs.

The effect of lairage duration on food safety is an area of contest with some hypothesizing that reduced lairage duration and time off feed improve food safety by reducing the pH of the digestive tract and improving gut membrane integrity. However, other suggest that reduced lairage duration and shorter time off feed leads to increased incidence of gut rupture during evisceration and subsequent carcase contamination due to increased gut fill. The published literature does not suggest that increased gut fill is associated with increased carcase contamination due to problems during evisceration (Ferguson et al., 2007; Wythes et al., 1984). Pre-harvest conditions including transportation, lairage, and diet can impact the gut microflora, level of shedding, and hide load of various microorganisms associated with food safety of beef carcases and products. Early work in this area found the prevalence of *Salmonella* spp. in the rumen was greater the longer the time period between cattle exiting a property and slaughter (Grau et al., 1968). However, the time periods tested ranged from 24h to 168h and these durations of transport and lairage are much longer than those typical of current feedlot industry practices. Cattle exposed to a longer duration of lairage may be withheld from feed for a longer period and thus present with reduced gut fill at slaughter which may reduce the incidence of spillage of gastrointestinal tract contents and the microorganisms present in those contents. Alternatively, cattle exposed to longer duration of lairage are known to have increased rumen pH favouring microbiological growth (Grau et al., 1968), and reduced gut membrane integrity which may increase the numbers of microorganisms present in the gastrointestinal tract and increase the incidence of rupture of gastrointestinal tracts during slaughter. The incidence of salmonellosis in cattle increases with stress such as transportation and lairage stress (Grau and Smith, 1974). Thus, a primary area of focus for the present study was to determine the effect of lairage duration on food safety parameters including total plate counts, coliforms, *E. coli,* and *Salmonella* in faeces, on hides, and on chilled-carcasses. This project provides valuable information to present to food safety regulators, processors, and on-plant veterinarians to evaluate the safety of short-duration lairage.

The present study aimed to evaluate the effect of lairage duration on carcase yield, quality and microbiological status in a large and industry-relevant data set while controlling factors such as chilling duration. Given inherent variation of experimental units within treatment (experimental error) due to such factors as randomisation to treatment, transportation, and variation is fat trimming in plant, large numbers of animals per experimental unit (dispatch pen), and adequate replication of pens are required to detect treatment differences if they exist. This study involved 2,226 feedlot steers in 14 dispatch pen replicates allowing advantages to detect treatment differences over previous smaller studies.

This study also evaluated the effect of lairage duration on the welfare of cattle by measuring key indicators of animal welfare including hydration status, liver and muscle glycogen levels, ultimate pH, and meat colour. Although cattle in lairage have access to water troughs, this does not mean that all cattle will drink and re-hydrate following transport. Hence, the present study focused on measuring several key indicators of hydration status including urine specific gravity, packed cell volume, and total protein of blood.

This MLA funded project was initiated with an integrated beef supply system to complete a commercial-scale investigation of short lairage. This project is consistent with the Red Meat Advisory Council's Red Meat 2030 strategic plan, increasing the value and yield of carcases and improving the health and welfare of our animals. The results of this project will provide feedlot producers, livestock transporter companies, abattoirs, on-plant veterinarians, beef processors, food safety regulators, and the Australian government data to evaluate the effect of lairage duration on carcase quality and yield and the safety of the practice in regards to microbiological contamination. The outcomes of this project will also be used to identify potential hurdles for adoption of the practice and methodologies to overcome those hurdles.

2. Objectives

2.1 Determine the effect of lairage duration on carcase yield including hot carcase weight, dressing percentage, and muscle glycogen levels

The effect of lairage duration of hot carcase weight, dressing percentage, and liver glycogen levels were compared by testing three durations of lairage including short (4 hours), mid (16.5 hours), and long (26.5 hours) duration in 14 replicates including 2,226 individual grainfed cattle.

2.2 Determine the effect of lairage duration on animal welfare through measurement of liver and muscle glycogen levels, ultimate pH, and meat colour

The effect of lairage duration on animal welfare parameters including hydration status (packed cell volume, total protein, urine specific gravity), liver glycogen levels, ultimate pH, and meat colour was evaluated.

2.3 Determine the effect of lairage duration on food safety parameters

Specific plate counts, coliform counts, *E.coli* counts, and *Salmonella* detection were completed on faeces, hide swabs, and chilled carcase swabs to determine the effect of lairage duration on food safety parameters.

2.4 Effectively communicate the results of this research to stakeholders through publications and presentations.

The results of this study have been widely communicated with the feedlot industry through a webinar hosted by the Australian Lot Feeders Association, project team meetings, key industry stakeholder meetings, and numerous virtual meetings with various industry organisations as requested by Meat & Livestock Australia.

3. Methodology

3.1 Animal welfare

This project was completed under the approval of the Queensland Government Department of Agriculture and Fisheries Animal Ethics Committee (Animal Ethics Committee Reference Number: SA 2021/11/811).

3.2 Experimental design

A single-blinded randomized complete block design was used to evaluate the effect of duration of lairage on animal welfare, carcass characteristics, and microbiological contamination of feedlot cattle.

The study compared three durations of lairage including 4, 16.5, and 26.5 hours.

Specifically, this project was completed in 14 replicates for a total of 2,226 steers. The experimental unit was the dispatch pen.

3.3 General

The cattle were fed at a commercial feedlot located in Condamine, Queensland, Australia and processed at a large, commercial abattoir in Brisbane, Queensland, Australia. The experiment was conducted from November to December 2021. At the feedlot, cattle had a stocking density of 14 m^2 per individual and were housed in cloth shaded experimental pens (3.0 m^2 shade per individual) with concrete feed bunks (25 cm per individual) and water troughs (75 mm per individual). Cattle were fed ad libitum with two deliveries per day.

The cattle were crossbred steers with low bos-indicus influence. The cattle had an average induction weight of 432.0 kg and were fed for 176 days on a high energy steam-flaked wheat ration that exceeded NRC 2016 requirements for beef cattle (National Academies of Sciences and Medicine, 2016). At the time of induction to the feedlot, steers were implanted with 20 mg 17-β oestradiol and 200 mg trenbolone acetate, vaccinated against Infectious Bovine Rhinotracheitis and *Mannheimia haemolytica*, and dewormed with an oral albendazole.

A home pen of 318 head were drafted from their feedlot pen into six experimental trucking pens of 53 individual cattle one week prior to feedlot exit. This is a normal time when cattle are drafted and scanned to ensure the cattle are free of a withholding period and fit for transport to an abattoir. Importantly, a randomisation schedule was used to balance trucking pen, lairage pen, and slaughter order to ensure these variables were balanced among treatments. Importantly, cattle were not mixed with new cattle or comingled at this time.

Cattle were randomised to one of the 3 following treatments:
a) Treatment 1 (Short): Depart feedlot at 5:00 a.m. the day of slaughter
b) Treatment 2 (Mid): Depart feedlot at 4:00 p.m. the day preceding slaughter
c) Treatment 3 (Long): Depart feedlot at 5:30 a.m. the day preceding slaughter

Each pen of cattle was transported from the feedlot to a large commercial abattoir in a separate B-Double combination truck with air bags for approximately 5.5 hours and a total distance of approximately 350 km. Observed average time at dispatch was 04:52, 15:58 and 6:02 for short, mid and long treatments, respectively (Table 3). All trucks of cattle were truck-weighed at feedlot exit on a calibrated weigh-bridge. Unloading and penning of cattle at the abattoir was audited. Cattle were unloaded from the truck into an allocated shaded abattoir pen with dirt floors (220 m^2, 3.0 m^2 per individual) with a water trough (3.0 meters x 0.6 meters). Cattle were not provided feed or hay during lairage. Cattle received a gentle belly wash of non-potable water from spray nozzles on the floor of concrete-floored abattoir holding pens for 30 minutes approximately 2 hours prior to slaughter. Fifteen minutes prior to slaughter, cattle received an additional potable water wash delivered from overhead in a holding yard for approximately 30 seconds.

Cattle were stunned with a non-penetrative stunner and processed according to industry standards. Observed time at stun was 14:48, 14:32 and 14:25 for short, mid and long treatments, respectively (Table 3). Immediately following exsanguination via severance of the carotid artery and jugular vein, all cattle were electrically stimulated to facilitate further exacerbate exsanguination. Electronic radio frequency identification, time of stun, visual identification, and body number were recorded. Carcasses were processed according industry standards and were chilled for an average of 17 hours prior to grading.

3.4 Sampling frequency for laboratory testing

A subset of 10% of the carcases were sampled for further laboratory testing. Samples included blood, hide swab, urine, liver, faeces, muscle, and chilled carcase swab. Specifically, samples were taken from the sample carcases for all of these testing procedures.

3.5 Packed cell volume and total protein of blood

Approximately 10 mL of whole blood was sampled into an EDTA tube during jugular exsanguination. Tubes were inverted five times and stored in a cooler with an ice pack until return to the laboratory. Capillary tubes were filled with blood and packed with clay. Tubes were centrifuged for five minutes at 10,000 RPM. Packed cell volume was measured using a haematocrit reader. Total protein of the plasma was measured using a refractometer.

3.6 Urine specific gravity

A urine sample was obtained post mortem by placing an 18-gauge needle connected to a 10 mL syringe into the bladder on the inspection table. The urine samples were stored in a cooler with an ice pack until return to the laboratory. Urine specific gravity was measured using a refractometer.

3.7 Liver Glycogen

A minimum 3 g tissue sample (approximately 2cm x 2cm x 2cm cube) was collected from the visceral surface of the liver near the bile duct. Samples were trimmed, placed into a cryovial tube with a screw-top lid, and immediately frozen in liquid nitrogen. Samples were transported in a liquid nitrogen tank to the laboratory where they were transferred to a freezer and stored at -20°C until laboratory analysis. Laboratory analyses for liver glycogen levels were conducted according to methods described by Coombes et al., 2014.

3.8 Muscle Glycogen

A minimum 2 g tissue sample (approximately 1cm x 1cm x 1cm cube) was collected from *Longissimus thoracis* at the location of 12th and 13th rib. Samples were taken prior to entry to the chillers and within 1 hour of stun at the same location on the chain to ensure sampling time post-mortem was consistent between samples. Samples were trimmed, placed into a cryovial tube with a screw-top lid, and immediately frozen in liquid nitrogen. Samples were transported in a liquid nitrogen tank to the laboratory where they were transferred to a freezer and stored at -20°C until laboratory analysis. Laboratory analyses for muscle glycogen levels were conducted according to methods described by Coombes et al., 2014.

3.9 Faecal sample

Approximately 50 g of faeces was collected from the rectocolon portion of the gastrointestinal tract, approximately 10-30 cm proximal to the anus. Faecal samples were stored in sterile 70 mL storage containers in a cooler with an ice pack until delivery to the laboratory for microbiological analysis.

3.10 Hide swab

Samples were obtained while wearing sterile gloves. Prior to hide removal, a 100 cm^2 area of the right butt (S3) site were swabbed using a Whirl-Pack sponge. A 10x10 cm grid was used to ensure sample size accuracy. The area was swabbed with 5 strokes on each side of the sponge and the sponge was stored into 25 mL Buggered Peptone Water in an individually labelled Whirl-pack bag.

3.11 Chilled carcase swab

Samples were obtained while wearing sterile gloves. Chilled carcass swabs were completed on a 300 cm^2 area including 3 x 100 cm^2 sites including the flank, brisket, and butt. One side of the sponge was used to sample the flank and brisket and the other side to sample the butt. The areas were swabbed with 10 strokes at each site and the sponge was stored into 25 mL Buggered Peptone Water in an individually labelled Whirl-pack bag.

3.12 Microbiological testing

Faecal, hide, and chilled carcase samples were stored at 1-5 degrees Celsius, and transported to the NATA accredited laboratory (Symbio Laboratories, Eight Mile Plains, Queensland, Australia) for analyses. Testing was completed in accordance with the 'Microbiology manual for sampling and testing of export meat and meat products' (DAWR, Version 1.03, Dec 2018). Testing was completed in accordance with the 'Microbiology manual for sampling and testing of export meat and meat products' (DAWR, Version 1.03, Dec 2018). Standard plate counts, coliform counts, and *E. coli* counts were completed by petrifilm. Identification of *Salmonella* spp. will was completed by rtPCR.

3.13 Carcase measurements

Hot standard carcase weight was recorded after evisceration and trimming according to the Aus-meat standard carcase trim requirements. After chilling for approximately 17 hours, chiller assessment was conducted by qualified plant graders. Body number, dentition, Aus-meat meat colour, MSA marbling, AusMeat marbling, pH at chiller assessment at the *M. longissimus dorsi* quartering site, fat colour, subcutaneous rib fat at the *M. longissimus dorsi* (Aus-meat standard site), P8 fat depth, left side bruise, right side bruise, left hot standard carcase weight, right hot standard carcase weight, total hot standard carcase weight, and eye muscle area at the *M. longissimus dorsi* quartering site. pH meters were calibrated prior to each grading session and every two hours within a session by qualified plant graders. Temperature probes were calibrated. Dressing percentage was calculated as the hot carcase weight divided by the truck weight times 100.

3.14 Statistical analyses

Data was analysed as a randomised complete block design with the experimental unit defined as the pen. The experiment was analysed using the PROC MEANS and PROC MIXED procedures of SAS (SAS Institute Inc., Cary, North Carolina, USA). Least square means were separated using the PDIFF procedure where significance was detected. For analyses, treatment was included in the model as a fixed effect. Block was included in the model as a random effect. Statistical significance of main effects were defined at $P \leq 0.05$ and a trend at $P \leq 0.10$ levels. Means were separated using the PDIFF option if significance of main effects *were* $P \leq 0.05$. Proc GLIMMIX was used for binomial data, specifically for presence/abscence microbiological data.

4 Results

4.1 Descriptive statistics

Simple descriptive statistics including average, standard deviation, minimum, and maximum values for 42 pens (14 blocks) of research cattle are presented in Table 1. These results provide a general overview of the data set. The steers (n=2,226) had an average induction weight of 432.0 ± 10.0 kg (mean ± standard deviation), were fed for 176.2 ± 2.5 days, weighed 739.2 ± 16.8 kg at feedlot exit, and had a dressing percentage of 54.56% ± 0.67 to produce a hot carcase weight of 403.3 ± 9.3 kg. Mean liver glycogen percentage was 4.79% ± 0.68%. Mean muscle glycogen was 1.44% ±0.12. Mean packed cell volume was 46.5% ± 1.7%.

Descriptive statistics for carcass quality grading and yield measurements are reported in Table 2. Carcases had an average MSA marbling score of 332.1 ± 12.5, Ausmeat meat colour of 2.2 ± 0.2, eye muscle area of 82.0 ± 4.4 cm^2 and ultimate pH of 5.56 ± 0.02. Standard plate counts, coliform counts, and *E. coli* counts are displayed in Table 2.

4.2 Effect of duration of lairage on carcase characteristics

There was no difference in entry weight *(P =* 0.27), average daily gain *(P =* 0.39), feedlot exit weight *(P =* 0.18), or dressing percentage *(P =* 0.16) among the three treatments of lairage duration (Table 3).

Cattle in the short-duration lairage treatment exited the feedlot at 4:52 AM on the day of slaughter, arrived at the abattoir at 10:27 AM on the day of slaughter, spent 4 hours and 20 minutes in lairage, were stunned at 2:48 PM to yield a total of 9 hours and 55 minutes off feed prior to stun, and were MSA graded 16 hours and 59 minutes later at 7:48 AM the day following slaughter (Table 3).

Cattle in the mid-duration lairage treatment exited the feedlot at 3:58 PM on the day prior to slaughter, arrived at the abattoir at 9:54 PM on the day prior to slaughter, spent 16 hours and 36 minutes in lairage, were stunned at 2:32 PM to yield a total of 22 hours and 33 minutes off feed prior to stun, and were MSA graded 16 hours and 49 minutes later at 7:21 AM the day following slaughter (Table 3).

Cattle in the long-duration lairage treatment exited the feedlot at 6:02 AM on the day prior to slaughter, arrived at the abattoir at 11:42 AM on the day prior to slaughter, spent 26 hours and 42 minutes in lairage, were stunned at 2:25 PM to yield a total of 30 hours and 39 minutes off feed prior to stun, and were MSA graded 17 hours and 9 minutes later at 7:34 AM the day following slaughter (Table 3).

The duration of lairage had a significant effect on hot carcase weight *(P =* 0.03). Carcases from the short duration lairage treatment were 7.4 kg heavier *(P ≤* 0.05) than carcases from the mid-duration lairage treatment. Carcases from the short duration lairage treatment were 6.2 kg heavier *(P ≤* 0.05) than carcases from the long-duration lairage treatment. There was no difference in hot carcase weight between mid and long-duration lairage.

The duration of lairage had a significant effect on packed cell volume (*P* ≤ 0.01). Cattle in the short-duration lairage treatment had lower (*P* ≤ 0.05) packed cell volume than cattle in mid or long duration lairage treatments.

Liver glycogen levels were significantly impacted *($P \leq 0.01$)* by the duration of lairage. Specifically, cattle exposed to short-duration lairage had the highest liver glycogen levels (5.37%), cattle exposed to mid-duration lairage had the intermediate liver glycogen levels (4.91%), and cattle exposed to long-duration lairage had the lowest liver glycogen levels (4.10%) ($P \leq 0.05$). Despite liver glycogen being different, muscle glycogen did not differ between treatments.

There was no effect of duration of lairage on MSA marbling *($P = 0.60$)*, meat colour *($P = 0.10$)*, eye muscle area *($P = 0.60$)*, rib fat thickness ($P = 0.66$), chiller assessment pH *($P = 0.25$)*, or MSA index *($P = 0.40$)* (Table 3).

4.5 Effect of duration of lairage on microbiological parameters of faecal samples, hides, and chilled-carcasses

There was no difference *($P > 0.10$)* in standard plate count, coliforms count, *E. coli* count, and *Salmonella* detection for faecal samples, hides, or chilled carcasses between the three durations of lairage (Table 4). There was no difference ($P > 0.10$) between durations of lairage in the proportion of faecal samples, hides, or chilled carcasses with positive standard plate counts, positive coliform counts, positive *E. coli* counts, and positive *Salmonella* detections (Table 5).

Table 1. Descriptive statistics of pens of study steers (n=42 pens, n=2226 steers)

Variable	Mean	Stdev	Minimum	Maximum
Entry Weight, kg	432.0	10.0	404.0	450.3
Days on feed	176.2	2.5	173.0	182.1
Average daily gain, kg/hd	1.74	0.09	1.61	1.96
Cattle weight at feedlot exit per hd, kg/hd	739.2	16.8	707.5	772.6
Hot carcase weight, kg	403.3	9.3	386.4	433.2
Dressing percent, %	54.56	0.67	53.29	57.11
Time of feedlot exit	8:57 am	5:10	4:00 am	4:35 pm
Time of abattoir arrival	2:41 pm	5:20	8:58 am	10:49 pm
Time of stun at abattoir	2:35 pm	1:30	10:58 am	6:38 pm
Time of grade at abattoir	7:34 am	1:12	4:50 am	12:08 pm
Duration of time in lairage, hours	15:53	9:22	2:29	4:26
Duration of time off feed prior to stun, hours	21:02	9:26	7:40	10:06
Duration of time from stun to grade, hours	16:59	0:44	15:47	19:03
Urine Specific Gravity	1.029	0.005	1.017	1.040
Liver glycogen, %	4.79	0.68	3.53	6.02
Muscle glycogen, %	1.44	0.12	1.24	1.93
Packed Cell Volume	46.5	1.7	43.2	51.4
Total Protein	91.2	3.6	78.0	97.3

Table 2. Descriptive statistics for carcase grading and food safety

Variable	Mean	Stdev	Minimum	Maximum
MSA marbling	332.1	12.5	287.2	353.8
AusMeat marbling	1.0	0.1	0.6	1.2
AusMeat meat colour‡	2.2	0.2	1.9	2.5
Fat colour	1.0	0.3	0.1	1.5
Eye muscle area, cm^2	82.0	4.4	74.9	93.8
Rib fat, mm	7.8	1.4	4.9	10.5
P8 fat, mm	19.8	2.5	13.2	23.8
Dentition	2.2	0.4	1.6	3.0
Chiller assessment pH	5.56	0.02	5.51	5.61
MSA index	50.11	1.27	46.74	52.51
Faeces standard plate count, CFU/cm^2	1.9×10^6	1.8×10^6	1.9×10^5	7.3×10^6
Faeces coliform count, CFU/cm^2	1.5×10^5	1.1×10^5	3.3×10^3	4.5×10^5
Faeces E. coli count, CFU/cm^2	1.4×10^5	1.1×10^5	3.3×10^3	4.5×10^5
Faeces Salmonella count, CFU/cm^2	0.0×10^0	0.0×10^0	0.0×10^0	0.0×10^0
Hide-on standard plate count, CFU/cm^2	2.7×10^6	4.1×10^6	5.1×10^4	1.3×10^7
Hide-on coliform count, CFU/cm^2	5.9×10^4	8.8×10^4	1.9×10^2	2.7×10^5
Hide-on E. coli count, CFU/cm^2	5.4×10^4	7.8×10^4	1.9×10^2	2.4×10^5
Hide-on Salmonella count, CFU/cm^2	0.0×10^0	0.0×10^0	0.0×10^0	0.0×10^0
Chiller standard plate count, CFU/cm^2	1.9×10^4	4.8×10^4	0.0×10^0	1.6×10^5
Chiller coliform count, CFU/cm^2	2.0×10^0	8.3×10^0	0.0×10^0	5.2×10^1
Chiller E. coli count, CFU/cm^2	4.0×10^{-1}	1.7×10^0	0.0×10^0	8.0×10^1
Chiller Salmonella count, CFU/cm^2	0.0×10^0	0.0×10^0	0.0×10^0	0.0×10^0

‡Meat colour was scored as 1A=1.00, 1B=1.33, 1C=1.67, 2=2.00, 3=3.00, 4=4.00, 5=5.00, 6=6.00.

Table 3. Effect of duration of lairage on carcase characteristics

	Duration of Lairage				
Variable	Short	Mid	Long	SE	*P-value*
Entry Weight, kg	434.6	429.6	431.9	2.673	0.27
Average daily gain, kg/hd	1.75	1.73	1.75	0.025	0.39
Cattle weight at feedlot exit per hd, kg/hd	744.4	735.0	738.1	4.483	0.18
Hot carcase weight per hd, kg/hd	407.8[a]	400.4[b]	401.6[b]	2.397	0.03
Dressing percent, %	54.79	54.48	54.41	0.178	0.16
Time of feedlot exit	4:52[a]	15:58[b]	6:02[c]	0.013	<0.01
Time of abattoir arrival	10:27[a]	21:54[b]	11:42[c]	0.014	<0.01
Time of stun at abattoir	14:48	14:32	14:25	0.017	0.56
Time of grade at abattoir	7:48	7:21	7:34	0.014	0.45
Duration of time in lairage, hours	4:20[a]	16:36[b]	26:42[c]	0.018	<0.01
Duration of time off feed prior to stun, hours	9:55[a]	22:33[b]	30:39[c]	0.044	<0.01
Duration of time from stun to grade, hours	16:59	16:49	17:09	0.008	0.31
Urine Specific Gravity	1.029	1.029	1.028	0.001	0.57
Liver glycogen, %	5.37[a]	4.91[b]	4.10[c]	0.117	<0.01
Muscle glycogen, %	1.44	1.44	1.40	0.027	0.44
Packed Cell Volume	45.4[a]	46.4[a]	47.6[b]	0.404	<0.01
Total Protein	90.3	91.1	92.1	0.955	0.25
MSA marbling	331.8	334.2	330.3	3.390	0.60
AusMeat marbling	1.0	1.0	1.0	0.028	0.79
AusMeat meat colour‡	2.2	2.3	2.1	0.044	0.10
Fat colour	0.9	1.0	0.9	0.075	0.44
Eye muscle area, cm^2	82.8	81.1	82.1	1.189	0.60
Rib fat, mm	8.0	7.8	7.6	0.390	0.66
P8 fat, mm	20.2	19.8	19.3	0.683	0.45
Dentition	2.2	2.2	2.3	0.097	0.58
Chiller assessment pH	5.56	5.57	5.55	0.006	0.25
MSA index	50.49	49.88	49.95	0.340	0.40

‡Meat colour was scored as 1A=1.00, 1B=1.33, 1C=1.67, 2=2.00, 3=3.00, 4=4.00, 5=5.00, 6=6.00.

[abc]Means with different superscripts differ $P \leq 0.05$

Table 4. Effect of duration of lairage on microbiological contamination

	Duration of Lairage				
Variable	Short	Mid	Long	SE	*P-value*
Faeces standard plate count, CFU/cm^2	$1.8x10^6$	$2.0x10^6$	$1.8x10^6$	$4.8x10^5$	0.89
Faeces coliform count, CFU/cm^2	$1.2x10^5$	$1.6x10^5$	$1.7x10^5$	$3.0x10^4$	0.10
Faeces E. coli count, CFU/cm^2	$1.1x10^5$	$1.5x10^5$	$1.6x10^5$	$3.0x10^4$	0.11
Faeces Salmonella count, CFU/cm^2	$0.0 x 10^0$	$0.0 x 10^0$	$0.0 x 10^0$	n/a	1.00
Hide-on standard plate count, CFU/cm^2	$3.1x10^6$	$2.6x10^6$	$2.2x10^6$	$1.1x10^6$	0.13
Hide-on coliform count, CFU/cm^2	$8.1x10^4$	$4.7x10^4$	$5.0x10^4$	$2.4x10^4$	0.24
Hide-on E. coli count, CFU/cm^2	$7.1x10^4$	$5.0x10^4$	$5.3x10^4$	$2.2x10^4$	0.49
Hide-on Salmonella count, CFU/cm^2	$0.0 x 10^0$	$0.0 x 10^0$	$0.0 x 10^0$	n/a	1.00
Chiller standard plate count, CFU/cm^2	$2.3x10^4$	$2.2x10^4$	$1.2x10^4$	$1.3x10^4$	0.73
Chiller coliform count, CFU/cm^2	$6.2x10^{-1}$	$3.8x10^0$	$1.5x10^0$	$2.2x10^0$	0.45
Chiller E. coli count, CFU/cm^2	$5.4x10^{-1}$	$7.1x10^{-2}$	$5.7x10^{-1}$	$4.5x10^{-1}$	0.68
Chiller Salmonella count, CFU/cm^2	$0.0 x 10^0$	$0.0 x 10^0$	$0.0 x 10^0$	n/a	1.00

Table 5. Proportion of faeces, hides, and carcases with microbiological contamination

	Duration of Lairage			
Variable	Short	Mid	Long	*P-value*
Faeces standard plate count, carcases				
Positive count	67 (100.0%)	71 (100.0%)	72 (100.0%)	1.00
No microbes detected	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Faeces coliform count, carcases				
Positive count	67 (100.0%)	71 (100.0%)	71 (98.6%)	1.00
No microbes detected	0 (0.0%)	0 (0.0%)	1 (1.4%)	
Faeces E. coli count, carcases				
Positive count	66 (98.5%)	71 (100.0%)	69 (97.2%)	0.87
No microbes detected	1 (1.5%)	0 (0.0%)	2 (2.8%)	
Faeces Salmonella count, carcases				
Positive count	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
No microbes detected	67 (100.0%)	71 (100.0%)	72 (100.0%)	
Hide-on standard plate count, carcases				
Positive count	72 (100.0%)	71 (100.0%)	69 (100.0%)	1.00
No microbes detected	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Hide-on coliform count, carcases				
Positive count	72 (100.0%)	71 (100.0%)	69 (100.0%)	1.00
No microbes detected	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Hide-on E. coli count, carcases				
Positive count	72 (100.0%)	71 (100.0%)	68 (98.6%)	1.00
No microbes detected	0 (0.0%)	0 (0.0%)	1 (1.4%)	
Hide-on Salmonella count, carcases				
Positive count	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
No microbes detected	72 (100.0%)	71 (100.0%)	69 (100.0%)	
Chilled carcase standard plate count, carcases				
Positive count	29 (40.3%)	26 (37.1%)	28 (40.0%)	0.92
No microbes detected	43(59.7%)	44 (62.9%)	42 (60.0%)	
Chilled carcase coliform count, carcases				
Positive count	3 (4.2%)	1 (1.4%)	4 (5.7%)	0.46
No microbes detected	69 (95.8%)	69 (98.6%)	66 (94.3%)	
Chilled carcase E. coli count, carcases				
Positive count	2 (2.8%)	1 (1.4%)	2 (2.9%)	0.83
No microbes detected	72 (97.2%)	70 (98.6%)	68 (97.1%)	
Chilled carcase Salmonella count, carcases				
Positive count	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
No microbes detected	72 (100.0%)	70 (100.0%)	70 (100.0%)	

5 Discussion

Feedlot cattle dispatch, transportation and lairage management are commonly overlooked areas of opportunity for the Australian feedlot industry. Removal of cattle from their home pen, loading, transportation and lairage can be inherently stressful events if not managed correctly. This may lower feed and water intake producing tissue shrink, tissue catabolism and lower carcase weight (Schaefer et al. 2001). Multiple approaches have been investigated to manage this period for feedlot cattle including feed and water provision to the point of dispatch (George et al. 2022), minimising time in lairage (Clariget et al. 2021; George & George, 2018), electrolytes either pre or post transportation (Schaefer et al. 1997), rest periods (Shorthose et al. 1972; Wythes et al. 1980 ab) and ante-mortem feeding (Schaefer et al. 2006).

For logistics purposes, cattle are often transported to lairage the day before slaughter to ensure they are present for a single antemortem inspection by the on-plant veterinarian, and the inventory of cattle is available for the following days slaughter to ensure a constant processing rate. Whilst the Australian processing industry has evolved to procure cattle from extensive pastoral properties with long-haul transportation, in the last decade the feedlot industry has grown to support a high concentration of enterprises within a 6 hour haul of most abattoirs. This may enable for a portion of the daily slaughter inventory the practice of short duration lairage (≤ 4 hours in lairage), contingent on cattle passing their ante-mortem inspection.

For Australian grass-fed cattle, research has evaluated recovery periods (rest, feed and water) after a 42 h rail journey where cattle were without feed for 4 days (Shorthouse et al. 1972); water and feed removal (dry curfew) for periods between 12 to 72h, followed by rehydration period of 48 h, and final 12 h dry curfew (Whythes et al. 1980a); and provision of either water (0 to 32 h) or water plus feed (32 h) after a 1420 km journey, prior to a further 16 h dry curfew pre-slaughter (Whythes et al. 1980b). In general, these studies reported that limiting dry curfew periods at saleyards and provision of water at the abattoir (prior to further pre-slaughter dry curfew periods) maximized carcase weight. In addition, the authors observed that rest periods of greater than 2 days in long haul cattle (either on feed + water; or water) decreased pH decline in carcases post-mortem. Whythes et al. (1981; 1983) further promoted animal welfare in the Australian beef industry by demonstrating provision of water in saleyards and abattoirs (wet curfew; water but no feed) had liveweight gain advantages over dry curfew practices for long-haul journeys.

Whilst the research of Whythes and Shorthose was critical to demonstrate to the abattoir and saleyard industry the value of providing water to cattle, it was focused on transport periods of greater than 12 hours, lairage durations between 16 hours and 4 days, variable periods of dry and wet curfew pre-slaughter, and grass-fed cattle. This project focused on research with grain-fed cattle, provided with ad libitum access to feed and water to dispatch, transported less than 6 hours to the processing plant, with total time off feed from dispatch to stunning of 9.6, 22.3 and 30.4 h, for 4.2, 16.4 and 26.4 h in lairage, respectively. The data produced by this study is therefore unique as it examines total fasting durations as short as 9.6 hours and is a valuable addition to the Australian literature on lairage practices for grain-fed cattle.

The current project reported a 7.4 and 6.2 kg carcase weight advantage to limiting time in lairage to approximately 4 h over mid and long-duration lairage treatments, respectively. Hot carcase weight gain responses have also been reported in international feed withdrawal studies in grain-fed cattle with similar fasting durations to this study. Recently, Clariget et al. (2021)

evaluated short duration lairage with cattle sourced from 4 feedlots in Uruguay. A total of 634 Bos taurus steers and heifers were utilised across 8 slaughter blocks to compare two fasting durations. Long fasting duration treatments were 23 to 29 h (7 to 9 h at the feedlot, 1.5 to 4 h transport and 14.5 to 16 h of lairage), and short fasting duration was 2 to 5.5 h (1.5 to 4 h of transport, 0.5 to 1.5 h of lairage). Cattle with short duration of fasting (and lairage) had a 3.53 kg HCW advantage (282.82 vs. 279.29 kg; $P \leq 0.05$).

Although water consumption in lairage was not measured in the Uruguay feedlot experiment, two separate experiments on fasting duration for grazing cattle by Clariget et al. (2021), reported higher water consumption in the day prior to slaughter and hydration at exsanguination (evidenced by hematocrit, globulin and total protein levels in blood) with shorter durations off feed. These grass-fed cattle in Uruguay drank very little water (only 2.5 L/animal in lairage) for the 12-13 hours they spent in lairage, and had lower water intake on farm by 12.0 to 16.7 L per animal compared to animals with animals with no feed withdrawal prior to transport. Whythes et al. (1982) similarly reported a low water intake (3.1 L/hd) for a 16 h lairage period for grassfed cattle transported 160 km. The current project observed similar packed cell volumes in the short and mid duration treatments, but an average 3.7% increase in packed cell volume ($P \leq 0.05$) in the long duration lairage treatment (Table 3). No differences in total protein of plasma were reported. Water intake (and overall hydration in muscle mass) are likely influenced by stress and total dry matter intake of cattle. Further research is required on rehydration of grain-fed cattle in lairage environments for different periods of feed withdrawal and transportation, but current evidence from this MLA project indicates limiting time in lairage for grain-fed cattle maximises hydration and carcase weight.

Recent Australian research (George et al. 2022) for domestic feedlot cattle applied feed withdrawal for 0, 4, 8 and 12 h prior to dispatch, including 1 hour for loading, 545 km/8.5 h haul, and overnight lairage for 14.5 h, resulting in cattle fasting for 24, 28, 32, 36 hours, respectively. Hot carcase weight was affected by feed withdrawal ($P = 0.045$). As duration of feed withdrawal increased, hot carcase weight linearly decreased ($P \leq 0.01$). Compared to 0 h of feed withdrawal, hot carcase weight decreased for 4, 8 and 12 h by 1.2, 1.1 and 1.8 kg, respectively. Muscle glycogen was not measured, although the researchers reported liver glycogen was affected by feed withdrawal ($P = 0.049$). As time of feed withdrawal increased, liver glycogen linearly decreased ($P \leq 0.01$). Compared to 0 h liver glycogen (4.64%), levels decreased by 5.4, 8.2, and 13.6% for 4, 8 and 12 h, respectively, reflecting mobilisation of glycogen reserves to maintain blood glucose status in fasting animals. Whilst the research of George et al. (2022) demonstrated losses in carcase weight and mobilisation of liver glycogen are evident after 24 h of fasting, the current research project reports these losses may begin as early as 9.6 hours off feed.

Muscle glycogen in the current project was not different between treatments. Levels of muscle glycogen in the current project were in general higher (1.40 to 1.44%) than the previous research of George and George (2018) with domestic trade heifers (1.0 to 1.3%). Liver glycogen however declined ($P \leq 0.05$) as time in lairage and total fasting duration increased, similar to the results of George et al. (2022). Liver glycogen is likely a more sensitive measure of metabolic state of cattle in lairage, and evidence of catabolism early in the lairage period to maintain blood glucose homeostasis during fasting. Although not statistically significant cattle in the mid and long-fed treatments had a 9.4 and 6.3 kg lighter body weight at feedlot exit than the short duration lairage treatment due to an extra 12.7 to 20.8 h on-feed at the feedlot prior to dispatch.

No effect of lairage duration (P > 0.05) was reported in the current project for microbiological contamination of faeces, hides, or chilled carcases when expressed on a concentration or proportion of positive carcases basis. No *salmonella* were observed in any sample collected, and only 1 positive hide identification for *E coli* was reported for the long duration treatment. Chilled carcases had similar positive E coli identification with 2, 1 and 2 carcases for short, mid and long duration lairage, respectively. George et al. (2002) similarly observed no effect of pre-dispatch feed withdrawal of 0, 4, 8 and 12 hours on *E coli* concentration or positive carcase proportions. Interestingly, pre-slaughter fasting has been reported to increase risk of *E coli* and *Camphlobacter* shedding as decrease in volatile fatty acid production with feed withdrawal and the concurrent increase in rumen pH may allow pathogen proliferation (Cray et al. 1988; Rasmussen et al. 1993; Welsch et al. 2021). Two studies have also reported feeding high roughage rations either pre or post fasting increase *E coli* shedding after 48 h of fasting (Jordan and McEwen, 1998; Buchko et al. 2000). Jordan and McEwen (1998) however noted that whilst a temporary change in ration and fasting does effect E. coli concentration in faeces, the changes were not large enough to be in incorporated into HACCP plans pre-slaughter.

Winter conditions present a different set of challenges with potentially less solar radiation, lower temperatures and cattle with greater dag scores. During winter, cattle coat cleanliness may be decreased due to wet pen conditions, necessitating washing either at the feedlot or abattoir to pass ante-mortem inspections at Australian abattoirs. Additionally, cattle transportation shrink may less will cooler temperatures, compared to summer. Further research is required during winter in common market categories of feedlot cattle in the Australian feedlot industry to determine effects on carcase characteristics and microbiological contamination with short duration lairage.

6 Conclusion

5.1 Key findings

This research clearly validates that reduced lairage duration is possible in both a large-scale feedlot and abattoir. Moreover, short duration lairage significantly increases hot carcass weight with no negative outcomes in meat quality and food safety parameters evaluated. The mechanisms of increased retained carcass yield are identified, with greater liver glycogen remaining in short duration lairage managed livestock. While in the present investigation the incidence of dark cutting beef was not affected, these short duration lairage managed cattle are significantly less likely under a higher dark cutting incidence scenario to produce carcasses with higher pH and therefore be graded as dark cutters. Furthermore, lower packed cell volumes (i.e., greater livestock hydration) and therefore higher animal welfare outcomes are achieved with short duration lairage, even in a well-managed and modern abattoir lairage environment.

5.2 Benefits to industry

The application of short duration lairage in grain fed steers increased hot carcass weight by 1.85%, in the present study. Extrapolation of data at $9.50 per kg hot carcase weight indicates an additional 7.4 kg and $70.30 increase in value per individual.

An independent impact assessment was also conducted Appendix 1. Considering the average response over the current study (B.FLT.4017) and a previous MLA study (B.FLT.4002), the value of an additional 5.7 kg HSCW was estimated at $35/head using five-year average historical prices. Extrapolation of this estimated benefit across the average number of grain fed cattle processed over the past 5 years represents the potential for an additional $97 million worth of HSCW from grain fed cattle in Australia annually.

This project demonstrated that reduced lairage duration provided a significant benefit in the profitability across the supply chain and improved sustainability by increasing the hot carcase weight per individual animal. Additionally, this project demonstrated the clear animal welfare benefits associated with implementing short duration lairage.

7 Future research and recommendations

Future work should focus on opportunities to simplify the logistical challenges associated with implementing short duration lairage in a commercial environment including electronic submission of regulatory paperwork such as national vendor declarations, transport scheduling, ante-mortem inspection scheduling, and improving coat cleanliness prior to abattoir arrival to reduce washing intervals required prior to slaughter during winter conditions.

8 References

AMPC, 2019. Is the animal fit to Process? Cattle. Australian Meat Processor Corporation, North Sydney.

BUCHKO, S.J., HOLLEY, R.A., OLSON, W.O., GANNON, V.P.J., and VEIRA, D.M. 2000. The effect of fasting and diet on fecal shedding of Escherichia coli O157:H7 by cattle. Can. J. Anim. Sci. December 2000 https://doi.org/10.4141/A00-025

CLARIGET, J., BANCHERO, G., LUZARDO, S., FERNANDEZ, E., PEREZ, E., LA MANNA, A., SARAVIA, A., DEL CAMPO, M., FERRES, A., and CANOZZI, M.E.A. 2021. Effect of pre-slaughter fasting duration on physiology, carcass and meat quality in beef cattle finished on pasture or feedlot. Research in Veterinary Science. 136:158-165.

CRAY, W.C., CASEY, T.A., BOSWORTH, B.T., and RASMUSSEN, M.A. 1998. Effect of dietary stress on fecal shedding of Escherichia coli 0157:H7 in calves. Applied and Environmental Microbiology. May 1998:1975-1979.

COOMBES S.V., GARDNER, G.E., PETHICK, D.W., MCGILCHRIST, P., 2014. The impact of beef cattle temperament assessed using flight speed on muscle glycogen, muscle lactate and plasma lactate concentrations at slaughter. Meat Sci 98, 815-821.

EDWARDS-CALLAWAY, L.N., and CALVO-LORENZO, M.S. 2020. Board invited review: Animal welfare in the U.S. slaughter industry - a focus on fed cattle. J. Anim. Sci. 98(4):1-21.

FERGUSON, D. M., SHAW, F. D. & STARK, J. L. 2007. Effect of reduced lairage duration on beef quality. *Effect of reduced lairage duration on beef quality,* 47**,** 770-773.

GEORGE, M.M and GEORGE, M.H., 2018. Effect of lairage timing and duration on rumen physiology and muscle glycogen. B.FLT.4002. Meat and Livestock Australia Limited, Locked Bag 1961, North Sydney, NSW 2059.

GEORGE, M., MEEHAN, D., MCGILCHRIST, P., JENSEN, P., BOWLER, D., HALE, A., MCMENIMAN, J., and GEORGE, M. 2022. Effect of feed withdrawal on truck effluent, animal welfare, carcase characteristics and microbiological contamination of feedlot cattle. MLA Final Report B.FLT.5009. Meat and Livestock Australia Limited, Locked Bag 1961, North Sydney, NSW 2059.

GIANNETTO, C., FAZIO, F., CASELLA, S., MARAFIOTI, S., GIUDICE, E. & PICCIONE, G. 2011. Acute Phase Protein Response during Road Transportation and Lairage at a Slaughterhouse in Feedlot Beef Cattle. *Journal of Veterinary Medical Science,* 73**,** 1531-1534.

GRANDIN, T., COCKRAM, M., & C.A.B. 2020. The slaughter of farmed animals: practical ways of enhancing animal welfare. CABI.

GRAU, F. H., L. E. BROWNLIE, and E. A. ROBERTS. 1968. Effect of some Preslaughter Treatments on the Salmonella Population in the Bovine Rumen and Faeces. Journal of Applied Bacteriology 31(1):157-163. doi: 10.1111/j.1365-2672.1968.tb00353.x

GRAU, F. H., and M. G. SMITH. 1974. Salmonella Contamination of Sheep and Mutton Carcasses Related to Pre-slaughter Holding Conditions. Journal of Applied Bacteriology 37(1):111-116. doi: 10.1111/j.1365-2672.1974.tb00421.x

JACOB, R. 2009. Lairage – Beef, Sheep, and Pigs. Meat 418/518 Meat Technology. The Australian Wool Education Trust licensee for University of New England, Armidale, NSW 2350.

JORDAN, D., and MCEWEN, S.A. 1998. Effect of duration of fasting and a short-term high roughage ration on the concentration of Escherichia coli Biotype 1 in cattle feces. J. Food. Protect. 61 (5):531-534.

KREIKEMEIER, K. K., UNRUH, J. A. & ECK, T. P. 1998. Factors affecting the occurrence of dark-cutting beef and selected carcass traits in finished beef cattle. *Journal of Animal Science,* 76**,** 388-395.

NCBA, 1992. Executive summary: National Beef Quality Audit. Published by the National Cattlemen's Association in coordination with Colorado State University and Texas A&M University.

RASMUSSEN, M.A., CRAY, W.C., CASEY, T.A., and WHIPP, S.C. Rumen contents as a reservoir of enterohemorrhagic Escherichia coli. FEMS Microbiol. Lett. 1993, 114, 79–84.

ROMERO, M. H., URIBE-VELÁSQUEZ, L. F., SÁNCHEZ, J. A. & MIRANDA-DE LA LAMA, G. C. 2013. Risk factors influencing bruising and high muscle pH in Colombian cattle carcasses due to transport and pre-slaughter operations. *Meat Science,* 95**,** 256-263.

SCHAEFER, A.L., JONES, S.D., and STANLEY, R.W. 1997. The use of electrolyte solutions for reducing transport stress. J. Anim. Sci. 75: 258-265.

SCHAEFER, A.L., DUBESKI, P.L., AALHUS, J.L, and TONG, A.K.W. 2001. Role of nutrition in reducing antemortem stress and meat quality aberrations. J. Anim. Sci. 79(E Suppl.):E91-E101.

SCHAEFER, A.L., STANELY, R.W., TONG, A.K.W., DUBESKI, P., ROBINSON, R., AALHUS, J.L., and ROBERTSON, W.M. 2006. The impact of antemortem nutrition in beef cattle on carcass yield and quality grade. Can. J. Anim. Sci. 86 (3): 317-323.

SHORTHOSE, W.R., HARRIS, P.V., and BOUTON, P.E. 1972. The effects on some properties of beef of resting and feeding cattle after a long journey to slaughter. Proc. Aust. Soc. Anim. Prod. 9:387-391.

WELCH, C.B., LOURENCO, J.M., SEIDEL, D.S., KRAUSE, T.R., ROTHROCK, M.J., PRINGLE, T.D., and CALLAWAY, T.R. 2021. The impact of pre-slaughter fasting on the ruminal microbial population of commercial angus steers. Microorganisms. 9:2625. https://doi.org/10.3390/microorganisms9122625

WHYTHES, J.R., MCLENNAN, S.R., and TOLEMAN, M.A. 1980a. Liveweight loss and recovery in steers fasted for periods of twelve to seventy-two hours. Australian Journal of Experimental Agriculture and Animal Husbandry 20(106):517-521.

WHYTHES, J.R., SHORTHOSE, W.R., SCHMIDT, P.J., and DAVIS, C.B. 1980b. Effects of various rehydration procedures after a long journey on liveweight, carcases and muscle properties of cattle. Aust. J. Agric. Res. 31:849-855.

WHYTHES, J.R., TYLER, R., DALY, J.J. BURNS, M.A. and LLEWELYN, D. 1981. Effect of various feed and water regimens at saleyards on the liveweight of store cattle. Australian Journal of Experimental Agriculture and Animal Husbandry 21(113): 553 - 556.

WYTHES, J.R., GOENER, P., LAING, A.R., and SHORTHOSE, W.R. 1982. Effect of access to water after a short journey on carcass traits and muscle properties of steers. Animal Production in Australia: 398-400.

WHYTES, J.R., BROWN, M.J., SHORTHOSE, W.R., and CLARKE, M.R. 1983. Effect of method of sale and various water regimens at saleyards on the liveweight, carcass traits and muscle properties of cattle. Australian Journal of Experimental Agriculture and Animal Husbandry 23(122):235-242.

WYTHES, J. R., SMITH, P. C., ARTHUR, R. J., & ROUND, P. J. 1984. Feeding cattle at abattoirs: the effect on carcass attributes and muscle pH. *Animal Production in Australia,* 15, 643–646.

9 Appendix

Short Duration Lairage for Grain Fed Cattle - Review and Impact Assessment

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Executive Summary

Background

Lairage is where cattle are held and rested after arrival at the slaughter facilities. Time in lairage enables cattle to recover and settle after transport prior to slaughter. The impact of time in lairage on various physiological aspects of cattle metabolism has been the subject of numerous research experiments to understand how time in lairage may impact upon final hot standard carcass weight (HSCW) and carcass quality aspects. In terms of carcass quality, of most interest is the impact of time in lairage on the incidence of dark cutting meat.

Investment by the Australian feedlot industry into research to quantify the impact of shorter duration of lairage on meat quality, carcass yield, animal welfare and microbiological status was made via two Meat and Livestock Australia (MLA) funded projects delivered in collaboration with feedlot veterinary and nutrition services company, Bovine Dynamics Pty Ltd.

Objective

MLA and Bovine Dynamics engaged Beattie Consulting Services and Richmond Hill Agribusiness to conduct an impact assessment of the results from this research, and to conduct a stakeholder engagement process to assess current usage of short duration lairage, requirements for effective use of short duration lairage and potential and actual challenges associated with adoption of the practice. The findings from these activities are presented in this report to assist industry to be more informed regarding the practice of short duration lairage for grain fed cattle in Australia.

Methodology

The approach in undertaking the impact assessment of research results involved assessment of economic impact of short duration lairage, defined as four hours or less in lairage. Economic impact was assessed by comparing the value of carcasses processed after short duration lairage to the expected value of the same carcasses slaughtered after a longer period of time in lairage. The assessment also involved identification of animal welfare and environmental/sustainability benefits of reducing time in lairage.

The stakeholder engagement process involved conducting semi-structured phone interviews with a total of 27 stakeholders, including processors, feedlot operators, transport companies, Department of Agriculture Fisheries and Forestry staff, the project researchers, MLA and representatives from the Australian Lot Feeders Association and the Australian Meat Industry Council.

Key Findings

MLA research has demonstrated that large economic benefits can be achieved from use of short duration lairage of four hours or less. The value of an additional 5.7 kg HSCW was estimated at $35/head using five-year average historical prices. Extrapolation of this estimated benefit across the average number of grain fed cattle processed over the past 5 years represents the potential for an additional $97 million worth of HSCW from grain fed cattle in Australia annually.

Other benefits identified by the research included improved animal welfare via reduced stress and environmental/sustainability benefits via reduced emissions intensity per carcass, estimated as a 1.2% reduction in emission intensity, equal to 0.34 kg CO2-e per kg carcass weight. Interviews with stakeholders during this review also provided examples of successful implementation and use of short duration lairage over an extended period of time to create productivity (increased yield and reduced dark cutters), animal welfare and sustainability benefits for producers, processors and consumers.

Despite the demonstrated benefits, the review also found that operating short duration lairage on any reasonable scale comes with challenges, and so will not be suitable for all supply chains. For those supply chains looking to adopt the practice, stakeholder engagement indicates that short duration lairage is only likely to make up a portion of the annual slaughter for individual supply chains given logistical difficulties and challenges. These difficulties and challenges, by sector, include:

Feedlots

- Loading curfews
- Poor lighting, especially in home pens
- Inadequate loading ramps
- Being ready to load when the truck arrives
- Staff availability/training
- Logistical/organisational skills of managers

Transport

- Availability of trucks
- Availability of drivers willing to transport out of hours
- Driver fatigue
- Truck delays increasing over longer distances/with poor road conditions

Lairage

- Accurate paperwork
- Dirty cattle
- Correct number of expected cattle arrive
- Cattle arrive on schedule

On Plant Veterinarians (OPV)

- Staff available for ante mortem inspections in time to allow for short duration lairage
- Difficulties with balancing other tasks required of OPVs
- Resistance to change

The requirements for effective implementation of short duration lairage within a supply chain essentially relate to reducing the risk of a plant stoppage. Stoppages are very costly to the processors, with one processor estimating a cost of $850 for every minute that the chain is not operating during a shift.

Key requirements identified by stakeholders for successful implementation of short duration lairage include:

- Increased logistical and organisational skills across the supply chain, from feedlots, to transporters to processors to deliver an increased level of precision in system management;
- Increased understanding along the supply chain of the importance of each activity being completed on time and to specifications;
- Ideally a supply of 'back-up' cattle on site or nearby to push up the list or to substitute when cattle arrival is delayed;
- Availability of sufficient OPV resources and OPV support for accommodating the changed requirements for a short duration lairage system;
- Consideration/review of OPV ante mortem inspection requirements for passing cattle as clean or conditional soiled for slaughter; and
- Confidence in the value of the expected benefits due to short duration lairage within a supply chain.

Stakeholders also identified a range of means by which industry could support increased adoption of short duration lairage along the supply chain:

- Funding of additional research around short duration lairage, including impacts on long fed cattle, impacts of shade and shelter in lairage, and trials within individual supply chains wanting to determine the benefits prior to adopting;
- Provide opportunities for industry stakeholders to see how short duration lairage works in practice, including overseas examples;
- Co-funding a system whereby supply chains can be assessed for baseline levels of best practice required for short duration lairage to identify the current system gaps and the strategies and processes required for addressing those gaps, including development of change management and communication plans;
- Informing all stakeholders along the supply chain about the practice of short duration lairage and the reported benefits of the practice, and providing regular updates to industry on new developments on the topic; and
- Proving opportunities for all stakeholders along the supply chain to provide input into discussions around finding solutions to the challenges associated with use of short duration lairage.

Stakeholders engaged during this review indicated a high level of interest in learning more about short duration lairage, what the benefits are and how to overcome some of the key challenges. This document is intended to inform future discussions around these issues to add further support for industry adoption of short duration lairage.

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1.0 Background

Lairage is where cattle are held and rested after arrival at the slaughter facilities. Time in lairage enables cattle to recover and settle after transport prior to slaughter. The Australian Standing Committee on Agriculture and Resource Management (SCARM) model code of practice for the welfare of livestock at slaughtering establishments recommends that for carcass quality purposes, a minimum of 2 hours rest period between arrival and slaughter is desirable (Anon, 2002). Longer, but unspecified, lairage periods are recommended when livestock have travelled for more than 6 hours or are stressed. The code requires that animals be provided with feed if they have been off feed for more than 24 hours. In practice, the standard lairage time for slaughter cattle in Australia typically ranges between 12 and 24 hours (Ferguson *et al*., 2007).

The impact of time in lairage on various physiological aspects of cattle metabolism has been the subject of numerous research experiments to understand how time in lairage may impact upon final hot standard carcass weight (HSCW) and carcass quality aspects. In terms of carcass quality, of most interest is the impact of time in lairage on the incidence of dark cutting meat. Dark cutting meat is a cut from an animal that has been subjected to stress before slaughter, and is consequently darker in colour than meat from a less stressed animal. Dark cutting meat usually has a very high pH (>6.0), resulting in higher water-holding capacity and more translucent muscle, which makes the meat appear dark. Consumers have a preference for bright red coloured meat, and thus the dark cutting carcasses are typically discounted to reflect their lower value to consumers.

It has been hypothesised that increased duration in lairage results in a greater incidence of dark cutting meat (Janloo, 1999, Kreikemeir *et al*.,1998). This is proposed to occur as a greater proportion of muscle glycogen is metabolised as the duration of lairage increases, such that reduced levels of antemortem muscle glycogen lower post mortem lactic acid accumulation which impedes pH decline, resulting in potentially more dark cutting meat (Ashmore *et al*., 1973, Scanga *et al*., 1998).

Investment by the Australian feedlot industry into research to quantify the impact of duration of lairage on meat quality, carcass yield, animal welfare and microbiological status was made via two Meat and Livestock Australia (MLA) funded projects delivered in collaboration with feedlot veterinary, nutrition and research services company, Bovine Dynamics Pty Ltd.

Project B.FLT.4002 was undertaken in 2018 to examine four different lairage treatments in 400 domestic short fed heifers. While the primary focus of the study was to assess timing of transport and slaughter on the incidence of dark cutting, the results also revealed significant differences in yield between treatments, such that shorter duration lairage was associated with higher dressing percentage and HSCW (George and George, 2018). This study recommended that time off feed prior to slaughter be reduced to less than 4 hours, lairage duration be reduced to less than 3 hours, and chilling duration increased to a minimum of 18 hours to reduce the incidence of dark-cutting in Australian feedlot heifers with an average HSCW of 225-325 kg.

However, the authors hypothesized the effect of lairage duration on meat colour was merely a small part of a much larger and more significant issue. Hence, a subsequent study in 2021, project B.FLT.4017, aimed to evaluate the effect of lairage duration on carcass yield, quality and microbiological status in a much larger and industry-relevant data set, while controlling factors such as chilling duration (George and George, 2022). The findings of this research thus present opportunities for increasing carcass value in terms of both quality and quantity by reducing the average duration of time in lairage, while guaranteeing food safety.

MLA and Bovine Dynamics engaged Beattie Consulting Services and Richmond Hill Agribusiness to conduct an impact assessment of the results from projects B.FLT.4002 and B.FLT.4017, and to conduct a stakeholder engagement process to assess current usage of short duration lairage (SDL), defined as four hours or less in lairage, requirements for effective use of SDL and potential and actual challenges associated with adoption of the practice. The findings from these activities have been presented in this report to assist industry to be more informed regarding the practice of SDL for grain fed cattle in Australia.

2.0 Methodology

The methodology in delivering on project objectives involved the following key elements:

1. Conducting an assessment of the impact of the findings from projects B.FLT.4002 and B.FLT.4017.
2. Engagement with industry stakeholders.

Impact Assessment

The approach in undertaking the assessment of economic impact of SDL, defined as four hours or less in lairage, was to evaluate the results from the research projects in terms of the value of carcasses processed after short duration lairage compared to the expected value of the same carcasses slaughtered after a longer period of time in lairage. Animal welfare and environmental/sustainability benefits of reducing time in lairage were also identified.

Stakeholder Engagement

A total of 27 industry stakeholders were interviewed over the phone during the review process. These included the following stakeholders:

- Processors x 8 (8 representatives from 5 businesses)
- Feedlot operators x 5
- Transporters x 3
- Australian Meat Industry Council (AMIC) x 1
- Australian Lot Feeders Association (ALFA) x 1
- Project researchers (Bovine Dynamics) x 2
- MLA/Meat Standards Australia (MSA) staff x 3
- Department of Agriculture, Fisheries and Forestry (DAFF) x 4 (managers and on plant veterinarians)

Stakeholders were asked a range of questions around current and planned future use of SDL where relevant, along with discussions around requirements for successful implementation of SDL and the current and potential risks and challenges, along with the benefits, of adopting the practice.

3.0 Findings

3.1 Impact Assessment

The following section provides the findings of an impact assessment of the results of two recent MLA funded research projects on SDL:

- Project B.FLT.4002: Effect of lairage timing and duration on rumen physiology and muscle glycogen
- Project B.FLT.4017: Effect of lairage duration on carcass quality, yield and microbiological status of feedlot cattle

Both projects were undertaken by Bovine Dynamics Pty. Ltd. funded by grain fed Levies, matched with Commonwealth funds through the MLA Feedlot R&D Program.

3.1.1 Overview of the Research

Project B.FLT.4002 (2018)

To determine the effects of timing and duration of lairage on rumen physiology, muscle glycogen and carcass traits of feedlot cattle, a 2 x 2 factorial experimental design was used to compare two feedlot dispatch times (afternoon prior to slaughter (PM shipped) and morning of slaughter (AM shipped)), and two slaughter times (morning slaughter (AM slaughtered) and afternoon slaughter (PM slaughtered)).

Average time in lairage ranged between 1.7 and 19.5 hours. The two treatments with the shortest lairage duration were AM shipped and AM slaughtered cattle and AM shipped and PM slaughtered cattle, with an average lairage duration of 1.7 and 7.2 hours, respectively. In contrast, average lairage duration for PM shipped cattle was 13.3 and 19.5 hours, respectively. The results of the experiment found that the cattle with the shorter average lairage time of 4.5 hours realised an additional 1.4 kg HSCW per head over the cattle with longer average time in lairage (16.4 hours).

There was minimal difference between the average AusMeat colour score for short and longer lairage duration, however the shorter duration cattle had a lower relative proportion of meat scores greater than 4. There was, however, some uncertainty regarding the impact of duration of chilling time prior to grading on meat colour, as cattle slaughtered in the morning had longer chilling time than cattle slaughtered in the afternoon (George and George, 2018). For this reason, any possible benefits of shorter duration lairage on reducing the incidence of dark cutting meat have been excluded from this analysis.

The overall conclusions drawn from the research were that the incidence of dark cutting in British-type heifers fed a high energy steam-flaked wheat and barley finisher ration for 64 days may be reduced by minimising the time off feed prior to slaughter to less than 4 hours, reducing the duration of lairage to less than 3 hours, and increasing the duration of chilling time to approximately 18 hours, but that further work was required to isolate the impacts of chiller time and time in lairage on the incidence of dark cutting. Most importantly, reducing time in lairage was found to result in an increase in HSCW.

B.FLT.4017 (2022)

Project B.FLT.4017 commenced in 2021 and concluded mid-2022. The project involved allocation of 2,226 steers to three treatments using a single-blinded randomized complete block design with 14 replicates using animals from a large commercial feedlot in south east Queensland. The treatments involved three durations of lairage including short (4 hours), mid (16 hours) and long (27 hours) duration at a large commercial abattoir in south east Queensland. Experimental data recorded included HSCW and dressing percentage, animal welfare indicators, muscle & liver glycogen testing and microbiological sampling and testing (faeces, hides, carcass).

The results of the experiment found that lairage duration had a significant impact on HSCW of cattle. Cattle exposed to short duration lairage yielded a 7.4 kg higher HSCW compared to mid-duration lairage. Short duration lairage yielded a 6.2 kg advantage in HSCW compared to long-duration lairage. In terms of animal welfare, the duration of lairage was found to have a significant effect on packed cell volume in that cattle exposed to longer duration of lairage were more dehydrated compared to cattle exposed to shorter duration lairage. The duration of lairage was also found to have a significant effect on levels of glycogen in the liver in that cattle exposed to longer duration of lairage mobilized glycogen reserves in their livers to maintain blood glucose status.

In relation to food safety, the research found that total microbiological counts (standard plate counts, coliform counts, *E.coli* counts, and *Salmonella* spp. detection) and the proportion of carcasses with microbiological contamination were not affected by lairage duration. The research also concluded that there was no effect of duration of lairage on meat quality, given no impacts were found on MSA marbling, meat colour, eye muscle area, rib fat thickness, chiller assessment pH, or MSA index.

The overall conclusions from the project were that the research clearly validated that reduced lairage duration is possible in both a large-scale feedlot and abattoir, and that lairage of 4 hours or less significantly increases HSCW, with no negative outcomes on the meat quality and food safety parameters evaluated.

3.1.1 Economic Impacts

The economic impacts of this research were assessed in terms of what the average carcass value would be with a longer lairage time, referred to as the counterfactual scenario, compared to what the average carcass value would be with a shorter period of lairage. The difference between the two scenarios is the estimated benefit per head of reducing time in lairage.

Counterfactual Scenario

The typical time in lairage for slaughter cattle ranges between 12 and 24 hours (Ferguson *et al*., 2007). The average time in lairage for the PM delivered cattle for project B.FLT.4002 was 16.4 hours, and fits within this range. The average time in lairage for the mid duration lairage group in project B.FLT.4017 was also 16.4 hours. Thus, for the current impact assessment, the experimental results for these two groups for each project respectively have been utilised as the counterfactual scenario to assess the impact of reducing lairage time on final carcass value. The assumptions utilised for the counterfactual scenario are provided in Table 1.

Table 1: Key assumptions for the counterfactual scenario

Variable	Value	Source
COUNTERFACTUAL ASSUMPTIONS Project B.FLT.4002		
Average lairage duration (hrs)	16.4	George and George (2018)
Average HSCW (Kg/Hd)	272.4	George and George (2018)
Days on Feed	64	George and George (2018)
Price per kg HSCW (c)	621	5 year average price for MSA heifers (MLA NLRS 2017/18-2021/22)
Total average carcass value per Hd	$1,691.60	= 272.4*$6.21
COUNTERFACTUAL ASSUMPTIONS Project B.FLT.4017		
Average lairage duration (hrs)	16.4	George and George (2022)
Average HSCW (Kg/Hd)	400.4	George and George (2022)
Days on Feed	176	George and George (2022)
Price per kg HSCW (c)	615	5 year average price for heavy steers (MLA NLRS 2017/18-2021/22 data)
Total average carcass value per Hd	$2,462.46	= 400.4*$6.15

Impact of Reducing Time in Lairage

The benefits of shorter lairage duration have been captured in terms of increased final HSCW based on the experimental results from projects B.FLT.4002 and B.FLT.4017. Table 2 presents the assumptions utilised for quantifying the impact of decreased lairage duration on overall carcass value for both projects.

Table 2: Key assumptions for impact of reduced time in lairage

Variable	Value	Source
IMPACT ASSUMPTIONS Project B.FLT.4002		
Average lairage duration (hrs)	4.5	George and George (2018)
Average HSCW (Kg/Hd)	273.8	George and George (2018)
Days on feed	64	George and George (2018)
Price per kg HSCW (c)	621	5 year average price for MSA heifers (MLA NLRS 2017/18-2021/22 data)
Total average carcass value per Hd	$1,700.30	=273.8*$6.21
IMPACT ASSUMPTIONS Project B.FLT.4017		
Average lairage duration (hrs)	4.3	George and George (2022)
Average HSCW (Kg/Hd)	407.8	George and George (2022)
Days on feed	176	George and George (2022)
Price per kg HSCW (c)	615	5 year average price for heavy steers (MLA NLRS 2017/18-2021/22 data)
Total average carcass value per Hd	$2,507.97	=407.8*$6.15

The difference between the carcass value with a shorter lairage duration and the counterfactual scenario for project B.FLT.4002 is $8.70 per head ($1,700.30-$1,691.60). Given that the heifers in the experiment were on feed for 64 days, this means that 5.7 heifers could be turned off per year (365 days/64 days).
The difference between the carcass value with a shorter lairage duration and the counterfactual scenario for project B.FLT.4017 is $45.51 per head ($2,507.97-$2,462.46). Given that the steers in this experiment were on feed for 176 days, this means that 2.1 steers could be turned off per year (365 days/176 days).

The average feedlot throughput relative to capacity over the past 5 financial years is 2.52 head (ALFA), representing an average of 145 days on feed (365/2.52). A regression analysis was conducted using the results from both projects to calculate an average industry benefit per head for 145 days on feed of $35.33 based on an additional 5.7 kg HSCW. Extrapolation of this estimated benefit per head across the average number of grain fed cattle processed over the past 5 years represents the potential for an additional $97 million worth of HSCW from grain fed cattle in Australia annually.

Interviews with industry stakeholders who are practicing SDL indicate that there are minimal additional costs associated with the practice, thus no additional costs have been accounted for in the analysis. There may be cost savings in some situations where cattle are otherwise fed in lairage when held over longer periods, however insufficient information was available to quantify such cost savings in the current analysis.

Risk Assessment of Impact

The greatest likely source of variability around the estimated impact of SDL on carcass value will be due to beef price, and the difference in average yield between shorter periods and longer periods of lairage. The magnitude of the impact of variation in the assumptions used on the estimated benefit per head of SDL have been assessed via a sensitivity analysis. The results of this analysis are presented in Table 3 for a high scenario (10% higher beef price and 10% higher difference in HSCW) and a low scenario (10% lower beef price and 10% lower difference in HSCW).

Table 3: Sensitivity of benefit per head to variation in beef price and difference in HSCW between the counterfactual and short duration lairage scenarios

Scenario	High Scenario +10% beef price and HSCW difference	Base Scenario for price and HSCW	Low Scenario -10% beef price and HSCW difference
Net benefit ($/Hd)	$42.74	$35.33	$28.62

3.1.2 Non-Economic Benefits

The investment in projects B.FLT.4002 and B.FLT.4017 also highlighted other benefits regarding animal welfare and environment/sustainability outcomes that were not measured in economic terms for this impact assessment but are none-the-less of value to industry.

Animal Welfare Benefits

Cattle are exposed to a variety of potential stressors during the period leading up to slaughter. These include loading, transport, unloading, washing, new noises and smells, time off feed/water and new surroundings. Lairage conditions can directly impact on animal welfare and can also exacerbate the welfare consequences of stressors the cattle have previously been exposed to prior to reaching lairage. The response of individual animals to stressors in the period leading up to slaughter is highly variable, however research indicates that prolonged exposure to a stressor will have a greater impact on animals, regardless of whether the individual response capacity of an animal is high or low (Gallo and Lizondo, 2000). Therefore, the longer the transport and fasting times (including time in lairage), the greater the probability of stress negatively affecting the welfare of animals (Gallo and Lizondo, 2000).

A study conducted by the European Food Safety Authority (EFSA) to inform international level discussions on animal welfare leading up to, and during slaughter, found that cattle in lairage are potentially exposed to the following welfare issues (Neilson *et al*., 2020):

- Thermal stress (heat/cold stress) caused by weather conditions and/or poor ventilation and access to mitigating factors in lairage (i.e. shade/shelter);
- Prolonged hunger related to period of time off feed;
- Dehydration which may result from poor access of individual cattle to clean water in lairage;
- Pain and fear due to mixing unfamiliar animals, noise exposure and improper design, construction and maintenance of lairage pens (e.g. type and condition of flooring, shape of yards, space available per animal); and
- Restriction of movement/unable to rest (fatigue) due to lairage conditions and design and space available.

The review identified various preventative or corrective strategies that could be used to eliminate or reduce the impacts of these animal welfare issues during lairage. These included minimising time off feed, reducing occurrence of loud unfamiliar noises near cattle, not mixing unfamiliar animals, and ensuring lairage design and conditions maximise animal welfare (e.g. shade and shelter, space allowance, easy access to clean water, floor cleanliness and comfort). It was noted that where no preventative or corrective actions can be taken, animals should be slaughtered as soon as possible, as delayed slaughter can seriously impair animal welfare (Neilson *et al*., 2020). These findings suggest that shorter duration lairage is likely to provide animal welfare benefits in many situations.

Project B.FLT.4017 reported data on two indicators of animal welfare, being the level of dehydration and liver glycogen levels. The study found that SDL improved animal welfare by reducing the level of de-hydration in cattle. Although cattle in lairage have access to water troughs, this does not mean that all cattle will drink and re-hydrate following transport (George and George, 2022). Lairage design, space available, water system design and level of contamination of water may affect consumption by individual animals during lairage (Neilson *et al*., 2020). The project also showed higher liver glycogen levels in cattle exposed to shorter duration lairage, which is a reflection of lower stress levels in these animals (George and George, 2022).

Environmental/Sustainability Benefits

The results from both MLA research projects indicate a higher HSCW per head for cattle slaughtered after exposure to shorter duration lairage. This increased yield per head results in a reduction in the emission intensity of the carcass[1]. A regression analysis of the data from both projects indicates that the percentage increase in HSCW per head for the average feedlot throughput relative to capacity over the past 5 financial years is 1.2%. It is assumed that the kilograms of carbon dioxide equivalent (CO2-e) greenhouse gases per animal is not significantly impacted by time in lairage prior to slaughter. If the kg CO2-e per animal stays the same, then this research has found that a 1.2% increase in carcass weight per head would equal a 1.2% reduction in emission intensity as a result of reducing time in lairage from around 16 hours to around 4 hours.

The Australian Beef Sustainability Framework (2022) estimates cattle emissions associated with grazing, feed-lotting, and associated activities at 12.6 kg CO2-e per kg liveweight. Using this value, along with the data from both research projects and regression analysis, results in an estimated reduction of 0.34 kg CO2-e per kg HSCW produced by reducing lairage time from around 16 hours to 4 hours or less. Note that total emissions per head are not altered, only emissions per kg of product due to a reduction in emissions intensity. This outcome contributes toward the industry goal of carbon neutral red meat production by 2030 (Red Meat 2030)[2].

3.2 Stakeholder Engagement

3.2.1 Summary of Findings

Research has demonstrated that large economic benefits can be achieved from SDL, along with animal welfare and environmental/sustainability benefits. Interviews with stakeholders during this review also provided examples of successful implementation and use of SDL over an extended period of time to create productivity (increased yield and reduced dark cutters), animal welfare and sustainability benefits for producers, processors and consumers.

Despite the demonstrated benefits of shorter duration lairage, this review also found that operating SDL on any reasonable scale comes with challenges, and so will not be suitable for all supply chains. Figure 1 provides a summary of the benefits and current challenges associated with use of SDL along the supply chain.

[1] Emission intensity of a carcass = kg CO2-e per animal/kg carcass weight

[2] RedMeat2030.pdf (rmac.com.au)

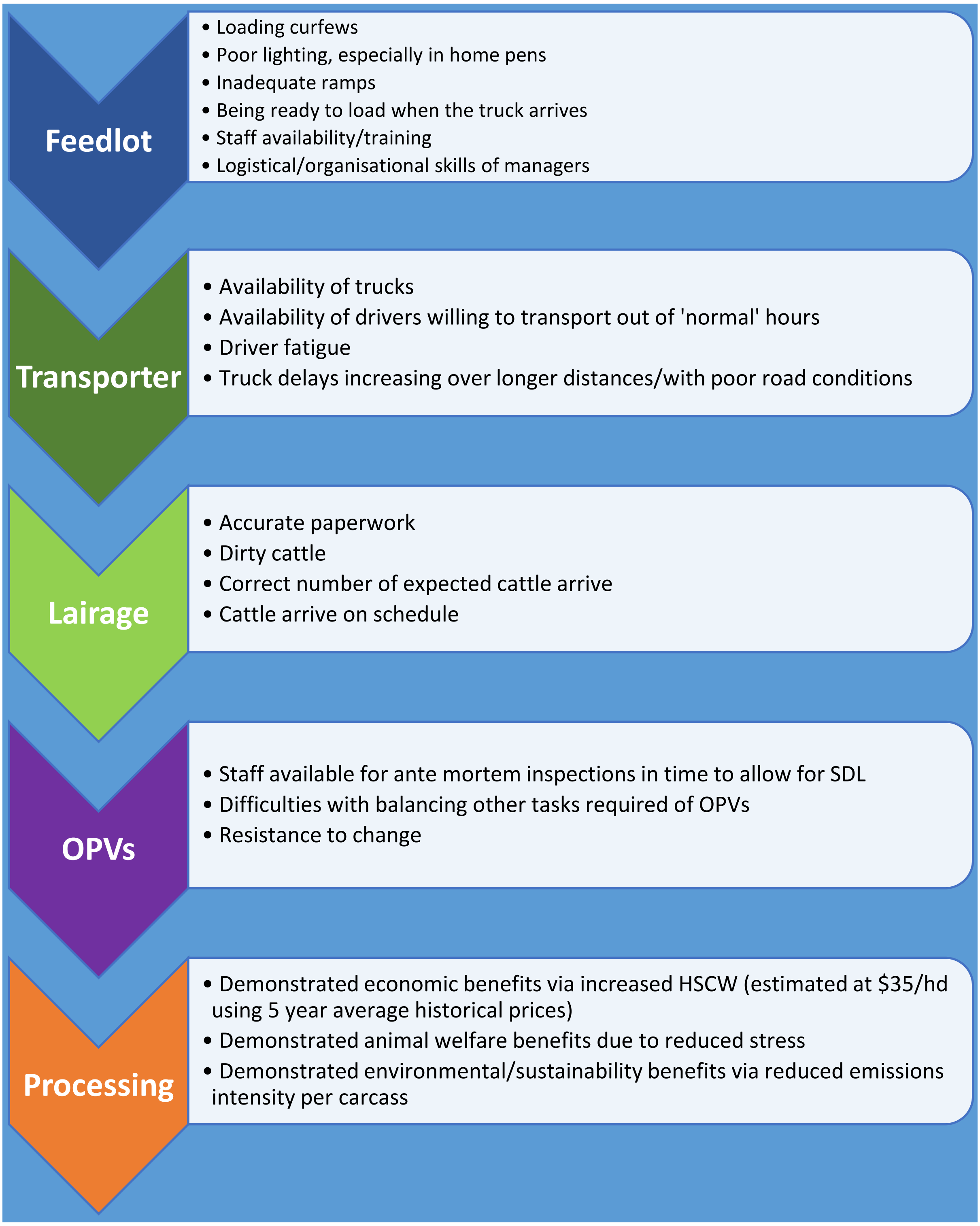

Figure 1: Summary of the challenges/barriers along the supply chain and the benefits associated with adoption of SDL

Vertically integrated supply chains offer the greatest potential for large scale adoption of SDL due to the lower risks associated with timely supply of cattle. Supply chains where transport distances are within 4-6 hours at most are more likely to be suited to use of SDL compared to those where greater travel distances are required. SDL is also more suited to practice during the warmer months when more daylight hours facilitate out of hours transport and cattle require less washing.

Beyond the limitations to use of SDL due to difficulties around out of hours transport (i.e., loading curfews, OH&S challenges at feedlots and driver fatigue), dirty cattle (largely breed and time of year dependent) and risks associated with the number (more or less head than booked in arriving) and timing of cattle arrival on site (increased risk of delays with transport distance), other key challenges associated with use of SDL identified by stakeholders included:

- Lack of mutual understanding among stakeholders along a supply chain of the importance of the timing and logistics of activities occurring as planned in order to facilitate use of SDL (e.g., timing of loading cattle at the feedlot, timing of arrival at the plant with correct paperwork, timing of ante-mortem inspections);
- Availability and willingness of OPVs to conduct additional ante mortem inspections required to facilitate use of SDL;
- Lack of clarity and reported variability around the requirements for passing ante mortem inspections as clean or conditional soiled for slaughter;
- Logistics associated with system processes and quality assurance (QA) requirements for different classes of cattle that limit the ability for flexibility to easily accommodate different cattle types during a shift; and
- Preference among some suppliers for longer periods of lairage.

In spite of these difficulties and challenges, SDL is being used at large scale by some plants with great success, and stakeholder engagement for this review has indicated a high level of interest in learning more about SDL, what the benefits are and how to overcome some of the key challenges. The following section provides further details around the benefits and challenges associated with adoption of SDL along the supply chain.

3.2.2 Processors

Processor Demographics

Table 4 provides an overview of the characteristics of the processors engaged during the review.

Table 4: Demographics of processors engaged

Variable	Range
Number of cattle processed per day	500 to 1,400
Operational days per week	5 to 7
Weeks of operation per year	49 to 51
No of kill shifts per day	1 or 2
Start time of first or only shift	5.00 am to 6.00 am
Start time of second shift	2.30 pm to 4.00 pm
Chain speed per hour (maximum)	60 to 150
Lairage Capacity	600 to 2,000
Lairage Set up	Mix of shade, concrete, dirt and rubber. All have water in each pen.
On Plant Veterinarians (OPVs)	One per shift
Wash capacity (at the plant)	15 to 300

Variable	Range
Wash type	Belly wash, soaker pens, high and low pressure hoses plus pre kill spray.
Proportion requiring washing	Summer – from none up to 40% (other than all receive a pre kill spray to remove dust). Winter – 10% to 100%.
Washing times	Up to 6 hours if dirty/daggy and all have a pre-kill spray.
Proportion requiring extended washing	From 10% to 100% in winter.
Cattle arrival times	All able to receive cattle outside of normal business hours.

Current Use of Short Duration Lairage

Three of the five businesses involved in the survey operate either with SDL, or use SDL at times during the year. Current level of use reported was a minor amount for one processor, 30% for another and between 50% and 75% of the cattle processed per day for the third. Use of SDL during the year was associated with the following factors:

- The class of cattle being processed – younger, smaller, short fed cattle are candidates for SDL;
- Clean cattle – those that require extensive washing are not likely to be suitable for SDL;
- Distance cattle are travelling to the processing plant. The longer the distance the more risk involved so less likely to be scheduled for SDL;
- Time of the year – more likely in summer than winter for some plants. SDL may be used to alleviate heat stress in summer;
- Processing plants with 2 shifts could use SDL for the end of the first shift and all or some of the second shift;
- Processing plants with only one shift may use SDL for the end of the shift. All plants require cattle on hand to start the first shift that will have arrived the day or night before processing starts; and
- Ownership of the cattle. Easier to do with cattle owned by the processor as they can control the timing of the whole process so there is less risk involved.

Of those processors surveyed who have already adopted SDL, the targets for future maximum proportion of all cattle slaughtered using SDL ranged from 50-75%, while one processor was unsure.

Successful Implementation

Use of SDL has been practiced by these processors from between two and 25 years. The reasons for adoption of SDL included:

- Reduction in proportion of dark cutting carcasses;
- Animal welfare benefits; and
- Increased carcass weights.

Example processor quotes around the benefits of SDL include:

"Dark cutters were the main driver – major financial cost."

"Animal welfare benefits – less time in lairage, less heat stress and less stress overall."

"We thought it made sense, so we trialed it and proved it worked and off we went."

"It's safer on the animals and adds weights for producers and weights through our facility so it's a win-win practice."

Of the processors who have successfully implemented SDL, they have found substantial financial benefits in less dark cutters and an increase in HSCW, along with significant animal welfare benefits. All have been able to manage the increased operational risk through better organisation of logistics and more accurate forward planning.

- **Reduction in dark cutters:** All processors who have adopted SDL have found a reduction in the number of dark cutters, or run at less than 1% dark cutters. One processor was able to quantify the difference SDL has made:

"For the cattle that are held overnight for next day kill (time in lairage 16 to 18 hours), dark cutting is 0.8% compared to cattle with same day kill (time in lairage 2 to 8 hours), dark cutting is 0.2%."

- **Increase in HSCW:** Two processors reported an increase in HSCW, and one processor was able to quantify the difference SDL has made:

"Extra HSCW due to SDL is 7kg/head on average."

- **Animal welfare benefits:** Less stress for the cattle, particularly reduced heat stress during summer months where there is no/limited shade in lairage.

Operational Changes and Additional Costs

Processors identified the following operational changes and costs required for using SDL:

- Increased levels of organisation and accurate forward planning are required for the tighter time frames of SDL;
- Correct paperwork at every stage – use of electronic NVDs (National Vendor Declaration) was recommended to mitigate paperwork problems;
- Possible additional ante mortem inspections by OPVs; and

- No additional costs were reported by those processors who have already implemented SDL.

Processors already using SDL plan to either continue at the current level or increase current usage.

Risks and Challenges of Implementation

The following risks and challenges associated with use of SDL were identified by processors:

- Main risk is not having cattle available to kill and causing a disruption to the processing plant;
- Transporters – willingness and ability to deliver cattle on time when required;
- OPV availability for additional ante mortem inspections;
- Staff attitudes and entrenched habits – managing change; and
- Lack of knowledge of the benefits of SDL and the research results throughout the industry.

For those plants that have adopted SDL, all of these challenges have been overcome by good communication and education of the parties involved. OPVs are available for ante mortem inspections as required at these plants.

There are up to 25 to 70% of cattle processed at the plants that have adopted SDL that are not processed inside the SDL timeframe. Reasons for longer lairage for these cattle include:

- Need to have cattle in lairage ready to start the first kill shift:

> *"We have to have cattle in the night before, we can't avoid that, so the question is just how full do you get it overnight for the morning run, how much risk do you want to take with being caught short. I think we want to be 3 hours in front is my take from a risk perspective."*

- Cattle that require extensive washing. Hairy, daggy, longer fed bigger cattle can require up to 6 hours washing.
- Contract cattle - cattle that are not owned by the processor can be problematic, as there is less control over exact numbers to arrive, cleanliness and time of arrival:

> *"It's difficult to do with contract cattle because of the distance involved and the cattle type."*

- Distance travelled. Cattle that are travelling over 6 hours are at a higher risk of not arriving within a small-time frame due to a number of reasons including weather, traffic conditions, road works, road accidents and breakdowns.

These reasons for longer duration lairage are consistent with the reasons for non-adoption of SDL by other processors.

Barriers to Adoption of Short Duration Lairage

Of the processors surveyed who have not adopted SDL, the reasons given for non-adoption include risk management, contract killing for different suppliers, OPV ante mortem inspection preferences, washing requirements, especially in winter in southern Australia, and distances cattle are travelling to the plant.

- **Risk management**: Processors reported that they cannot afford to not have enough cattle for the plant to operate continuously in the order they need to be processed. Cattle may be owned by more than one supplier, different types and/or classes of cattle with different washing and processing requirements coming from different locations. Example quotes are provided below:

"The more time you have them on site, the more time you've got to deal with something if it does go wrong, like a truck doesn't turn up. So it's a risk management decision."

"We would need to weigh up any benefits in yield compared to any operational costs before we would further consider. When we stop the chain at our abattoir, it costs us about $850 per minute. So, if we had to stop to wait for the vet, or because cattle needed more washing, that's the cost for every minute we're delayed. So, if its 100% foolproof and nothing can go wrong, we'd be same day killing every day, but it's not and the risk and costs are so high if there is a delay."

"We definitely have suppliers who are asking for SDL, but we just don't do it because we have no control and it's too risky. We don't have control over the truck and there's a lot of variables that impact on how many cattle we kill in a day e.g., HGP management, offal, hides, changeovers, washdowns, that affect the total amount of cattle being killed for the day. If someone says, yeah I'll be there at 9am, and they get there at 11am, it's a problem, so I generally don't go with it if I get a request for same day kill, unless I know the fellow and I know where it is and I know that they understand the process and how important it is to be there when you need to be there. It's just too risky, especially if we don't have cattle on the abattoir."

"You're far better off finding out at 10pm the night before that a load has failed to come, whether they've forgotten, or broken down, or something else has gone wrong - people are capable of anything."

- **Logistics of contract killing for outside suppliers**: It's difficult to ensure cattle numbers and paperwork are correct, cattle are clean and will arrive on time. Time frames are too short with SDL to correct any mistakes or manage schedule changes, and some suppliers prefer longer periods of lairage. Example quotes include:

"We don't love doing it, it just puts too much pressure on trucks, on drivers, on stockmen at both ends i.e., the feedlot and the plant. We would only really

actively persist with a same day kill if we were seeing carcass data that was of concern."

"A lot of people have different beliefs on how soon they want to get them here prior to slaughter. I have some clients who like to bring them down 2 days before kill - they think that's the best way to do it. Some people deliver their cattle at 9am in the morning for next day kill - that's what they want to do to give them time to have a feed and rehydrate them (about 21 hours min prior to kill)."

"You can have 120 booked in and they'll deliver 80 in a rising market, or they can have 180 booked in and deliver 200 in a falling market, so every scenario you think can go on, goes on, all the time. This is the kind of uncertainty we're dealing with as it is. Under or over delivery happens every day, so it's a constant juggling act."

"If we're killing 700 on a day and we've got 300 cows, 300 HGP free cattle and 100 HGP cattle, you can't just turn up whenever you want and slot in when they arrive. There's a whole slaughter floor procedure around QA on offal management, hide management, HGP management and segregation. It's not as easy as turning up and tipping them in the race and she'll be right."

"We're not doing SDL as the logistics are too hard."

- **OPV ante mortem inspections:** In these plants the ante mortem inspections are conducted once per shift, prior to commencement of the shift for the whole shift. Additional inspections would create additional workload and interrupt other tasks:

"He doesn't like it (SDL) in that he likes to go down there and do his ante mortem inspections then carry on with his next job. He has to kit up, put different clothing on to do ante mortem compared to slaughter floor etc. So it's a bit of inconvenience for him."

"OPVs don't want to do additional inspections too frequently as they have other tasks during the day."

- **Washing cattle**: Mud and dags on longer fed cattle in winter can require many hours of cleaning in order to pass the OPV inspection for cleanliness. Breed of cattle also affects this, with hairier cattle requiring more cleaning.

- **Distance from the feedlot to the plant:** As distance increases above 6 hours travel, the opportunity for delays increase significantly – weather, traffic flows, road works and breakdowns can all affect arrival times.

- **Evidence of the benefits:** While processors acknowledge the benefits reported from research, they would need to be convinced that they would receive those kinds of benefits in their own systems before committing to the practice. For example:

> *"We have to base any decision to shorten lairage on meat colour/quality, not on yield. Once they're dead you don't know what they would have yielded with a shorter time in lairage so you can't really go on that. If someone said to me, I can guarantee you 100%, a 2% better dressing percentage through same day kill by using SDL, we would do it, but we don't know if we would get that. We like the idea of it and it may show weight benefits but I just don't think we could do it on a grand scale logistically without being sure because it's hugely risky."*

There are significant barriers to the adoption of SDL as detailed above. For those processors who have been able to overcome these barriers, there are significant economic and animal welfare benefits. Adoption of SDL for up to 75% of the animals processed per day has been demonstrated to be possible by one processor over a long period of time. However, there are many factors that make this unachievable for all processors, but consideration could be given to adoption of SDL at some times of the year for some cattle where circumstances allow.

Industry Assistance to Support Adoption

Processors identified several opportunities for industry, through MLA/MSA, ALFA and AMIC, to support industry decision making and implementation around use of SDL:

- Inform all stakeholders along the supply chain of what the benefits of SDL are, and what is required for effective implementation;
- Engage all stakeholders along the supply chain to find solutions to the challenges associated with use of SDL;
- Provide opportunities for industry stakeholders to see how SDL works in practice, including overseas examples;
- Provide processors and feedlots with an opportunity to measure the impacts of SDL in their own systems using trials; and
- Provide co-funding for processors to complete best practice audits around requirements for use of SDL to identify the baseline, to identify what changes are required to implement SDL, and to develop individual supply chain change management and communication plans. It was suggested that such activities could be co-funded through the MLA Donor Company.

3.2.3 Feedlots

Feedlot Demographics

Table 5 provides an overview of the characteristics of the feedlots engaged during the review.

Table 5: Demographics of feedlots engaged

Variable	Range

Number of cattle shipped for slaughter per week per feedlot	800 to 3,000
Length of journey	1 to 15 hours
Time of exit from the feedlot	4.00 am to 9.00 pm
Ship out of business hours	Yes for all
Currently or have practiced SDL	Yes for all
Percentage of cattle shipped for SDL	5% to 50%

Feedlot Exit Times

Feed-lotters identified some challenges and limitations to the times that cattle can exit individual feedlots. These include council curfews, night operation and staffing issues.

- Feedlot licenses with council planning requirement curfews. These can vary for each license:

> *"We can bring trucks in but we can't exit cattle before 6am and we can't exit cattle after 10pm."*

- OH&S issues associated with droving and loading cattle at night:

> *"There's considerable OH&S issues with droving black cattle in the dark so we only do it when there's sufficient daylight. The earliest loading is at 6am in the summer when there's enough daylight. And again, in summer we can load up to 8-9pm at night."*
>
> *"We have lighting but it's still poorer visibility than daytime so extra care is required."*

- Limitations to staff availability:

> *"It is difficult to get staff starting at 3.00am and then have enough staff for the rest of the day. Lighting and health and safety are issues – we need to have 2 people not just 1 at night."*
>
> *"We struggle to get enough people now. Out of hours trucking is the exception."*

- Night operation. One feedlot has installed additional lighting and prefers to operate at night to reduce heat stress on the cattle over summer - cattle exit at 2.00am.

Feedlot SDL Benefits

The benefits of SDL reported by the feedlots included improved animal welfare, increased carcass weights and reduced dark cutters:

"The less time they spend on concrete the better from a welfare perspective."

"Reduced impact from heat load on the cattle, reduced dark cutters and improved yield, heavier weight and less shrinkage"

"Benefits are improved meat quality, reduced shrinkage and improved animal welfare."

"Reduced dark cutters and great body weights, about 2kg extra on trade steers, and we're seeing about 4kg extra on an export steer. We're running at about 0.5% dark cutters."

Feedlot SDL Costs

Minimal additional costs were identified by the feedlots for use of SDL. Reported additional costs ranged from nil to some additional staff costs for extra out of hours loading, some additional administration work as it requires *"more planning and more admin to run"*, and some additional lighting.

Feedlot SDL Challenges and Limitations

The main reported challenges and limitations for feedlots using SDL are managing the logistics, processor OPV ante mortem inspections, distances travelled, ensuring cattle are clean enough and government regulations. Example quotes from feedlot operators are provided below:

"Our roads are terrible. The distances travelled are high and there are curfews."

"We need to get the paperwork right to minimise any delays. We now use eNVDs as cattle leave so the paperwork is always right when they arrive."

"Because of the distance to plants, freight availability can be a challenge at times."

"Strong communication and organisation are required as we have to get a whole lot of ducks lined up to make it work."

"The main challenges relate to staff issues and possible breakdowns/delays due to the distances involved."

"OPVs are different between plants - some are ok for the cattle to be there 1 hour before, and some want them there 6 hours before or others at other plants want them there the day before to do ante mortem inspections. It also depends on the

OPV and the plant and whether they are prepared to do the ante mortem inspections once a day or go to the lairage more often."

"Extra precision and organisation are required to manage trucking and lairage schedules and dealing with the processors to make it happen at their end."

"It will only work when cattle are clean enough."

"As long as they can get the logistics sorted around washing cattle, that's the biggest impost, washing cattle, and that's a physical time requirement."

All feedlots surveyed intend to maintain or increase their current use of SDL.

Industry Assistance to Support Adoption

Suggestions provided by stakeholders surveyed for assistance from MLA and ALFA to support increased industry adoption of SDL included:

- The value proposition for SDL needs to be clearly explained and demonstrated for all parties;
- Published research results need to be promoted regarding the animal welfare, food safety and yield benefits of SDL;

"More publicity of the benefits of SDL and help removing the barriers. There needs to be a shared understanding of the mutual benefits among all stakeholders."

- Education and consistency of decision making by OPVs nationally. Clearer guidelines and less subjective assessments so all parties understand the decisions made and the need to get OPVs on side to support increased use of SDL;

"Validation of the benefits and published results regarding animal welfare, food safety and yields. It will then be a commercial decision for the business. Need to get the OPVs on board - inform them of the benefits and get them onside. Published reports in a commercial context would help."

"Standardise the OPV requirements between plants."

3.2.4 Trucking Industry

SDL Challenges and limitations

Three trucking businesses were surveyed during this review. Of these businesses, one has current involvement in SDL. All had similar challenges and limitations that they felt needed consideration for SDL to be successfully implemented. These included timeliness of transport, council curfews, processor holding capacity, OH&S for drivers, feedlot and processor facilities and the effect of distances travelled.

- **Timeliness of loading and unloading:** Cattle need to be ready to load from the feedlot at the arranged time. Any delays in loading and unloading will have a flow on effect for all industry sectors. Example quotes are provided below:

"It all comes back to delays to trucking schedules at feedlots and processors, which happen regularly. There would need to be a whole lot more organisation and preparation at the feedlot end to make it work than what there is now. Some feedlots are very well-oiled machines but many are not."

"Set times so trucks are ready and stick to their schedules. Don't have trucks waiting around - load and go, no delays. Accommodate the driver and look after them."

"Better management at feedlots, more planning, precision and accountability for doing things on time so trucks get away on schedule and therefore arrive on schedule and are able to get back for the next load on schedule."

"We're left waiting around for extended periods of time at around 1 in 3 feedlots we work with."

- **Government regulations:** Some feedlots and processors have curfew restrictions on the time cattle can be loaded from the feedlot or unloaded to the processor. There can also be restrictions on the time weighbridges are open, some are not open until 7.30am.

"Some processors have curfews for delivery, such as not after 11pm and not before 6am because of urban requirements for noise and traffic."

- **Processor holding capacity:** Some processors have restrictions on their holding capacity so any delays at the plant may mean delays unloading cattle and therefore disruption to the trucking schedule for subsequent loads.

- **OH&S for drivers:** A big concern for all trucking businesses is driver safety, especially driving between 12.00am and 4.00am. Poor loading facilities and loading and unloading at night were also identified as presenting OH&S concerns.

"By 11.00pm all cattle are off trucks at feedlot or plant or yards overnight. We don't do overnight driving."

“Dealing with fatigue is an OH&S issue for drivers. Loading and unloading in the dark is also an OH&S issue. At present we try not to have drivers on the road between midnight to 4 am.”

“The number one priority of any changes would be to ensure that we can make them without compromising driver safety.”

- **Facilities at feedlots and processors:** For more efficient and timely transport, better facilities such as lighting, safe and efficient loading ramps and double deck ramps are needed.

“If we need to streamline this and make it as efficient and productive as possible, we need to have the right tools in place to assist with that, and that is double deck loading ramps, safe access to livestock crates and upgraded and increased lighting.”

- **Travel distance:** Not only the length of the journey, but the weather, terrain, road conditions and traffic flow will all impact on expected arrival times and the margins that need to be allowed. The longer the distance traveled the more variable expected arrival times can be.

“Less than 400kms same day kill is possible if there’s a double shift at the plant. If there’s only one shift at the plant, then 200kms may pull it up.”

“Generally, we can do SDL only over short distances - may be able to do it up to 300kms.”

Successful Implementation Strategies

Trucking companies surveyed reported that the key factors required to allow successful implementation of SDL include excellent communication, and an understanding of the practice of SDL by all parties involved so that all scheduled events in the process can happen on time.

“We have a great relationship with the feedlots, and we work as a team. You need good communication between all parties.”

Support for Implementation

Suggestions provided by transport company stakeholders for support for implementation include more industry engagement about research into SDL, the goals SDL hopes to achieve and better communication between all parties involved. Example quotes are provided below:

"It's all about industry engagement and collaboration across all aspects of the supply chain, from the start. That engagement with us needs to happen now, so we can go on the journey with you, and we may very well have some good ideas that will help if you ask."

"The trucking industry has a large number of internal communications that could be used by MLA/ALFA to distribute information via newsletters etc."

"This whole thing is going to come down to communication, understanding everyone's perspective, being realistic and planning."

"There has been transport companies involved in SDL, but for the broader industry we still don't know enough about it, so there's a massive education/information sharing gap there at the moment. Get some info out to the trucking industry now, before your report comes out, so that we are more informed sooner to get people thinking about it and to understand what the basics of it are. It could be a one or two-page document sent out through the various trucking industry comms channels and networks, and there's plenty of them."

The trucking industry is vital to the successful implementation of SDL. The ability to deliver cattle on time all the time is crucial for SDL to operate successfully. There are limitations to when cattle can be trucked, such as curfew regulations, that are individual to each feedlot and processor. OH&S factors for drivers, such as facilities like lights and loading ramps, not driving between 12.00 am and 4.00 am, and driver fatigue are all issues that need consideration.

Distance from the feedlot to the processor is also a major issue that needs to be considered when planning any SDL opportunities. As distance increases over 400 kms between the feedlot and processor, it would seem the increased variability of travel times would make SDL a much higher risk. All trucking businesses engaged during this review were positive about the use of SDL and wanted more information and to be consulted at the earliest opportunity.

3.2.5 DAFF

Four DAFF staff members, including OPVs, with various duties within the system and level of knowledge of and experience with SDL were engaged during this review.

Ante mortem inspection by OPVs

All export cattle require an ante mortem inspection by an OPV prior to slaughter. The destination market will determine the specific requirements of that inspection. Some overseas markets require ante mortem inspections within 12 hours of arrival and within 12 hours of slaughter. The NVD and any other paperwork must be checked and completed by the OPV. Ante mortem inspections are only one of the duties an OPV is required to conduct at an abattoir. Other duties in other parts of the plant require appropriate cleanliness and clothing that is different from clothing that is suitable for the lairage area for ante mortem inspections. Example DAFF stakeholder quotes are provided below:

"Cattle must be inspected within 12 hours of arrival and within 12 hours of slaughter. What is considered normal practice is plant specific."

"We've got to view and sign them off and designate a status - unconditional, conditions such as ok for health or maybe cleanliness conditions, emergency kill or suspect slaughter e.g., cancer eye - look at later on slaughter floor - do at the end of the run. Viewing pre wash and then discuss chain speed and trimmers for contamination."

"The OPV will negotiate with the plant about how the washing will suit the conditions/cattle, maybe extra washes, soaked prior to washing and/or different kill practices, extra trimmers, slow the chain speed. We constantly evaluate this."

"If you're being asked to do an ante mortem every 2 hours, it really does impact on your work, and you've got to be much better at organising and scheduling your activities to make it work."

"There's no scheduling system – the OPV normally allocates ante mortem 15 minutes prior to first knock, then additional ante mortem inspections as required if more cattle come in. Depends on the set-up and arrival of stock and set up at the plant. OPVs should be available when required."

"Tailgating is when there are ante mortem inspections as they come off the trucks so they can be washed and killed ASAP.

The number of times per day that current ante mortem inspections are completed by OPVs varies from plant to plant, and is determined by the OPV and the processor.

SDL Implementation Challenges and Limitations

SDL could involve more ante mortem inspection requirements by some OPVs. This would depend on the current set up, facilities and practices in place at each plant. Example DAFF stakeholder quotes are provided below:

"Maybe SDL could take up to 2 or 3 extra ante mortem inspections. Cost would depend on how other duties could be arranged and physical set up of the plant."

"Depends on the plant, current practices and location of the vet office relative to the lairage."

"It would require more logistical management/organisation to ensure that the chain is not interrupted."

"The biggest issue is workload of the OPV and how often ante-mortem inspections are required and management of workload."

"Need to work through the issues, time to manage all current duties and fit extra duties in. Expect there would be an increase in time spent by OPVs in lairage."

"So generally speaking, animals coming out of an intensive feedlot system are largely healthy and even lines of cattle. And our instructions have a clause in them that for even lines of cattle, only a proportion has to be looked at in motion, so you don't have to look at all of them, and what proportion is not specified."

"The biggest impact for someone in my position is going to be the way that it changes how we operate day to day and for some people it will be a bigger change than for others, depending on personality and how long you've been doing it a certain way. No-one likes change, and if you've done ante mortem for the first hour of your day for the past 15 years then someone tells you to do ante mortem every two hours, then there's going to be pushback and resistance."

"A key factor is cattle cleanliness and hygiene. This is a variable factor, generally associated with feedlot cattle and winter/cooler months and rain. The implications are significant though if cattle require extensive cleaning prior to being passed or the implications of being passed as a conditional class as "soiled" cattle. Dirty feedlot cattle are a massive issue."

SDL implementation will require good planning, organisation and communication between the plant and the OPVs. The OPV guidelines for inspection appear to be very discretionary in some areas. These include the definition of cleanliness, what is 'adequate' time in lairage, and the proportion of cattle within a line that need to be inspected. This is not surprising given the difficulty with being able to be completely prescriptive for every situation. It can, however, lead to widely different interpretations and practices at different plants which can impact upon the ability of the plant to practice SDL.

Cost of OPVs

OPVs and Food Safety Meat Assessors (FSMAs) are paid by DAFF with full cost recovery from the processors as per cost recovery implementation statement: meat exports 2021-22 (CRIS) and the individual contract with each processor. The number of OPVs and FSMAs allocated at a plant are set by DAFF. Example quotes are provided below:

"It is fully cost recovered from the processor. OPVs charge for their time depending on the agreement with the individual plant. Each plant has an individual agreement as they have different conditions."

"Every export plant has a base allocation of 1 OPV. DAFF has a system to allocate workload hours, where verification workload tool (VWT) is more than 1, can provide an additional resource – a government meat inspector (FSMA rover) to help the vet do some of their tasks. If SDL is more workload we could allocate a FSMA (rover) to assist the vet. Bigger plants have rovers, or part of one, it depends on verification workload. They only have one OPV per shift. Bigger plants have rovers or part of each shift e.g., 0.4 or 0.5, depends on the verification workload tool, but they only ever have one OPV per shift."

The number of ante mortem inspections conducted per day appears to be an area of contention for some plants and OPVs. If SDL changes current work practices this could be an issue that may require some further investigation and negotiation.

Additional Resources to Support Adoption

SDL and the benefits that flow from it do not appear to be widely known and understood by OPVs. All DAFF employees interviewed were interested and expressed a wish for more knowledge of SDL. Suggestions to support adoption included distribution of research results, written materials, webinars, presentations at OPV training meetings and presentations to all stakeholders. Example quotes are provided below:

"Education for all parties. More materials and research results and raw data and involvement in trials that show the cost benefit analysis."

"The average vet is probably completely unaware of the project at the moment. I have mentioned it to a few colleagues, and we've had some discussions around it but generally speaking across the industry it's not widely known about."

"I think having a better understanding of how other countries actually operate on this would be helpful to increase general understanding and acceptance."

"Super interested in SDL research - only heard about it on Friday. I have colleagues that would also be very interested."

Suggestions were also made on how to manage the expected increase in the OPV ante mortem workload. They include a review of the OPV and FSMA allocations via the Verification Workload Tool (VWT). This review could prove useful as part of a change management strategy.

"VWTs are not commonly done unless there's a major change. It should be considered if implementation of SDL is being considered."

3.2.6 Industry Organisations

Adoption of SDL

Representatives from ALFA and AMIC were engaged during the review. These representatives acknowledged that there are demonstrated benefits from use of SDL, including productivity for carcass weight, reduced dark cutting and animal welfare benefits. They acknowledged processors run a difficult, highly complex business with many players involved, and that there will need to be a clear value proposition to drive adoption. Example quotes are provided below:

"Need to weigh up the risks vs the benefits for the processors. It will be a commercial decision for the processor – they cannot afford to not have enough cattle on hand."

"It needs to be well planned and documented and contingency plans in place."

"We would support a voluntary use of SDL, with agreed industry guidelines on how to implement it, that clearly outlines these processes and how it works."

"There needs to be a clear value proposition and the information needs to be out there as soon as possible."

"We need to help each business make an informed decision."

Stakeholders from both organisations commented on the need for clear and comprehensive communication for all stakeholders on all aspects of SDL.

3.2.7 MLA/MSA and Researchers

MLA/MSA and the SDL researchers identified the goal of SDL as being to reduce the time in lairage for cattle to four hours or less. These stakeholders commented on the benefits of SDL verified by the research projects as improved animal welfare and increased HSCW, with no change to food safety standards. Stakeholders commented on the importance of animal welfare benefits of SDL to industry as measured in the research projects:

"Reduced stress means less dark cutters. Significantly improved management of heat stress in summer and hydration - an hour at a plant is not the same as an hour at a feedlot. General health of the animal is improved as shown by data

from the trial regarding glycogen, rumen pH and liver function. The cattle are less hungry and thirsty and less stressed."

SDL Implementation Challenges

MLA/MSA staff and the Bovine Dynamics researchers perceive the challenges to adoption of SDL as including risk management for processors, increased planning and logistics management required, transport distances, staff availability and cleanliness of cattle. Example stakeholder quotes are provided below:

"Adequate time to clear paperwork, NVDs, adequate washing, communication with transporters and maintaining OH&S so all staff are operating safely."

"eNVDs can speed up paperwork. Logistics of trucking and time barriers - plan buffer times and benchmark on time arrivals, look at how others operate."

"Cattle cleanliness - more focus on clean cattle arrival - clean when leaving the feedlot. More focus on cleanliness guidelines - objective measurements on food safety standards."

"Ensure resourcing of OPVs is appropriate."

Supporting Adoption

MLA, along with other industry organisations, can assist with adoption in a number of ways. The publication, communication and education of research results to all sectors of the industry need to be developed and facilitated. Adoption plans and options could be tailored to each individual business from a common template for situations where SDL is appropriate. Example quotes include:

"I think education and communication is important to support change."

"Resources to ensure those communications and extension keep happening because these things don't just happen after a one-off conversation, it takes time to get people on board."

"Small steps to start the process to show it can be incrementally implemented."

"Do demonstrations with interested businesses on a small scale and expand as benefits are exposed."

"Find the barriers and challenges to be addressed and work out the solutions and continue to set goals. Don't set unrealistic goals - start conservatively then upscale."

Logistical barriers may mean that same day kill is at least initially a more realistic target, even where lairage times are more than 4 hours. This may mean the target is to get to up to 50% of grain fed cattle killed on the same day when SDL is practicable:

"I think 80% - 100% of major plants could adopt some form of SDL. Possibly 30 to 50% of grain fed cattle in these plants (not in winter in southern states) could use SDL."

The researchers for projects B.FLT.4002 and B.FLT.4017 suggest that future work should focus on opportunities to simplify the logistical challenges associated with implementing short duration lairage in a commercial environment, including electronic submission of regulatory paperwork such as national vendor declarations, transport scheduling, ante-mortem inspection scheduling, and improving coat cleanliness prior to abattoir arrival to reduce washing intervals required prior to slaughter.

Further, the B.FLT.4002 project report highlights the fact that producers are not made aware of the time that cattle arrive at an abattoir, the period of time their cattle remain in lairage, the conditions of lairage, the time that cattle are slaughtered, or the time of grading. Given the results of the project demonstrated that these conditions have a significant impact on HSCW, it will be important to drive improvement in these areas by providing feedback to producers regarding timing of cattle arrival, slaughter and grading.

Feedback provided during the industry survey undertaken during this assessment indicates that further research is desired into the impact of SDL on long fed cattle, on Wagyu cattle in particular, and on the impact of shade and shelter in lairage facilities on meat quality.

4.0 Conclusions

MLA research has demonstrated that large economic benefits can be achieved from use of SDL. The value of an additional 5.7 kg HSCW was estimated at $35/head using five-year average historical prices. Extrapolation of this estimated benefit per head across the average number of grain fed cattle processed over the past 5 years represents the potential for an additional $97 million worth of HSCW from grain fed cattle in Australia annually.

Other benefits identified by the research included improved animal welfare via reduced stress and environmental/sustainability benefits via reduced emissions intensity per carcass, estimated as a 1.2% reduction in emission intensity equal to 0.34 kg CO_2-e per kg carcass weight. Interviews with stakeholders during this review also provided examples of successful implementation and use of SDL over an extended period of time to create productivity (increased yield and reduced dark cutters), animal welfare and sustainability benefits for producers, processors and consumers.

Although the animal welfare and sustainability benefits associated with shorter duration lairage were difficult for stakeholders to quantify, they nonetheless noted the high value associated with these types of benefits in light of increasing consumer concern, both domestically and internationally, with animal welfare and increased demand for ethically produced products, and the industry objective of carbon neutral red meat production by 2030 (Red Meat 2030). Businesses can use these demonstrated animal welfare benefits and reduced emissions intensity benefits when promoting their products to customers.

For those supply chains looking to adopt the practice, stakeholder engagement indicates that SDL is only likely to make up a portion of the annual slaughter for individual supply chains given logistical difficulties associated with transport distances, dirty cattle during autumn/winter, system processes and QA requirements for different types of cattle, and preferences among some suppliers for longer periods in lairage.

The requirements for effective implementation of SDL within a supply chain essentially relate to reducing the risk of a plant stoppage. Stoppages are very costly to the processors, with one processor estimating a cost of $850 for every minute that the chain is not operating during a shift. Key requirements identified by stakeholders for implementing SDL include:

- Increased logistical and organisational skills across the supply chain, from feedlots, to transporters to processors to deliver an increased level of precision in system management;
- Increased understanding along the supply chain of the importance of each activity being completed on time and to specifications;
- Ideally a supply of ‘back-up’ cattle on site to push up the list or to substitute when cattle arrival is delayed. This can be achieved if lairage capacity allows or if there is a feedlot on site or close by;
- Availability of sufficient OPV resources and OPV support for accommodating the changed requirements for an SDL system;
- Consideration/review of OPV ante mortem inspection requirements for passing cattle as clean or conditional soiled for slaughter; and
- Confidence in the value of the expected benefits due to SDL within a supply chain.

Stakeholders also identified a range of means by which industry could support increased adoption of SDL along the supply chain:

- Funding of additional research around SDL, including impacts on long fed cattle, impacts of shade and shelter in lairage, and trials on individual supply chains wanting to determine the benefits prior to adopting;
- Provide opportunities for industry stakeholders to see how SDL works in practice, including overseas examples;
- Co-funding a system whereby supply chains can be assessed for baseline levels of best practice required for SDL to identify the current system gaps and the strategies and processes required

for addressing those gaps, including development of change management and communication plans;

- Proving opportunities for all stakeholders along the supply chain to provide input into discussions around finding solutions to the challenges associated with use of SDL; and
- Informing all stakeholders along the supply chain about the practice of SDL and the reported benefits of the practice, and providing regular updates to industry on new developments on the topic.

Stakeholders engaged during this review indicated a high level of interest in learning more about SDL, what the benefits are and how to overcome some of the key challenges. This document is intended to inform future discussions around these issues to add further support for industry adoption of SDL.

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6.0 References

Anon, (2002). Standing Committee on Agriculture and Resource Management Model Code of Practice for the Welfare of Animals: Livestock at Slaughtering Establishments. CSIRO Publishing, SCARM Report No. 79.

Ashmore, C. R., Carroll, F., Doerr, L., Tompkins, G., Stokes, H. and Parker, W. (1973). Experimental Prevention of Dark-Cutting Meat. *Journal of Animal Science:* 36**,** 33-36.

Australian Beef Sustainability Framework Annual Update 2022. Red Meat Industry Advisory Council absf_update_2022_web.pdf (sustainableaustralianbeef.com.au)

EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare), Nielsen S.S., Alvarez J., Bicout D.J., Calistri P., Depner K., Drewe J.A., Garin-Bastuji B., Gonzales Rojas J.L., Gortazar-Schmidt C., Michel V., Miranda Chueca M.A., Roberts H.C., Sihvonen L.H., Spoolder H., Stahl K., Velarde A., Viltrop A., Candiani D., Van der Stede Y. and Winckler C. (2020). Scientific Opinion on the welfare of cattle at slaughter. *EFSA Journal* 2020;18(11):6275, 107 pp

Ferguson, D.M., Shaw, F.D. and Stark, J.L. (2007). Effect of reduced lairage duration on beef quality. *Australian Journal of Experimental Agriculture*: 47, 770-773.

Gallo, C., and G. Lizondo, G. 2000. Efectos de diferentes tiempos de ayuno antes del sacrificio sobre el contenido de glucógeno muscular y hepático y el pH final de la canal en novillos. In: Resúmenes del XI Congreso Nacional de Medicina Veterinaria. p. 25-27.

George, M. and George M. (2018). Effect of lairage timing and duration on rumen physiology and muscle glycogen. MLA Project B.FLT.4002 Report.

Janloo, S. (1999). Environmental impact of withholding feed on composition of ruminal contents, carcass quality, and cattle performance. In: Dolezal, G. (ed.). ProQuest Dissertations Publishing.

Kreikemeier, K., Unruh, J., and Eck, T. (1998). Factors affecting the occurrence of dark-cutting beef and selected carcass traits in finished beef cattle. *Journal of Animal Science:* 76**,** 388-395.

Scanga, J., Belk, K., Tatum, J., Grandin, T. and Smith, G. (1998). Factors contributing to the incidence of dark cutting beef. *Journal of Animal Science:* 76**,** 2040-7.