



final report

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Preliminary investigation into on farm factors contributing to ecchymosis

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Abstract

The undesirable appearance of ecchymotic lesions in meat necessitate additional trimming and handling of carcasses that result in a reduction in labour efficiency, loss of product and market opportunities. Despite this, the incidence, severity and economic penalties associated with the presence of ecchymosis in the Australian lamb and sheepmeat industry is poorly quantified or understood. The significant difference in the prevalence of ecchymosis between lines of lambs within the current study support the hypothesis that non-processor related factors may be contributing to ecchymosis. This is further supported by significant relationships between ecchymosis and rainfall at farm of origin, time in lairage, hot carcass weight and fat depth, as well as age in the current study. These interactions suggest that stress, on-farm management and nutrition may be contributing to the prevalence of ecchymosis observed in the current study, and should be further investigated.

Executive summary

Ecchymosis is the escape of blood from ruptured blood vessels into the surrounding tissues, and presents as darkened spots on the surface of the muscle, causing an undesirable appearance (Leet *et al.*, 1977). It has been documented in multiple species at slaughter, including cattle, deer, pigs and sheep (Burson *et al.*, 1983; Mulley R, 2008). The undesirable appearance of ecchymotic lesions in meat necessitate additional trimming and handling of carcasses that result in a reduction in labour efficiency and loss of product and potential market opportunities, thus presenting an economic loss to Australian processors. Despite this, the incidence, severity and economic penalties associated with the presence of ecchymosis in the Australian lamb and sheep meat industry is poorly quantified. Furthermore, little is known in regards to underlying factors that may contribute to ecchymosis, with previous research suggesting that ecchymotic lesions are caused by the increase in blood pressure and muscular contractions associated with the pre-slaughter stunning process (Gilbert and Devine, 1982). However, it has been found that haemorrhages can also be electrically induced in the brain and other tissues that do not contain skeletal muscle, implying that it is unlikely that muscle contraction is the primary cause of capillary rupture (Hassin, 1933).

This study thus focussed on factors external to processing that may influence the incidence and/or severity of ecchymosis. The significant difference in the prevalence of ecchymosis between lines of lambs in the current study supported the hypothesis that factors other than processing may cause, or contribute to, ecchymosis in lambs. The occurrence of ecchymosis in the current study was significantly associated with average annual rainfall at the farm of origin, supporting results from a preliminary study conducted by Gray (2017) who found that the prevalence of ecchymosis was higher in lambs from areas of lower average annual rainfall. Rainfall can significantly affect pasture quality through its influence on soil composition, pH, aeration, nutrient availability and the movement of solutes from the environment through the soil (Fatubarin and Olojugba, 2014). French (1946) reported high and low rainfall can disrupt mineralisation resulting in deficiencies in common minerals such as copper (Cu) and selenium (Se). Accordingly, Cu and Se concentrations in the livers of lines of lambs affected by ecchymosis were analysed in the current study, however neither mineral showed a significant interaction with the prevalence of ecchymosis. The underlying mechanism causing the relationship between rainfall and ecchymosis thus needs further exploration, including an investigation into pasture and grazing management prior to slaughter.

In addition to rainfall, time in lairage also had a significant, positive relationship with the incidence of ecchymosis in the lines of lambs observed in the current study. However, there was also an interaction between carcass weight, lairage time and the risk of ecchymosis such that heavier lambs had a higher risk of ecchymosis with shorter lairage times, while lighter lambs had an increased risk of presenting with ecchymosis with longer lairage times. The interaction between lairage time and ecchymosis suggests a possible correlation with either stress, nutrition or both. The relationship between carcass weight and lairage time with ecchymosis suggests that heavier animals may have the capacity to recover from the stress of transport prior to slaughter, and thus mitigate the risk of ecchymosis, while this potential for recovery may be absent or reduced in lighter and smaller animals.

Age was also significantly correlated with the incidence of ecchymosis, such that lambs were twice as likely to present with ecchymosis as hoggets (14% in lambs compared to 7% in hoggets), and mature

animals had a negligible occurrence of ecchymosis (<1%). This trend may be explained by a higher level of hormonally induced capillary fragility in younger animals compared to mature animals, or an increased susceptibility to stress in young versus older animals. Regardless, the economic impact of ecchymosis in older animals is insignificant due to both the lower incidence, and also the lower overall carcass value. In contrast, lambs experienced a much higher rate of ecchymosis, and are considered a more valuable product economically.

An economic analysis has not been undertaken within this study due to two constraints. At the commencement of this study David Rutley was employed by Thomas Foods International (TFI) and was engaged by the project to undertake the economic analysis and facilitate the work to be undertaken at TFI. During the undertaking of this work David Rutley ceased employment with Thomas Foods International as a result of the fire that closed the Murray Bridge plant in January 2018. This meant David was unable to conduct an economic analysis within Thomas Food International and despite the work still being carried out at the Lobethal plant there were no other personnel employed by TFI at Lobethal that were available to undertake the analysis due to their current workloads.

An additional compounding factor to undertaking an economic analysis is that the requirements for individual markets and the cuts required for these individual markets including export and domestic varies significantly between abattoirs. The additional time and devaluing of cuts when ecchymosis affected carcasses are processed which ultimately results in trim and additional labour within the boning room is complex and requires a focused study to determine the cost.

The results of this study show that it is likely that pre-slaughter processes may impact on the incidence and severity of ecchymosis in lambs in South Australian abattoirs, and that the prevalence of ecchymosis presents a reduction in production and processing efficiency, and an economic loss to the industry. Areas requiring further investigation include on-farm handling, management and nutrition and total curfew time including transport and lairage length and conditions. Management of pre-slaughter factors known to contribute to ecchymosis will lead to an increased efficiency of production and greater financial returns to the industry.

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1 Background

Ecchymosis refers to pinpoint rupturing of capillaries in the musculature resulting in a localised haemorrhage. When observed in sheep and beef carcasses, it appears as darkened spots on the surface of the muscle tissue. Ecchymosis results in a carcass being downgraded, heavily trimmed or condemned. As a result, it is a point of entry rejection to many of our export markets. Previous work has investigated risk factors such as the role of stunning to exsanguination interval (rev. by Grandin, 1980) or the effects of dietary coumarins (Restall, 1980). However, there is scant research into the prevalence and variation in ecchymosis, and the factors contributing to it. Preliminary work conducted by the University of Adelaide and Rural Solutions South Australia has detected an average incidence of ecchymosis of 4.5% ranging from 0%-19%. This project seeks to further quantify the incidence of ecchymosis in lambs processed in South Australia and identify nutritional, pre-slaughter management and abattoir lairage factors that may be contributing to the incidence.

2 Project objectives

By August 31st 2018 the participant will have:

- Quantified the incidence of ecchymosis in lambs processed in South Australia
- Gathered preliminary data on the condition, including:
 - Determining if there is significant variance between lines of lambs (in which case farm management factors may be contributing to the incidence of ecchymosis).
 - Repeating work conducted at JBS Bordertown in phase 1, at TFI Lobethal and determining if distance travelled, average rainfall from farm of origin, breed, carcass weight or time in lairage has an impact on the incidence of ecchymosis.
 - Comparing the incidence of ecchymosis between lines of lamb and mutton and determine if age is a factor.
 - Determining whether the Cu and Se status of individual animals or lines of lambs correlates with the incidence or severity of ecchymosis.
 - Ascertaining if stress is a factor contributing to the incidence of ecchymosis.
 - Estimating the cost of ecchymosis to the SA lamb industry.
 - Developing recommendations for further work required to reduce or eliminate the condition and impact on the lamb industry.

3 Methodology

3.1 Abattoir measurements

3.1.1 Ecchymosis scoring

Data for this study was collected from TFI, Lobethal, South Australia, over a seven day period from 18th–27th April 2018, with scoring conducted in both the morning and afternoon shifts. Commercial lines of lambs, hoggets and mutton were delivered to the abattoir and processed in accordance with

TFI's procedures. Following processing, grading, tagging and electrical stimulation, carcasses were individually scored for ecchymosis in the intercostal muscles based on lesion count and severity, on a scale of 1 - 3 (Figure 1). Carcasses scored as one had minimal presence of ecchymosis with 3-4 lesions. A score of two represented a mild case of ecchymosis with 5-10 obvious lesions, while score three showed severe ecchymosis with 10 or more lesions within the rib cage. Carcasses with no lesions were recorded as unaffected, and assigned a score 0. Lot number, body number and consignment type (direct or saleyard) was also recorded for each carcass.



Figure 1. Ecchymosis score 1, 2 and 3, from left to right, observed by dark red/purple lesions in the intercostal muscle between the rib bones. Photo by Gray (2017).

Age, breed, sex, hot weight, fat grade, property identification code (PIC) and kill time were obtained from the abattoir's slaughter floor database for each carcass scored. Unloading time and date of each consignment were obtained from National Vendor Declaration forms.

3.1.2 Liver sample collection

On days three and four of measurement, small (5-10g) liver samples were collected from lines being scored for ecchymosis using a modified corer on the offal chain during processing. Samples were placed in tubes labelled with lot number, and frozen at -4°C within 4h of collection for storage prior to laboratory analysis. Samples were collected from 10 randomly selected carcasses per consignment of >100 animals, with samples collected from 21 lots of directly consigned lines in total.

Copper samples were analysed by flame atomic absorption spectrometry (AAS) on a wet weight (mmol/kg) basis, and Se samples were analysed by coupling glutathione peroxidase reaction with glutathione reductase as a means to estimate Se (U/g) at a commercial laboratory (Regional Laboratory Services, Victoria).

3.2 On-farm records

The PIC for each consignment was used to determine the location of origin from which the annual average rainfall for the farm of origin was obtained. Average annual rainfall at the farm of origin was included in the secondary analysis of liver mineral composition.

3.3 Statistical analysis

Data was preliminarily analysed in Microsoft Excel and conclusively analysed using IBM SPSS statistical package (version 25). Statistical model development was completed using a backwards stepwise elimination process from the maximum model. The maximum model included factors, covariates and their quadratic terms, all first order interactions and a higher order interaction between factors. During the elimination of non-significant interactions and effects, the marginality requirements of Nelder (1994) were maintained. The model development process eliminated the least significant interaction or effect, based on Type III sums of squares, until all interactions and effects were significant at the 5% significance level ($P < 0.05$). Complex models were simplified by increasing statistical stringency and reducing the significance level to 1% ($P < 0.01$). Deviations from this procedure are described where applicable.

3.3.1 Primary analysis

Individual carcass traits, breed, hot weight (kg), palpated fat depth at the GR site (mm) and time spent in lairage (hours) were analysed for association with ecchymosis using a SPSS generalised linear mixed model. Management group, or the lot, was fit as a random effect, with ecchymosis as the target as a binomial effect as either a 0, or 1 (score 1, 2 or 3).

As the overall prevalence of ecchymosis observed in mutton was significantly lower than in lambs ($P < 0.0001$), only lamb observations were used in this analysis. Suffolk ($n=114$) and Dorper ($n=260$) breeds were removed due to low repetition within lots. Observations without a known consignment ($n=1$) or from a market consignment ($n=53$) were also removed due to insufficient repeatability. After appropriate elimination of data, there were 12,754 observations in total used within this analysis.

The maximum model consisted of kill date, kill shift and breed as factors, their three two-way interactions and three-way interaction. The following traits were fit as covariates:

- Hot standard carcass weight (kg)
- Palpated fat depth (5-25 mm)
- Lairage time (hours)
- Absolute deviation of an individual from the average lot hot weight (kg)
- Standardised distance of an individual from the average lot hot weight (kg)
- Absolute deviation of an individual from the average lot fat depth (mm)
- Standardised distance of an individual from the average lot fat depth (mm)

All covariates and their quadratic terms were fit and tested within the model, as well as all two-way covariate, and two-way covariate and factor interactions, noting that if quadratic terms of two covariates are included in the model then the interaction between both linear terms must be retained to satisfy marginality requirements.

Due to complexity, the statistical stringency of the model was increased to the 1% level ($P < 0.01$).

3.3.2 Secondary analysis

This analysis used a SPSS generalised linear model to test the associations between the prevalence of ecchymosis and lot variables. Lots were adapted into management groups ($n=166$), accounting for the lots that were split for processing. All lots: lamb, hoggets and mutton, were included in this analysis.

'Number of carcasses with ecchymosis' per lot was fit as the dependant variable with the number of trials 'lot size'. The covariates that were fit as main effects include:

- Average annual rainfall at the farm of origin (mm)
- Average lot hot carcass weight (Kg)
- Average lot palpated fat depth (mm)
- Average lot lairage time (hours)
- Average liver copper (mmol/Kg)
- Average liver GSPx (U/g)

Average liver copper and GSPx were only applicable for the 21 lots from which they were sampled.

4 Results

4.1 Abattoir measures

4.1.1 Ecchymosis prevalence

A total of 21,364 carcasses were scored for the presence and severity of ecchymosis over the 7 day measurement period. After removal of Suffolk and Dorper breeds, as well as market consignments due to insufficient representation, ecchymosis scores from 12,754 lambs were included for analysis from 89 lines that averaged 14.1% incidence of ecchymosis, ranging from 0 to 41.5%, while both hoggets (7.0% average (0 – 22.2%); $n=121$) and mutton (0.7% average (0-7.6%); $n=8037$) had a significantly lower rate of carcasses affected by ecchymosis than lambs ($P < 0.0001$; Table 1). There was a significant difference in the incidence and severity of ecchymosis observed between lines of lambs ($P < 0.0001$). Of the 1,809 lambs affected by ecchymosis, 51.7% were score 1, 36.3% were score 2 and 12% were score 3. There was no difference in the incidence of ecchymosis observed in lambs processed in either the morning or the afternoon shift.

Table 1. The incidence, range and severity of ecchymosis observed in 175 lines of lambs, hogget and mutton along with average hot standard carcass weight (HCWT; kg) and palpated fat (mm).

	Sex	No. lines	Incidence of ecchymosis (%; range)	Score 1	Score 2	Score 3	HSCW (kg)	Fat (mm)
Lambs	U	89	14.1 (0 – 41.5%)	7.3%	5.1%	1.7%	25.4	17
Hogget	U	28	7.0 (0 – 22.2%)	0.04%	0.007%	0.007%	27.1	16.9
Mutton	M	18	0.5	0.5%	-	-	29.2	8
	F	40	1.0 (0 – 7.6%)	1%	0.08%	0.01%	24.4	10.6

4.1.2 Liver mineral analysis

Ten liver samples from 21 lines of lambs that were affected by varying degrees of ecchymosis (1% - 37%) were analysed for average Cu and Se content, with neither mineral having a significant interaction with the incidence of ecchymosis (P= 0.980 for Cu; P=0.088 for Se). Average liver Cu ranged from 0.11mmol/kg-1 to 2.34mmol/kg-1, with a normal range in healthy individuals between 0.23 to 3.67mmol/kg-1, and 3 of the measured lines falling below the normal range. Average liver Se ranged from 4.76U/g to 16.19U/g, with a normal range of 2.0-25.0U/g, and none of the measured lines falling outside normal ranges (Figure 2).

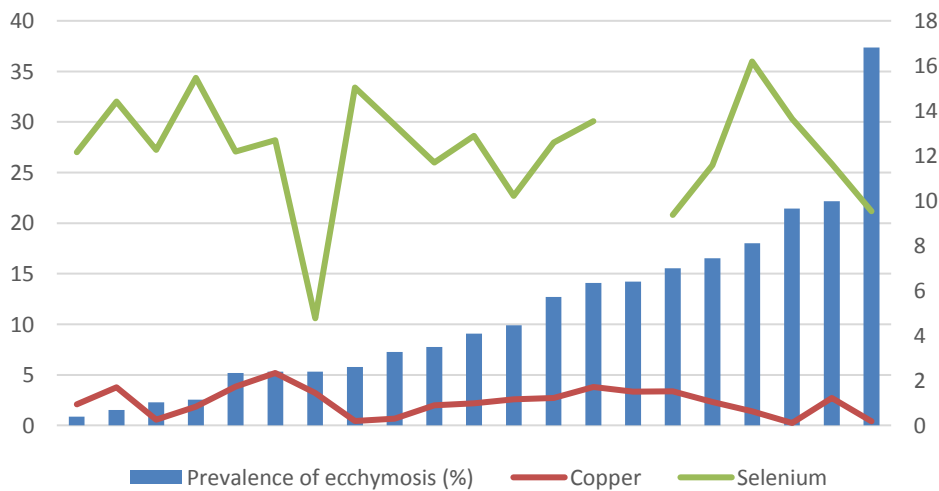


Figure 2. The average Copper (red line; mmol/kg-1) and Selenium (green line; U/g) concentrations in liver samples taken from lines of lambs with a range of ecchymosis (blue column; %).

4.1.3 Carcass weight and fat

Average hot standard carcass weight of lines of lambs was 25.4 ± 3.86 , and average palpated fat depth was 17.1 ± 4.82 . Both average hot standard carcass weight (P=0.030) and average palpated fat score (P<0.001) of lines of lambs had significant positive interactions with the incidence of ecchymosis in lambs (Figure 3).

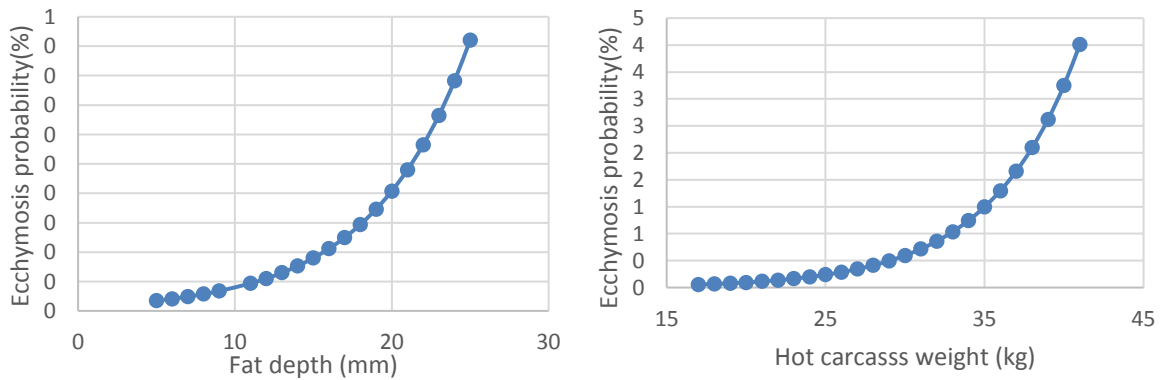


Figure 3. Interactions between (a) palpated fat depth (mm) and (b) hot carcass weight (kg) and the probability of ecchymosis in lines of lambs.

4.1.4 Time in lairage

Time spent in lairage had a significant positive interaction with the prevalence of ecchymosis in lines of lambs such that increased time in lairage resulted in increased prevalence of ecchymosis ($P=0.001$; Figure 4). Time spent in lairage ranged from 13.21 hours to 40.95 hours, and averaged 24.26 hours.

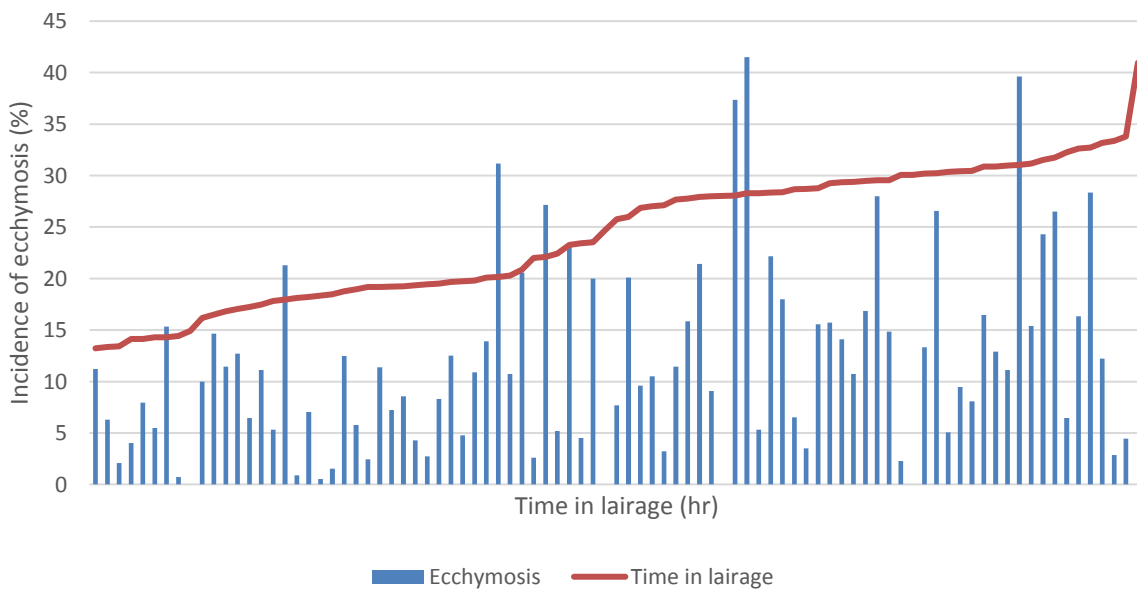


Figure 4. Time spent in lairage (hrs) for each consignment of lambs, and the corresponding prevalence of ecchymosis (%) in each line.

Further, there was a significant interaction between HCWT and time spent in lairage such that the risk of ecchymosis increased for heavier lambs (>30kg HCWT) with less time in lairage (<18hrs; $P<0.005$). Risk of ecchymosis was lowest when lighter lambs spent less time in lairage, and heavier lambs spent more time in lairage.

4.2 On-farm factors

4.2.1 Distribution

Lines of lambs scored for ecchymosis originated from across South Australia and Victoria. There was no discernible pattern of prevalence relating to region of origin (Figure 5).

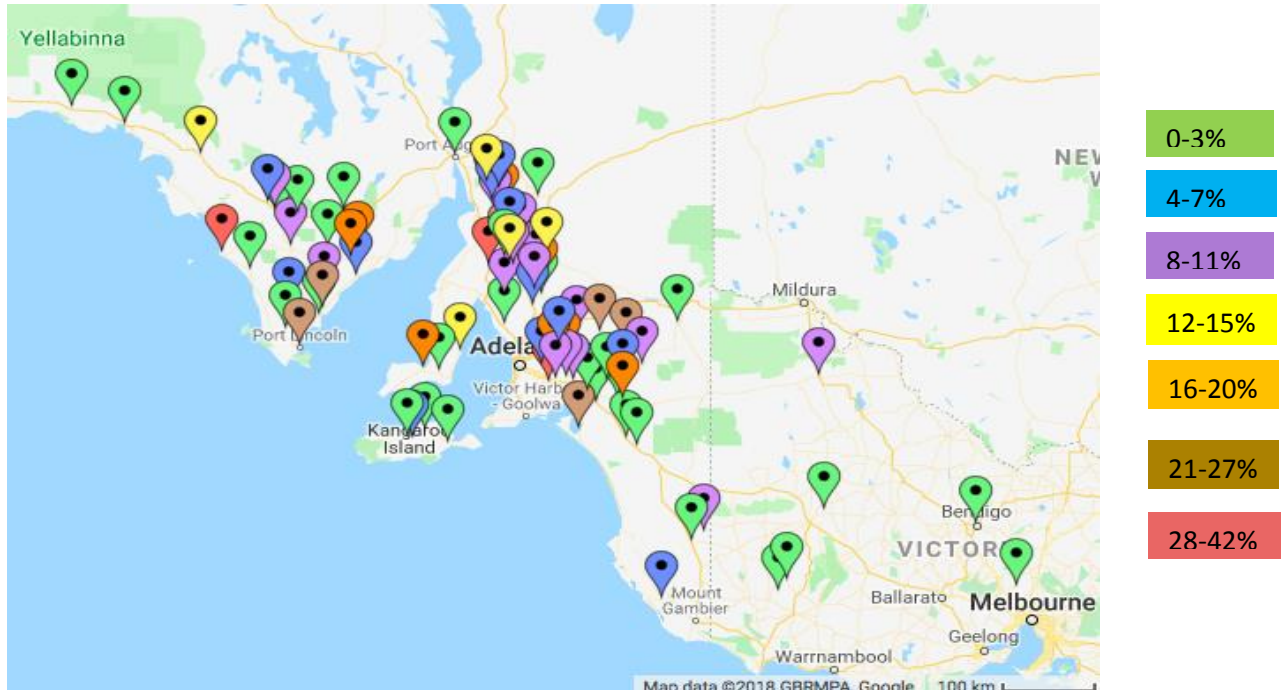


Figure 5. Geographic origin of all lines of lambs assessed for ecchymosis, grouped in colour according to prevalence: green 0-3%; blue 4-7%; purple 8-11%; yellow 12-15%; orange 16-20%; brown 21-27%; red 28-42%.

4.2.2 Rainfall

Average annual rainfall at farm of origin for lines of lambs ranged from 272mm to 811mm, with an overall average of 435.2 ± 131.33 mm. When analysed at the lot level, rainfall at farm of origin had a significant relationship with the prevalence of ecchymosis in lines of lambs, such that lower average annual rainfall at farm-of-origin resulted in a higher risk of ecchymosis prevalence ($P < 0.001$; Figure 6).

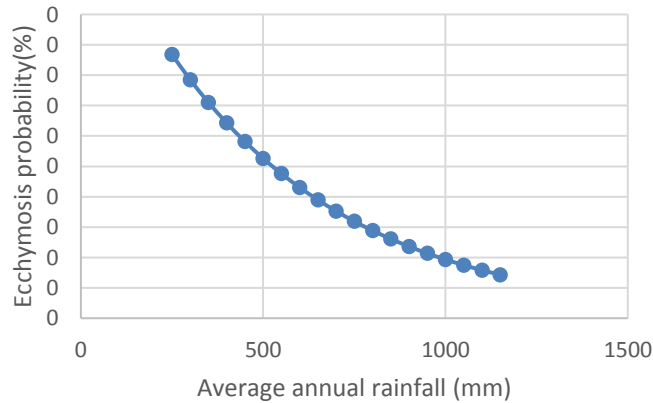


Figure 6. Interaction between average annual rainfall (mm) at farm-of-origin, and the probability of ecchymosis in lines of lambs.

4.2.3 Breed

Lines of lambs assessed over the 7 day measurement period were classified into one of five breeds: Merino, cross-bred, Highlander, Suffolk and Dorper. However, due to insufficient numbers of Suffolk's and Doper's, these animals were removed from the data-set. There was no significant difference in the prevalence of ecchymosis in lambs across each of the different breed categories ($P=0.353$).

4.3 Economic analysis

An economic analysis was not completed due to two factors: 1) a change in availability of TFI staff after the Murray Bridge plant fire in January 2018, and 2) it was determined that further time-in-motion study would be required to track the impact to cut level and this detailed work was out-of-scope for this study.

5 Discussion

Ecchymosis has been anecdotally identified as a constraint to lamb production in South Australian abattoirs as a result of loss of product through trimming, possible rejection of product into certain markets and increased labour costs associated with extra trimming and handling of product. Despite this, there has been little research conducted into the incidence and potential causes or contributing factors, with the prevalence and economic impact of ecchymosis poorly quantified.

This study quantified that the incidence of ecchymosis observed in lines of lambs over a 7 day period at Thomas Foods International Lobethal plant was 14%, and ranged from 0–42%, with a significant difference between lines of lambs. The difference between lines supports the hypothesis that factors external to the abattoir may be contributing to the variation in the incidence of ecchymosis in lambs, and supports preliminary data presented by Gray *et al.*, (2017). However, this finding contradicts many other studies of ecchymosis in lambs, which have focussed largely on processing factors such as stunning method, and stick-stun interval (Leet *et al.*, 1977, Kirton *et al.*, 1981a, Kirton *et al.*, 1981b), rather than factors external to the plant. Such external factors may include age, breed, time in lairage,

transport time and type, distance travelled to abattoir, rainfall at farm of origin, carcass weight and fat, feed type at farm of origin and other farm management factors. Accordingly, a number of these variables were tested in the current study.

Indeed, a number of the variables tested had significant relationships with the prevalence of ecchymosis in lambs, and thus supported the inference that on-farm, or non-processing related factors may contribute to the prevalence of ecchymosis. Such variables included average annual rainfall at farm of origin, time in lairage, average hot carcass weight and palpated fat depth, as well as an interaction between hot carcass weight and time spent in lairage. The significant relationship with average annual rainfall at the farm of origin was consistent with results of a preliminary study by Gray *et al.* (2017). It was thus hypothesised that an interaction between rainfall and the mineral status of pastures and soils at the property of origin may be causative of variation in the prevalence of ecchymosis in lambs, with known deficiencies of minerals such as Cu and Se caused by either high or low rainfall (French, 1946). To test this theory, the current study analysed Cu and Se content in the livers of lambs from lines with varying degrees of ecchymosis, however neither mineral had a significant interaction with the prevalence of ecchymosis. This suggests that variation in mineral status at farm of origin as a result of rainfall is unlikely to cause a rainfall-ecchymosis relationship. A possible explanation is the type of pasture grazed prior to processing, with pastures high in coumarins for example (common in *Melilotus* spp.) known to increase blood vessel fragility and prothrombin time, both of which are predisposing factors for ecchymosis. Indeed, Restall (1980) found an increased incidence of ecchymosis in lambs whose primary diet was a clover with high coumarin content. Thus, the mechanism for the interaction between rainfall and ecchymosis needs to be explored further, with opportunity for future work to investigate pasture type, grazing management, seasonal variability and transport conditions prior to slaughter to identify this mechanism.

Time spent in lairage was also highly correlated with the prevalence of ecchymosis in lambs, with longer times in lairage leading to an increased prevalence of ecchymosis. However, there was also an interaction between carcass weight and time spent in lairage, with the risk of a heavy carcass having ecchymosis reduced with longer times in lairage. The interaction between lairage time and ecchymosis suggests a possible correlation with either stress, nutrition or both, with 6-24h in lairage offering animals the opportunity to recover from the stress of transport, an unfamiliar environment and social mixing prior to slaughter (Liste *et al.*, 2011; Knowles *et al.*, 1993). The relationship between carcass weight and lairage time suggests that heavier animals may have the capacity to recover from the stress of transport prior to slaughter, and thus mitigate the risk of ecchymosis, while this potential for recovery may be absent or reduced in lighter and smaller animals. Unfortunately the transport records associated with the lines observed were not sufficient to provide total time or distance travelled from farm to abattoir, and thus will need to be researched further in future.

Age was a significant factor for determining the presence of ecchymosis in the current study, with half the prevalence observed in hoggets compared to lambs, and negligible amounts seen in adults. Thus, the economic impact of ecchymosis in older animals is considered insignificant and has not been investigated further throughout the study. It is unknown why younger animals are more susceptible to ecchymosis, possibly via interactions with resilience to stressful conditions in older animals, increased structural development of blood vessels leading to the mitigation of blood pressure experienced during stunning prior to slaughter, or other structural differences. It has been

determined that capillary fragility is subject to adrenal hormone regulation, specifically glucocorticoids (Kramar 1953), and it's known that with age, the sensitivity of glucocorticoids is suppressed (Boscaro *et al.* 1998). This suggests that ecchymosis may have an increased prevalence in younger animals resulting from their increased sensitivity to glucocorticoids, and therefore increased capillary fragility. Nevertheless, the economic impact of ecchymosis is greater in lambs than older animals due to both the increased prevalence, and also the increased value of lamb compared to mutton.

Economic impact of ecchymosis to the industry was far more complex to determine than initially thought which was further complicated with the TFI employee assigned to the task ceasing employment whilst the study was being undertaken. Carcasses that are affected by more than 5 lesions (score 2 or greater) are individually identified within TFI at Lobethal via a stamp stating 'Ecchy'. These carcasses are subjected to additional trim in the boning room and often a carcass will have cuts modified as a result in trim which in many cases is a lower grade cut. Whilst there is no evidence to suggest that ecchymosis affects eating quality it is aesthetically unappealing.

It has been highlighted through this study that abattoirs in general, including TFI have a poor understanding of the economic impact of ecchymosis to their business despite the investment in inspecting, identifying affected carcasses and processing them differently.

5.1 Project objectives

The current study has addressed the project objectives as per below:

- *Quantified the incidence of ecchymosis in lambs processed in South Australia*
The project successfully identified the incidence of ecchymosis in lambs processed in South Australia at an average of 14%, with a range of 0-42%.
- *Gathered preliminary data on the condition, including*
 - *Determined if there is significant variance between lines of lambs (in which case farm management factors may be contributing to the incidence of ecchymosis)*
There is significant variance between lines of lambs ($P < 0.0001$).
 - *Repeated work conducted at JBS Bordertown in phase 1 at Thomas Foods Lobethal and determine if distance travelled, average rainfall from farm of origin, breed, carcass weight or time in lairage has an impact on the incidence of ecchymosis*
Average rainfall, carcass weight and time in lairage all have significant relationships with the incidence of ecchymosis in lines of lambs. There is no significant interaction between breed and ecchymosis in lambs. Unfortunately, the transport data supplied was insufficient to determine the total transport time between farm and abattoir, thus this point was not addressed in the current study.
 - *Compared the incidence of ecchymosis between lines of lamb and mutton and determine if age is a factor*
There is a significant difference in the incidence of ecchymosis between lambs and older animals, with lambs exhibiting higher prevalence of ecchymosis.

- *Determine the Cu and Se status of individual animals or lines of lambs correlates with the incidence or severity of ecchymosis*

Neither copper nor selenium collected from the livers of lambs from lines affected with ecchymosis had a correlation with the prevalence of ecchymosis.

- *Ascertained if stress is a factor contributing to the incidence of ecchymosis*

It is likely that there is an interaction between stress associated with time in lairage and ecchymosis. This needs to be explored further, and total curfew and transport times incorporated into the relationship.

- *Estimated the cost of ecchymosis to the SA lamb industry*

The cost of ecchymosis to the SA lamb industry was unable to be undertaken due to the unforeseen circumstances of David Rutley from TFI ceasing employment during the study. The complexities of market requirements at an individual plant level were not known when the study commenced. To determine a cost to the SA lamb industry a detailed study needs to be undertaken in future work.

- *Developed recommendations for further work required to reduce or eliminate the condition and impact on the lamb industry*

Recommendations of further work have been articulated throughout the discussion, and include analysis of on-farm handling, management and nutrition from birth to slaughter as well as analysis of total curfew, transport and lairage time prior to slaughter.

6 Conclusions/recommendations

This project has successfully quantified the incidence and economic impact of ecchymosis in the South Australian lamb industry. The results highlight that a significant improvement in production efficiency could be achieved with a reduction of ecchymosis in lambs. In order to effectively reduce the incidence of ecchymosis, further research must be done into on-farm handling and management factors, as well as the impact of stress from total curfew, transport and lairage times and their effects on ecchymosis. Once the causal factors of ecchymosis are better understood, a clear and precise pre-slaughter management plan may be developed to assist both producers and processors to mitigate the impact of ecchymosis on the Australian lamb industry, and increase production efficiency.

7 Key messages

- Ecchymosis has a prevalence of around 14% in lambs, but up to as much as 42% in some lines.
- It is likely that pre-slaughter factors are contributing to the prevalence of ecchymosis.
- Research into the underlying pre-disposing factors will allow development of pre-slaughter management guidelines to mitigate the risk of a carcass presenting with ecchymosis.
- Defined guidelines will reduce the economic impact of ecchymosis in the lamb industry.

- Further research is required into:
 - On-farm nutrition and handling
 - Total curfew time, including transport and lairage
 - Transport conditions (length, type, temperature)
 - Seasonal variations

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