Final Report to the

Agricultural Producers Commission

Pork Producers Committee

Understanding Western Australian pork quality across commercial production systems and season

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Technical Summary

This project conducted an industry-wide audit of pork carcase and meat quality parameters, particularly colour and pH, to establish if the differences between free range and conventional pork attributes observed in an earlier Pork Innovation WA (PIWA) project (GGRD-2015-0069-AGSC, 2019) were consistent across the wider WA pork industry.

Fourteen conventional farms (indoor and/or deep-litter) and six free range farms were identified as being representative of WA growers and genotypes. Carcase and pork quality data were collected monthly from Linley Valley Pork Abattoir between October 2020 and November 2021.

Free range pork carcases were consistently lighter (kg) and leaner (P2 depth) than pork carcases from conventional production systems and variability within carcase weight and fat depth was greater for free range carcases. This agrees with the findings from the previous PIWA project (GGRD-2015-0069-AGSC, 2019).

pH measured within the carcase and for the pork loin was within the range considered as "normal" for Australian pork quality. pH was similar between production systems and varied across seasons. Carcase meat colour, at the exposed muscle surface of the *Obliquus abdominus*, differed across production system and season, however for the most part the differences were too small to be detected by the untrained eye, apart from winter, where a lighter muscle colour was detectable in free range carcases. Pork steak (*Longissimus thoracis*) colour was also lighter for free range pork in autumn, winter and spring. This contrasts with the previous project where free range pork was darker during spring and low seasonal temperatures were identified as the potential cause via the depletion of muscle glycogen stores, impacting the extent of pH decline and hence pork colour. Pork quality attributes such as colour, drip loss and cook loss are often determined by the rate and extent of pH decline after slaughter. In this study the differences in measures of pork quality were mostly aligned with the corresponding differences in pH measures of the carcase (pH_{18}) and pork loin (pH_{24}).

The results indicate that for commercial pork production in Western Australia, season contributes more to variability in pork carcase and meat quality attributes than does the type of production system. However, as seasonal impacts are magnified within free range production, the outcomes reported for free range pork are more variable. This can be both beneficial and detrimental to carcase and fresh pork quality traits (Trezona, 2022).

Exploring strategies (on-farm and/or during processing) to manipulate pH decline within muscle after slaughter may enable seasonal impacts, and therefore variability within WA fresh pork, to be reduced.

Background

Currently 30% of fresh pork produced in Western Australia is from Free Range (FR) production systems. The remaining 70% of fresh pork is produced primarily in conventional intensive and deep litter production systems (CONV). Studies have found differences in pork quality from pigs reared in FR and CONV environments however such differences are not always influenced favourably or consistently by FR production (Edwards, 2005). In 2019 Pork Innovation WA completed the project "Establishing WA as the Australian centre for the production of high-quality free-range pork", supported by the Agribusiness Innovation Fund. The purpose of the project was to assist the FR pork industry in WA to consistently supply quality pork, thereby aiding in securing existing markets and encouraging the investigation of new market opportunities (including export markets). A component of the project focused on assessing carcase and pork quality attributes over a 12-month period to determine whether there was a significant impact of production system and season on quality. Pork from pigs raised in a FR system was compared with pork from pigs produced in a conventional intensive (indoor) production system of the same genotype and raised under a similar feeding program.

The results suggested that average carcase quality was similar for pigs from both production systems however live weight of FR pigs at slaughter, and therefore carcase weight, was more variable. There were some differences between objective pork quality measures which suggested that there may be differences in pork quality between FR and CONV raised pigs.

The development of the pH of meat as the carcase cools is recognized as a quality attribute of major importance (Eikelenboom *et al*., 1995) because pH impacts a wide range of technological and sensory quality parameters such as colour, juiciness, tenderness, flavour, shelf life etc. The previous study found higher pH for FR pork, which is expected to positively affect pork quality and sensory traits. This finding however was not clearly supported by the other measures of objective pork quality that were investigated such as shear force (indicator of tenderness) and cook loss (contributes to juiciness) which were similar for pork from both production systems. Moisture lost during the chilling of carcases was lower for FR carcases, which positively effects quality and is preferred by the processor, however drip loss from the loin muscle was higher for FR pork meaning the meat may be less juicy when eaten. In addition, higher drip loss in FR pork may impact the presentation of fresh product, where purge may be more evident in the bottom of the packaging and therefore be less attractive to the consumer at the point of purchase. There were seasonal differences observed in fresh pork colour, where FR pork was slightly darker during spring (likely to be associated with the higher pH that occurred simultaneously). The subtle visual colour difference may not impact domestic customers, however WA's current primary export market, Singapore, is sensitive to colour differences (and the difference occurred at a level that could be detected by the consumer).

This project looked to broaden the scope of PIWA's 2019 project by conducting an industry-wide audit of pork quality parameters, particularly colour and pH, to establish if the differences between FR and CONV pork attributes observed in the earlier project were consistent across different growers and genotypes.

Aims

1. To conduct an industry-wide audit of pork quality parameters across production systems (primarily free range and conventional / deep-litter) and season.
2. Determine the quality parameters of Western Australian pork.

Methods

Quantifying pork quality from Western Australian production systems

Abattoir data were collected over a 14-month period between October 2020 to November 2021 to provide an overall snapshot of the quality of pork produced in Western Australia. The data were collected from Linley Valley Pork, an export accredited, single species abattoir which processes approximately 90% of the pork in Western Australia.

Source farms: Carcases from commercial genotypes, primarily a mix of Landrace x Large White x Duroc, were selected from different commercial farms and identified as being produced under CONV or FR production systems. Conventional production systems were APIQ✓® Indoor accredited, which includes concrete and/or slatted floor as well as deep-litter production systems, or a combination of both. The FR production systems were APIQ✓® Free Range accredited.

Fourteen farms were identified as focus farms supplying pork from CONV production systems, while six farms were identified as suppliers of pork from FR production systems. The selected farms provided a representation of the WA pork industry and information and data relating to carcase and pork quality was collected each month.

Processing: Pigs were processed under commercial conditions where they were stunned using a CO_2 dip-lift stunner (Butina, Denmark) set at 90% CO_2 for approximately 180 seconds before exsanguination, scalding, dehairing, evisceration and carcase dressing. Total processing time from exsanguination to chiller entry was 35 minutes. Chillers were set at 2°C and were either a plenum chiller or a forced draft airflow chiller design. Pigs from different suppliers were processed across different days.

Carcase data: Hot carcase weight and P2 backfat depth (PorkScan™ system, PorkScan Pty Ltd, Canberra, ACT) information was recorded before carcases entered the chiller and data were retrieved from the abattoir recording system. Data describing carcase faults (skin damage, carcase faults), as identified by Australian Authorised Government Officers (qualified meat inspectors), were retrieved for 3 deliveries /quarter for each focus farm.

pH, colour and quality audit: Colour (*Obliquus abdominus*) and pH (*Longissumus thoracis*) were measured from approximately 30 randomly selected carcases/farm/month between October 2020 to November 2021. Measures of pH and colour were made in the chilled carcase approximately 18-24 hours after slaughter.

Objective pork quality: Five pork samples were collected / target farm / quarter (*where samples were available to be purchased) approximately 24 hours after slaughter for objective meat quality assessment.

To compare objective quality attributes of fresh pork approximately 800 g of the *Longissimus Thoracis* (LT) muscle, rind on, boneless, was removed from the left-hand side of the sample carcases. A 2 cm thick steak was cut from the sample and the fresh surface was allowed to bloom for 30 minutes at room temperature (~18^{o}C) after which colour (L*, a* and b*) was measured at a location on the surface devoid of visible fat and connective tissue with a Minolta Chroma meter CR-400 (Minolta, Osaka, Japan). The pH was measured using a portable pH/temperature meter (Cyberscan pH 300, Eutech Instruments, Singapore) fitted with a polypropylene spear-type gel electrode (Ionode J44, Ionode Pty Ltd., Brisbane, QLD) and a temperature probe.

Differences between total pork colour (ΔE) were quantified from the average L*, a*, b* measures by using the following formula:

$$\Delta E_{Lab} = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2}$$

(http://colormine.org/delta-e-calculator).

Drip loss was measured using a modification of the method described by Rasmussen and Andersson (1996). The muscle was cut to a 40±2 g cube, devoid of visible external fat and connective tissue, then wrapped in netting and suspended in a sealed plastic container. The samples were stored for 24 h at 4°C and then removed and gently patted dry to remove excess moisture before being re-weighed. Drip loss was calculated as the weight lost (difference between the initial and post storage weights) expressed as a percentage of the initial weight.

An 80±5 g sample, devoid of visible external fat and connective tissue, was cut from the loin samples to measure cooking loss (Bouton, Harris, & Shorthose, 1971). The samples were bagged individually and suspended from a metal rack and into a water bath which was pre-heated to 70°C. The samples were cooked at 70°C until an internal temperature of 70°C was reached (approximately 40 minutes). After removal from the water bath, the samples were cooled in running water for 10 minutes then refrigerated at 4°C until completely cooled (approximately 1 hour). Samples were removed from the bag, patted dry to remove excess moisture and re-weighed. Cooking loss percentage for each sample was determined by dividing the difference in the raw and cooked weights by the weight of the raw pork sample.

Statistical analysis: Data were analysed using the GENSTAT 22 program (VSN International Ltd., Hemel Hempstead, UK). General analysis of variance (ANOVA) procedures (unbalanced design) were used to determine the main effects of season and production system on carcase parameters and objective meat quality measures. Free range accredited farms were compared to all other production systems, primarily conventional and deep litter eco shelters (CONV).

A level of probability (P) of <0.050 was used to determine statistically significant difference between the treatment means. A level of probability of between 0.050 and 0.100 was determined to be a trend and probability greater than 0.100 was deemed as not significant.

Data have been de-identified within the project report.

Results

Carcase Characteristics

Carcase weight: When interpreting differences in carcase weight between production systems it must be acknowledged that different farms, regardless of production system, may supply different markets/customers and therefore market pigs to target different carcase weight specifications.

Overall, average carcase weight was lower for FR pigs and is likely a reflection of lower live weight at slaughter (Table 1). In general, across productions systems, carcase weights were heaviest during winter and lightest during summer ($P<0.001$). Backfat depth at the P2 site was significantly lower for FR carcases ($P<0.001$), at an average of 1.3 mm less than CONV carcases. Seasonally carcases were leaner in winter and spring compared to summer and autumn ($P<0.001$).

Variability in carcase weight and P2 depth was higher for FR carcases as indicated by the larger standard error reported in Table 1 and the error bars depicting standard deviation within each farm's carcase weight data set in Figure 1, where the error bars for the FR farms tend to be longer than the error bars for CONV production systems.

Table 1. Carcase weight and P2 fat depth by season and production system (October 2020-November 2021).

	Season	**Conventional**	**se**	**Free range**	**se**	**Prod system**	**Season**	**PxS**
Carcase weight (kg)	Summer	70.14	0.270	62.97	0.414	**<0.001**	**<0.001**	**<0.001**
	Autumn	71.20	0.286	64.24	0.458			
	Winter	72.94	0.223	62.97	0.414			
	Spring	72.14	0.237	60.28	0.309			
	Annual	71.78	0.125	62.87	0.191			
P2 (mm)*	Summer	10.96	0.093	9.44	0.142	**<0.001**	**<0.001**	0.070
	Autumn	10.38	0.097	9.49	0.156			
	Winter	10.37	0.078	9.10	0.129			
	Spring	10.37	0.081	8.95	0.114			
	Annual	10.49	0.045	9.30	0.072			

** P2 adjusted for differences in carcase weight (fat depth has a strong, significant relationship with carcase weight therefore weight is considered as a covariate in statistical analysis; P<0.001).*

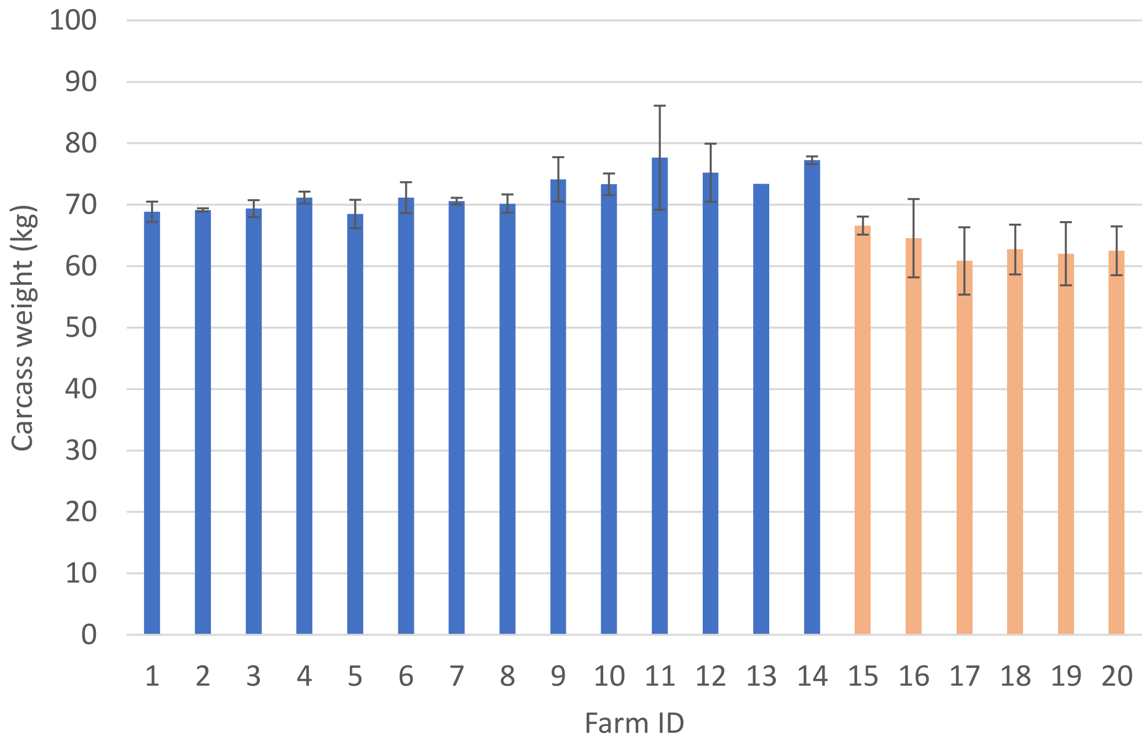

Figure 1. Average carcase weight (kg) by farm (October 2020-November 2021).

Conventional production systems: ▯; *Free range production systems:* ▮

Carcase faults: Free range carcases had a significantly higher percentage of faults, as identified during processing, compared to carcases from CONV production systems (Figure 2). Faults with 0.1% or less occurrence are not presented in this report. The incidence of abscesses was not affected by production system, however arthritis, bloat, broken ribs, bruising, erysipelas, machine damage and contamination occurred at a higher incidence in FR carcases.

Season impacted the incidence of carcase faults. Bruising was highest in winter and lowest in summer (P=0.003) and is likely explained by the occurrence of wet conditions during loading/unloading and transport. Stress factors, including sudden changes in environmental temperature, can trigger clinical erysipelas which may explain the higher incidence during winter and spring (P<0.001).

Production system did not impact the occurrence of carcase contamination, however there was an impact of season (P<0.001) where contamination was significantly higher during spring compared to other times of the year. Total faults were higher during winter and spring compared to summer and autumn (P=0.002).

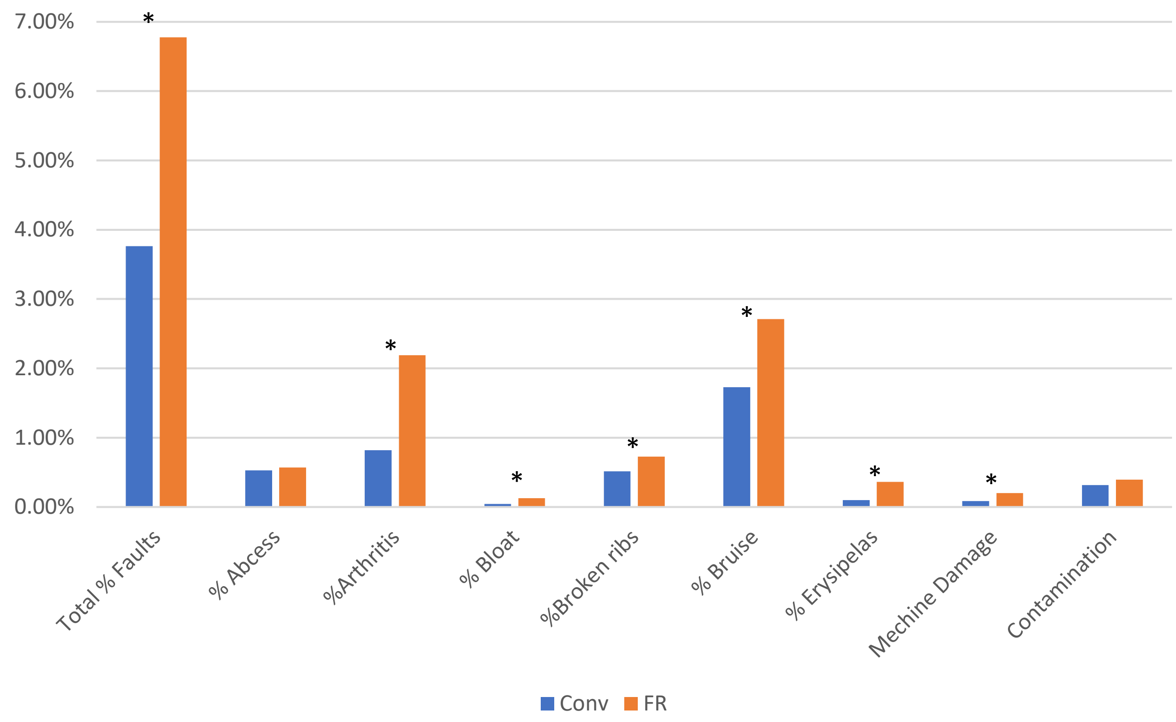

Figure 2. Percentage occurrence of carcase faults for herds raised under conventional and free range production systems (slaughtered between October 2020 - November 2021) processed at Linley Valley Pork abattoir. ** indicates significant difference (P<0.05).*

Carcase pH and colour: A total of 3658 carcases from the identified farms were measured for pH and colour. There was a significant effect of production system and season, and an interaction between the two factors was evident (P<0.001). pH_{18} measured in the intact loin was higher in carcases from pigs raised in CONV systems and, on average, was higher during winter and autumn compared to summer and spring (Table 2). In real terms the actual difference in average pH between production systems and season was very low, at less than 0.05 units (pH 5.65 conventional; pH 5.63 FR). Across seasons the average pH ranged between 5.61-5.69 (FR spring, FR autumn respectively) and all measures were within the range considered as "normal" for fresh pork (normal range: pH 5.5-5.7; Du *et al*., 2001; Jose *et al.*, 2013a).

Table 2. Carcase pH_{18} by production system and season.

				P-value		
	CONV	**FR**	**se**	**System**	**Season**	**System*Season**
Annual	5.65	5.63	0.005	**<0.001**	**<0.001**	**<0.001**
Summer	5.62	5.62	0.010			
Autumn	5.67	5.70				
Winter	5.66	5.63				
Spring	5.64	5.61				

Pork carcase colour (*Obliquus abdominus*) differed between production system and season (Table 3). Free range carcases were lighter (L*), redder (a*) and more yellow (b*) (P<0.001) compared to carcases from CONV production systems. Seasonally, pork colour was lightest and less red in winter and darkest (L*), redder (a*) and more yellow (b*) in autumn (P<0.001). Human perception of pork colour is primarily linked with L* measures whereas a* and b* seem less important (Alvarez-Rodriguez *et al.*, 2015). A difference of two L* units is easily detected by the naked eye. Results suggest that consumers could potentially detect a difference in colour between pork produced in CONV and FR production systems during winter.

Measures of L*, a* and b* describe different aspects of a colour space. The difference between two colours, or colour spaces, is expressed as ΔE. A difference of 1 - 2 ΔE units can be detected by experienced observers whilst differences greater than 2 units can be detected by inexperienced observers (e.g. consumers) (Mokrzycki and Tatol, 2012). Quantifying the difference in total colour between the CONV and FR pork, as determined by the calculation of ΔE, indicated that overall the colour difference was subtle ie. ΔE =1.181 (and was less likely to be noticed by inexperienced observers), however, by season there was an obvious difference in colour between carcases from CONV and FR production systems during winter, ΔE =3.276.

Table 3. Impact of production system and season on surface colour of the *Obliquus abdominus.*

					P-value			
		Conv	**FR**	**se**	**System**	**Season**	**System*season**	***ΔE***
Annual	**L***	34.39	35.4	0.172	<0.001	<0.001	<0.001	**1.181**
	a*	10.44	10.78	0.102	0.005	<0.001	<0.001	
	b*	8.56	9.07	0.079	<0.001	<0.001	<0.001	

Season		**Conv**	**FR**	**se**	***ΔE***
Summer	**L***	34.86	35.10	0.350	0.306
	a*	10.33	10.52	0.208	
	b*	8.25	8.26	0.161	
Autumn	**L***	38.33	38.83	0.350	0.804
	a*	11.42	11.61	0.208	
	b*	10.87	11.47	0.161	
Winter	**L***	32.13	34.71	0.350	**3.276**
	a*	9.61	10.95	0.208	
	b*	8.15	9.66	0.161	
Spring	**L***	33.11	33.95	0.350	0.863
	a*	10.45	10.35	0.208	
	b*	7.63	7.80	0.161	

ΔE: The calculated difference in colour from the average colour measures (L, a*, b*) of production system and season.*

Pork Quality Measures

Technological pork quality was determined for pork steak samples (*LT*) that were collected and processed approximately 24 hours after slaughter (Table 4, Table 5).

Production system did not impact pH_{24} however there was an effect of season (P=0.002) where pH_{24} was highest during summer and lowest during winter and spring.

pH_{24} is impacted by glycogen stores in muscle before slaughter as glycogen reserves affect the progression of pH decline after slaughter. Factors that impact muscle glycogen stores are not necessarily related to specific production systems and may include prolonged exposure to low environmental temperatures, extended time off-feed, prolonged stress (during transport), and stress immediately prior to slaughter.

The differences in pH may have been sufficient to impact other pork quality parameters as quality attributes are influenced by the rate and extent to which pH declines during post-mortem metabolism, during the transformation of muscle into meat. Lower pH pork tends to retain less moisture, is less tender and lighter in colour compared to higher pH pork.

Percent drip loss was affected by production system and season where pork from FR systems had a higher percentage of drip loss compared to CONV produced pork. Drip loss was higher in general during winter and spring. This outcome aligns with the lower measures for pH_{24}. Differences in cook loss were not as obvious however there was a significant effect of season and an interaction between season and production system on the percentage of moisture lost after cooking. Cook loss was highest for pork from CONV production systems during winter and spring.

Colour measures for the pork steak samples were affected by production system and season. The ΔE values indicated that colour differences between pork from CONV and FR systems were detectable by the untrained eye in summer, autumn and winter (Table 6) Where FR pork was lighter/paler than CONV pork. For the most part, lighter pork colour corresponds with lower pH_{24} values.

For all pork quality measures, FR data were more variable compared to the CONV data as indicated by higher standard error values.

Table 6. The calculated difference in colour of the *Longissimus thoracis* between carcases from conventional and free range produced pigs. *The ΔE value was calculated from the average colour measures (L*, a*, b*) of production system and season.*

		ΔE
Overall		0.806
Season	Summer	**3.403**
	Autumn	**4.063**
	Winter	**2.733**
	Spring	1.720

Table 4. Impact of production system on pork quality attributes of carcases collected between October 2020 and November 2021.

		Production System			
		Conventional	**Free Range**	**sed**	**P-value**
pH_{24}		5.55	5.53	0.024	0.312
Drip loss (%)		5.40	6.92	0.650	**0.014**
Cook loss (%)		22.30	21.98	0.760	0.490
Pork colour					
(L. thoracis)	**L***	47.79	48.5	0.785	**0.051**
	a*	3.83	3.92	0.799	0.663
	b*	5.94	6.31	0.262	**0.034**

Table 5. Impact of production system and season on pork quality attributes of carcases collected between October 2020 and November 2021.

		Summer		**Autumn**		**Winter**		**Spring**			**P-value**		
Production System		CONV	FR	CONV	FR	CONV	FR	CONV	FR	sed	System	Season	System* season
pH_{24}		5.57	5.65	5.60	5.50	5.52	5.50	5.52	5.49	0.048	0.3121	**0.002**	0.117
Drip loss (%)		4.66	4.32	4.86	7.39	6.05	8.78	5.88	6.93	1.25	**0.014**	**0.028**	0.359
Cook loss (%)		21.94	22.06	17.47	21.57	24.37	22.67	24.84	21.67	1.47	0.490	**<0.001**	**0.001**
Pork colour													
(L. thoracis)	**L***	44.04	40.79	48.79	52.14	47.61	49.83	49.93	50.20	1.53	**0.051**	**<0.001**	**0.029**
	a*	1.99	1.43	2.53	4.09	2.57	3.93	7.32	5.63	1.55	0.663	**<0.001**	0.329
	b*	5.49	4.65	6.99	8.68	6.58	7.41	4.87	4.70	0.509	**0.034**	**<0.001**	**0.003**

Conventional (CONV); Free range (FR)

Outcomes

Free range pork carcases were consistently lighter (kg) and leaner (P2 depth) than pork carcases from conventional production systems. Variability within carcase weight and fat depth was greater for FR carcases.

Carcases from FR systems had a higher incidence of carcase faults, particularly arthritis, bruising and erysipelas.

pH_{18} measured within the carcase was similar between production systems and was within the range considered as “normal” for desirable pork quality.

Carcase meat colour, depicted by the colour of the exposed muscle surface of the *Obliquus abdominus*, differed across production system and season, however for the most part the differences were too small to be detected by the untrained eye. During winter however, the colour difference was obvious, where FR carcases had a lighter muscle colour.

Pork steak (*Longissimus thoracis*) colour was also lighter for FR product compared to pork from CONV production systems in autumn, winter and spring. This contrasts with previous findings reported by Trezona (2019) where pork from FR production was darker in colour during spring. Low seasonal temperatures were identified as a potential cause of depleted muscle glycogen stores and hence resulted in darker coloured pork.

Drip loss was higher for FR pork and, overall, was higher during winter and spring. This aligned with the lowest measures for pH_{24} and, similarly to the results reported by Trezona (2019), the implications may extend to packaging decisions for fresh FR pork products. Higher levels of drip loss will result in higher levels of purge (juice) in display trays or bags. Cook loss was impacted more by season than production system and was higher during winter and spring, particularly for CONV pork.

Variability was consistently higher for all pork quality measures in FR produced pork compared to CONV pork.

Conclusion

In commercial pork production within Western Australia, season contributes more to variability in pork carcase and meat quality attributes than does the type of production system. However, as seasonal impacts are magnified within FR production because environmental conditions are not buffered/controlled to the same extent as in conventional and deep-litter systems, the outcomes reported for FR produced pork are more variable. This can be both beneficial and detrimental to carcase and fresh pork quality traits (Trezona, 2022). Differences in the various measures of pork quality were mostly aligned with the corresponding differences in pH measures of the carcase (pH_{18}) and pork loin (pH_{24}).

To reduce variability in pork carcase quality, novel strategies to mitigate seasonal impacts and manage the pH decline within muscle after slaughter, particularly in FR production systems, should be explored.

Recommendations

Explore strategies (on-farm and/or during processing) that manipulate pH decline within muscle after slaughter to reduce seasonal impacts on Western Australian produced pork, particularly for product from FR production systems.

Acknowledgements

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