Final Report to the

Agricultural Produce Commission

Pork Producers Committee

Feeding *Lupinus albus L.* to immunocastrated male pigs to reduce feed intake and backfat

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Technical Summary

Immunization against gonadotropin releasing factor (GnRF) is an effective strategy to eliminate boar taint. However immunocastrated males have an increased feed intake, growth rate and backfat compared to entire males. Albus lupins have shown potential in overcoming the issues of the increased feed intake and backfat associated with immunocastrated males but the inclusion concentration of *Lupinus albus L.* (albus lupins) previously used was not optimal.

Two hundred and sixteen pigs were used in an experiment with the objective to determine the concentration of albus lupins to be included in the diet of immunocastrated males which would maximize the decrease in feed intake and backfat whilst optimizing the effect on growth rate. Immunocastrated male pigs were fed varying concentrations of albus lupins (0 to 200 g/kg) from 2 weeks after the second immunization against GnRF for 14 days pre-slaughter. Growth performance, carcass characteristics and economic considerations were determined.

Increasing the concentration of albus lupins decreased daily gain for d 15-28 ($P=0.004$) and for the overall period from d 0-28 ($P=0.034$). Average daily feed intake was also decreased as the concentration of the albus lupins increased for d 15-28 ($P<0.001$) and d 0-28 ($P=0.003$). Carcass weight and backfat decreased as the concentration of albus lupins in the diet increased ($P=0.011$ and $P=0.024$, respectively). There was no difference in the feed cost per pig from d 15-28 ($P>0.05$). According to the pricing grid used in this experiment the price received per kg increased ($P=0.037$) and there was a trend for carcase value to increase ($P=0.087$) as the concentration of albus lupins in the diet increased.

The suggested inclusion concentration of albus lupins to optimize growth performance, carcass characteristics and economic considerations is 130 g/kg albus lupins. This research provides further evidence that albus lupins can be included in the diets of immunocastrated male pigs for 14 days pre-slaughter and two weeks after the second immunization against GnRF to decrease feed intake and subsequently backfat.

Background to Research

Immunization of entire males against gonadotrophin releasing factor (GnRF) is an effective strategy to eliminate boar taint. However, immunocastrated males have an increased feed intake, growth rate and backfat compared to entire males (Dunshea *et al.* 2001a; Cronin *et al.* 2003; Lealiifano *et al.* 2011). Body composition measured using dual-energy X-ray absorptiometry has also shown that the majority of fat deposition in immunocastrated pigs occurs 2 to 3 weeks after the second immunization against GnRF (Moore *et al.* 2016a,b). Management strategies to limit this fat deposition and promote lean deposition are required.

A way to manage the increase in feed intake and increase in fat deposition in immunocastrated male pigs is to restrict feed intake through the inclusion of an in-feed ingredient. *Lupinus albus* L. (albus lupins) have been found to reduce feed intake in several pig experiments (Dunshea *et al.* 2001b, Van Nevel *et al.* 2000, Moore *et al.* 2016b, Moore *et al.* 2017). Dunshea *et al.* (2001b) suggests that the most likely mechanism by which albus lupins affect feed intake is by delayed transit in the stomach and small intestine. This delayed transit then feedbacks on satiety signals. Previous experiments at Medina Research Station have found that the inclusion of albus lupins at 20% in the diet of immunocastrated males in the second 2-week period after the second immunization against GnRF reduced feed intake, improved feed conversion and reduced backfat but the impact on growth rate was inconsistent (either similar or significantly lower than entire males fed a standard finisher diet).

Thus, albus lupins have shown potential in overcoming the issues of the increased feed intake and backfat associated with immunocastrated males. However, the inclusion concentration of albus lupins previously used was not optimal. It is desirable to identify the most appropriate inclusion concentration to maximize the decrease in feed intake and backfat whilst minimizing the negative effect on growth performance. If an appropriate concentration of albus lupins can be determined then the production of immunocastrated males may be optimized for producers.

Objectives of research

1. To determine the concentration of *Lupinus albus* to be included in the diet of immunocastrated males which will maximize the decrease in feed intake and backfat whilst optimizing the effect on growth rate.
2. Undertake a cost-benefit analysis of including albus lupins in the diets of immunocastrated males.

Hypotheses

1. As the concentration of *Lupinus albus* in the diet of pigs immunized against GnRF increases, the feed intake and growth rate of the pigs will decrease until a plateau is reached at the optimum inclusion concentration.
2. The backfat of pigs immunized against GnRF will decrease as the concentration of *Lupinus albus* in the diet increases.

Methodology

This experiment was conducted at the Department of Primary Industries and Regional Development (DPIRD) Medina Research Centre, and the experimental protocol used in this study was approved by the DPIRD Animal Research Committee and by the Animal Ethics Committee (AEC number 17-6-13). The animals were handled according to the Australian code of practice for the care and use of animals for scientific purposes (NHMRC, 2013).

Experimental design

A total of 216 Large White × Landrace × Duroc immunocastrated male pigs were used in this experiment. The experiment was a completely randomised design with six concentrations of *Lupinus albus L.* (albus lupins; 0, 40, 80, 120, 160 and 200 g/kg).

Animals and Housing

Two hundred and sixteen pigs (Large White x Landrace x Duroc) who had received their priming dose of an anti-gonadotrophin releasing factor immunological product (Improvac®, Zoetis Australia, Rhodes, Australia) were sourced at 72.6 ± 6.13 kg live weight (LW) from a commercial facility. The pigs were individually identified with ear tags, weighed and stratified on their LW before being randomly allocated to treatment. The pigs were group housed (*n* =6) in a naturally ventilated grower/finisher shed and they had *ad libitum* access to water and feed via a single-spaced feeder.

Diets and feeding regime

On d 0, all pigs were fed Control 1 (Table 1, 13.5 MJ DE and 0.64 g standardized ileal digestible lysine (SID)/MJ DE) and they also received the second dose of the anti-gonadotrophin releasing factor vaccine. On day 15 the pigs were fed their allocated diets for 14 days pre-slaughter. The diets contained either 0, 40, 80, 120, 160, 200 g/kg albus lupins (variety Amira). They were formulated to the same nutrient specifications (13.5 MJ DE and 0.50 g SID/MJ DE). The two extreme diets (Control Low - 0 g/kg Albus lupins and Albus 200 g/kg albus lupins) were blended using a Feedlogic system (automated feed delivery system, FeedPro, Feedlogic Corp., Wllmar, MN, USA) in the appropriate ratio to obtain the four middle diets. For example, to obtain the 80 g/kg albus lupins, 60% of the diet was the 0 g/kg diet and 40% of the diet was the 200 g/kg diet. The composition of the experimental diets is given in Table 1. The diets were also analysed for quantitative amino acid composition (Australian Proteome Analysis Facility, Sydney, NSW, Australia) and the results are presented in Table 2.

Table 1: Composition of the experimental diets.

Diet	Control High	Control Low	Albus
Ingredients, g/kg, as-fed basis			
Barley	24.32	49.39	41.48
Wheat	45	30	29.89
Mill run	5	5	5
Lupins, angustifolius	20	10	0
Lupins, Albus	0	0	20
Meat meal	4.18	2.31	2.00
Tallow	0.63	1.95	0.44
L-Lysine	0.32	0.24	0.07
Methionine	0.087	0.023	0
Threonine	0.039	0	0
Tryptophan	0.011	0.001	0
Limestone	0.031	0.589	0.619
Salt	0.2	0.25	0.2
Choline chloride	0.060	0.132	0.180
Phytase[1]	0.02	0.02	0.02
Vitamin and mineral premix[2]	0.1	0.1	0.1

Nutrient composition[3]			
DE, MJ/kg	13.5	13.5	13.5
CP, g/kg	17.9	14.4	17.4
g SID Lys/MJ DE[4]	0.64	0.50	0.50

[1] Phytase from Phyzyme Danisco Australia Pty Ltd; [2]Provided per kilogram of final diet: 7,000 IU Vitamin A, 1,400 IU Vitamin D_3, 20 g Vitamin E, 1 g Vitamin K, 1 g Vitamin B_1, 3 g Vitamin B_2, 1.5 g Vitamin B^6, 15 mg Vitamin B_{12}, 12 g niacin, 10 mg pantothentic acid, 0.19 g folic acid, 30 mg biotin, 10.6 g calcium pantothenatic, 60 g iron, 100 g zinc, 40 g manganese, 10 g copper, 0.2 g cobalt, 0.5 g iodine, 0.3 g selenium, and 20 g antioxidant; [3] Calculated composition; [4] SID: Standardised ileal digestible lysine/MJ digestible energy

Table 2. Quantitative amino acid analysis of the diets used.

Amino Acid, g/kg as-fed basis	Control High	Control Low	Albus
Histidine	3.9	3.2	3.7
Isoleucine	5.7	4.8	6.2
Leucine	10.7	9.0	11.1
Lysine	9.2	7.0	7.5
Methionine	2.4	1.8	1.4
Phenylalanine	6.7	5.9	6.8
Threonine	5.7	4.5	5.6
Valine	6.9	6.0	7.2

Growth Performance

Pigs were weighed weekly and feed intake was determined on day 0, 7, 14, 21 and 28 to measure average daily gain and voluntary feed intake. The feed conversion ratio was calculated on a weekly basis from when the feeding of the experimental diets commenced.

Slaughter procedure

Four weeks after the second vaccination against GnRF and implementation of the experimental diets the pigs were individually tattooed and transported to a commercial abattoir (approximately 90 min transport time) the day before slaughter. The pigs were stunned using a carbon dioxide, dip-lift stunner set at 85% CO_2 for 1.8 min (Butina, Denmark). Exsanguination, scalding, dehairing and evisceration were performed using standard commercial procedures. Hot carcass weight (HCW, AUSMEAT Trim 13; head off, fore trotters off, hind trotters on; AUS-MEAT Ltd, South Brisbane, Qld, Australia) and P2 backfat depth, 65 mm from the dorsal midline at the point of the last rib (PorkScan Pty Ltd., Canberra, Australia) were measured approximately 35 min after exsanguination, prior to chiller entry (2 °C, airspeed 4 m/s).

Statistics

One way analysis of variance was performed with the GENSTAT 18 program (VSN International Ltd, Hemel Hemsptead, UK) to analyse the main effect of albus lupin concentration on growth performance, carcass quality, feed costs, price per kilo received and carcase value. Pen was used as the experimental unit. The response to albus lupins was also tested for linear and quadratic effects using polynomial orthogonal contrasts. A level of probability of < 0.05 was used to determine statistical difference between the means. A level of probability of < 0.1 but > 0.05 was determined to be a trend. Fisher's-protected least significant differences were used to determine differences among treatments.

The optimal concentration of albus lupins to include in the diet was identified for each significantly different parameter using a split line regression fitted to the treatment means in GENSTAT 18.

A cost-benefit analysis was also undertaken.

Results

There were some differences in the analysed concentrations of amino acids between the Control Low and Albus diets. Despite the differences in analysed concentrations of amino acids all (with the exception of methionine) were above the estimated standardized ileal digestible amino acid requirements of pigs from 80-120 kg LW as outlined in NRC (2012). Methionine was lower in both the Control Low and Albus diets than that estimated in NRC (2012).

Growth performance

As expected there was no difference between treatments for daily gain, feed intake and the feed conversion ratio for d 0-14 (all P>0.05; Table 3). Increasing the concentration of albus lupins decreased daily gain for d 15-28 (P=0.004) and for the overall period from d 0-28 (P=0.034). Average daily feed intake also decreased as the concentration of albus lupins increased for d 15-28 (P<0.001) and d 0-28 (P=0.003). There was no effect of increasing the concentration of albus lupins on the feed conversion ratio from d 15-28 (P>0.05) and d 0-28 (P>0.05). Final liveweight decreased as the concentration of albus lupins in the diet increased (P=0.005).

There was a negative linear effect of increasing the albus lupin concentration on final liveweight (P<0.001), daily gain (d 15-28 P<0.001 and d 0-28 P=0.003) and feed intake (d 15-28 P<0.001 and d 0-28 P =0.003). There were no quadratic effects for daily gain, feed intake or feed conversion ratio for any other time periods. Figure 1 shows the linear and quadratic relationships between the growth performance variables for d 15-28 and for the final liveweight.

Table 3: Growth performance for immunocastrated male pigs fed different concentrations of albus lupins from 78.9 to 112.4 kg LW (n=6).

	Albus lupins (g/kg)								*P*-value	
	0	40	80	120	160	200	SED[1]	*P*-value	Lin[2]	Quad[3]
Initial LW[4]	78.9	79.2	79.6	78.7	78.5	78.4	0.779	0.651	0.245	0.386
Final LW	114.1[a]	113.8[a]	113.2[ab]	111.4[bc]	112.2[ab]	109.6[c]	1.158	0.005	<0.001	0.464
Daily gain (kg/day)										
d 0-14	1.18	1.25	1.24	1.24	1.22	1.20	0.041	0.494	0.989	0.069
d 15-28	1.33[a]	1.22[ab]	1.16[bc]	1.09[bc]	1.19[ab]	1.03[c]	0.072	0.004	<0.001	0.369
d 0-28	1.26[a]	1.24[ab]	1.20[abc]	1.17[bc]	1.21[ab]	1.12[c]	0.043	0.034	0.003	0.886
Feed intake (kg/day)										
d 0-14	2.65	2.61	2.70	2.67	2.71	2.61	0.075	0.723	0.923	0.328
d 15-28	4.04[a]	4.05[a]	3.74[ab]	3.62[b]	3.59[b]	3.45[b]	0.178	0.012	<0.001	0.617
d 0-28	3.34	3.33	3.22	3.14	3.14	3.05	0.109	0.079	0.003	0.945
Feed conversion ratio (kg/kg)										

d 0-14	2.25	2.09	2.17	2.16	2.22	2.18	0.098	0.646	0.998	0.407
d 15-28	3.04	3.35	3.25	3.34	3.04	3.42	0.194	0.250	0.349	0.717
d 0-28	2.66	2.70	2.68	2.71	2.61	2.74	0.099	0.844	0.779	0.806

[1]SED: standard error of difference of the means; [2]Lin: Linear; [3]Quad: Quadratic; [4]LW: liveweight

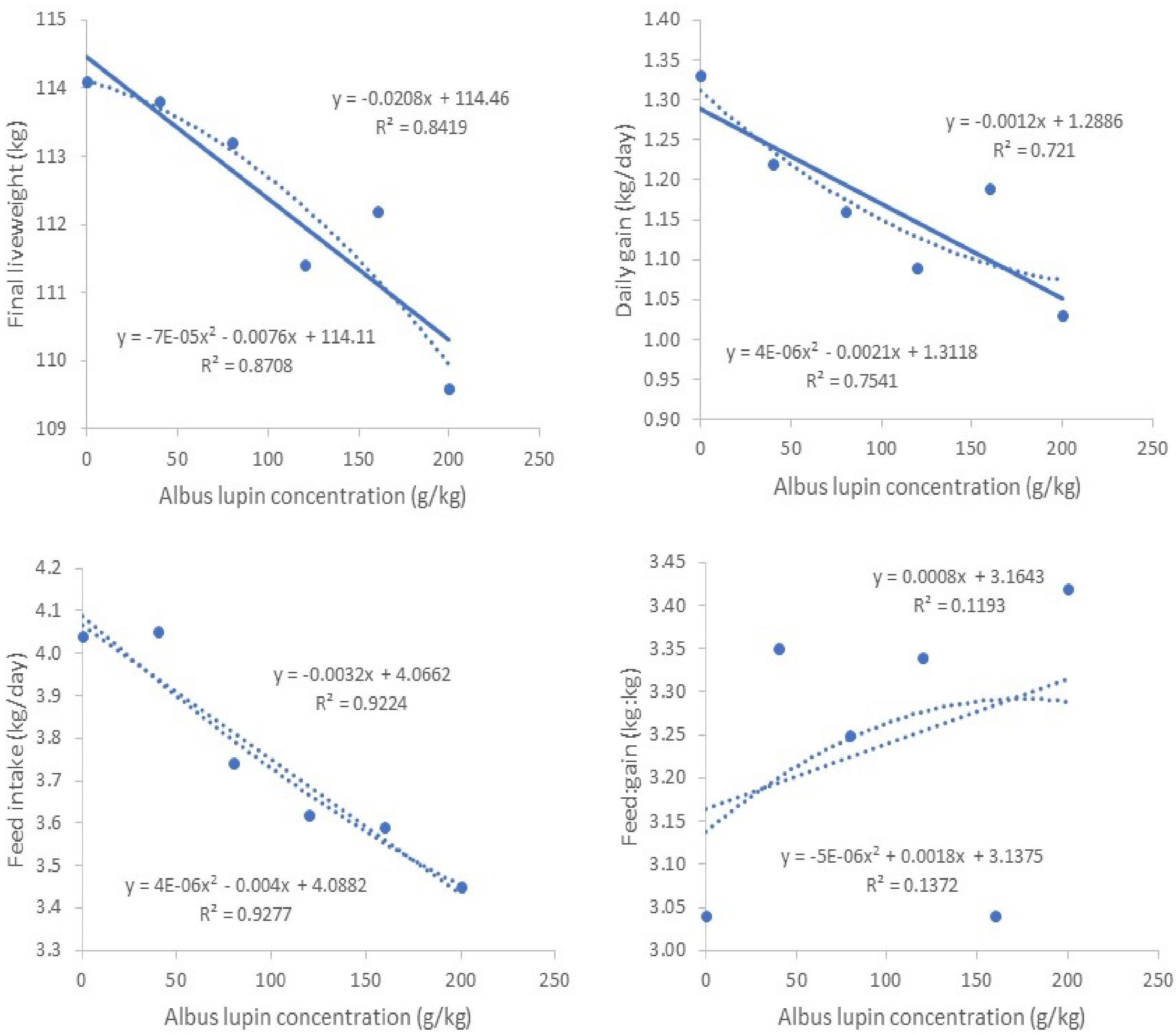

Figure 1: Linear and quadratic relationships for final liveweight, daily gain (d 15-28), feed intake (d 15-28) and feed to gain (d 15-28) for immunocastrated male pigs fed diets with varying concentrations of albus lupins.

Carcass data

Carcass weight and backfat decreased as the concentration of albus lupins in the diet increased (P=0.011 and P=0.021, respectively; Table 4). There was no effect of albus lupin concentration on dressing percentage (P>0.05). There was a negative linear relationship of increasing the albus lupin concentration on carcass weight and backfat (P=0.001 and P=0.004, respectively; Figure 3). There was no relationship between carcass weight and backfat (Figure 2).

Table 4: Carcass data for immunocastrated male pigs fed different concentrations of albus lupins from 78.9 to 112.4 kg LW (n=6).

	Albus lupins (g/kg)								*P*-value	
	0	40	80	120	160	200	SED[1]	*P*-value	Lin[2]	Quad[3]
Carcass weight (kg)	74.8[a]	74.9[a]	74.8[a]	72.6[bc]	73.8[ab]	71.5[c]	1.043	0.011	0.001	0.339
Dressing %	65.5	65.8	66.2	65.2	65.7	65.2	0.536	0.462	0.410	0.339
Backfat (mm)	12.2[a]	11.6[ab]	11.8[ab]	11.0[bc]	11.7[ab]	10.2[c]	0.563	0.021	0.004	0.532
Backfat (mm)[4]	12.1	11.5	11.7	11.1	11.7	10.4	0.596	0.232	0.082	0.725

[1]SED: standard error of difference of the means; [2]Lin: Linear; [3]Quad: Quadratic; [4]Carcass weight used as a covariate

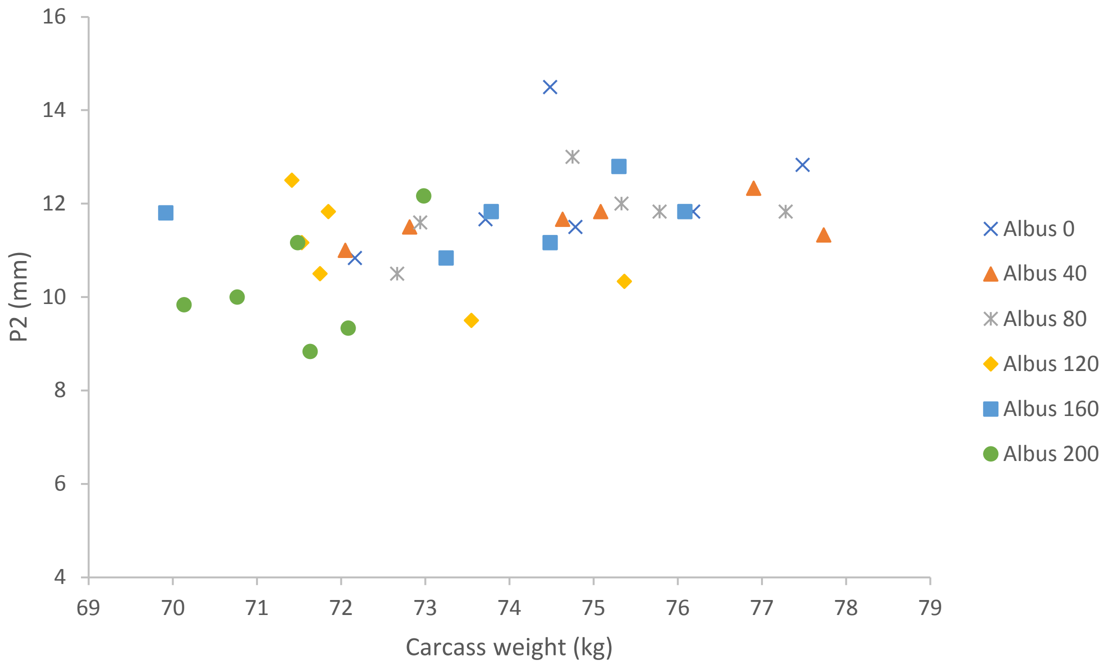

Figure 2: Carcass weight against P2 (mm) for each dietary concentration of albus lupins (n=6).

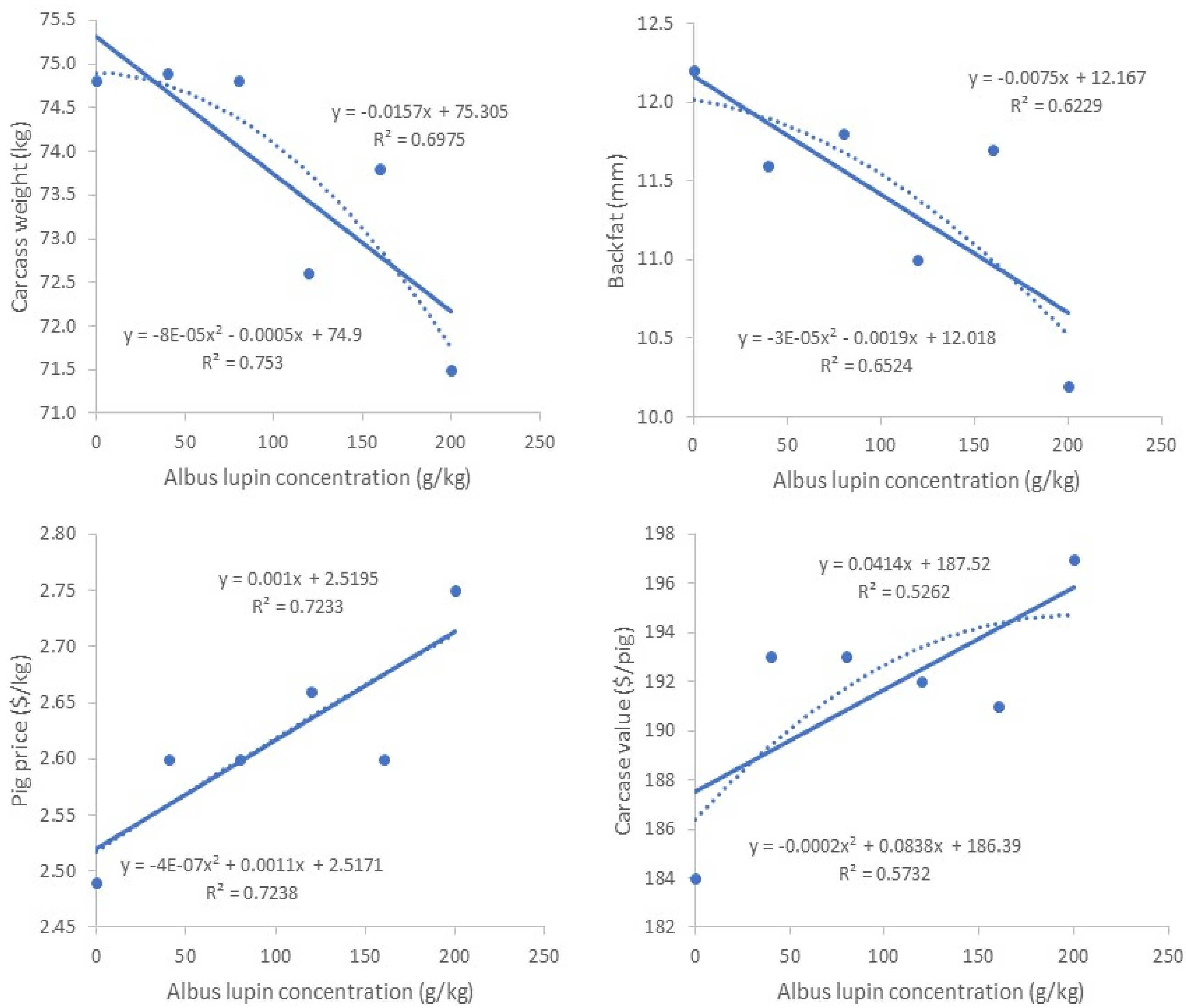

Figure 3: Linear and quadratic relationships for carcass weight, backfat, pig price and carcase value for immunocastrated male pigs fed diets with varying concentrations of albus lupins.

Cost and Revenue

There was no difference in the feed cost per pig from d 0-14 or from d 15-28 ($P > 0.05$ for both; Table 5). The price received per kg increased linearly ($P=0.004$) as the concentration of albus lupins in the diet increased. There was a linear trend ($P=0.087$) for carcase value to increase as the concentration of albus lupins in the diet increased.

Figure 4 shows the proportion of carcases in each backfat category at each albus lupin concentration. As the concentration of albus lupins increases there are more pigs in the highest P2 price category (≤12 mm).

Table 5: Feed costs and revenue for immunocastrated male pigs fed diets with varying concentrations of albus lupins.

	Albus lupins (g/kg)								*P*-value	
	0	40	80	120	160	200	SED[1]	*P*-value	Lin[2]	Quad[3]
Feed cost/pig ($)										
d 0-14	18.60	18.23	19.04	18.71	18.79	18.48	0.430	0.539	0.746	0.335
d 15-28	26.51	25.82	25.42	25.05	26.01	25.01	1.021	0.653	0.234	0.563
Price/kg ($)[4]	2.49[a]	2.60[abc]	2.59[ab]	2.65[bc]	2.59[ab]	2.75[c]	0.078	0.037	0.004	0.964
Carcase value ($)	184	193	193	192	190	196	4.89	0.230	0.087	0.583

[1]SED: standard error of difference of the means; [2]Lin: Linear; [3]Quad: Quadratic; [4]Price/kg based on generic price schedule provided by processor current as at April 2018.

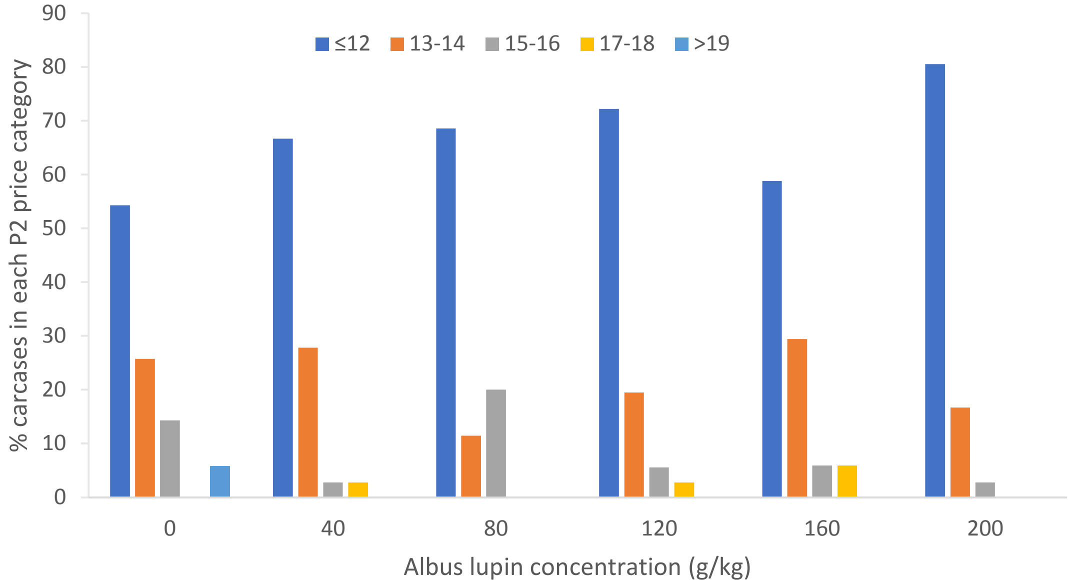

Figure 4: The percentage of carcases in each backfat price category when fed diets with varying concentrations of albus lupins.

The predicted concentration of albus lupins in the diet for daily gain, feed intake, carcass weight, backfat, price/kg and carcase value as determined by split line regression analysis is given in Table 6. The split line regression graphs are given in Appendix A.

Table 6: Predicted albus lupin concentration to optimise each parameter determined from a split line regression analysis.

Parameter	Dietary albus lupin concentration (g/kg)
Daily gain	120
Daily feed intake	142
Carcase weight	62.7
Backfat	138
Price/kg	134
Carcase value	40.6

Cost benefit analysis

A cost benefit analysis for each concentration of albus lupin in the diet is given in Table 7. The return to the producer of approximately $10/pig is maximised at 40 and 80 g/kg albus lupins in the diet. At 120, 160 and 200 g/kg albus lupins the returns to the producer are between $3-4/pig. The returns to the producer are largely dependent on the cost of the albus lupins and the price schedule from the processor at the time of the analysis.

Table 7: Cost benefit analysis of including varying concentrations of albus lupins in a finisher diet on a per pig basis.

	Albus lupins (g/kg)					
	0	40	80	120	160	200
Costs						
Reduction in growth/carcass weight[1] ($)	0	0.288	0	6.34	2.88	9.50
Total costs ($)	0	0.288	0	6.34	2.88	9.50
Benefits						
Reduction in feed costs ($)	0	0.69	1.09	1.46	0.5	1.5
Increase in carcase value ($)	0	9	9	8	6	12
Total benefits ($)	0	9.69	10.09	9.46	6.5	13.5
Net margin/pig ($(	0	9.98	10.09	3.12	3.62	3.97

[1]Assumption: Carcasses in optimal P2 and weight range; Price schedule and feed costs used were those current in April 2018 and March 2018, respectively.

Discussion

The hypothesis that as the concentration of *Lupinus albus* in the diet of pigs immunized against GnRF increases, the feed intake and growth rate of the pigs will decrease until a plateau is reached at the optimum inclusion concentration was supported. A split line regression analysis found that the optimum inclusion concentration of albus lupins in the diet of immunocastrated pigs to maximise growth rate was 120 g/kg while to minimize feed intake the concentration was 142 g/kg. Although an optimum inclusion concentration of albus lupins was determined there was also a linear relationship between both growth rate and feed intake and the concentration of albus lupins with growth rate and feed intake decreasing as the concentration of albus lupins increased. The reduction in feed intake and growth rate of albus lupins when included in the diet at 20% concurs with Moore *et al.* 2016a and Moore *et al.* (2017). Albus lupins are thought to decrease feed intake by delayed transit through the stomach and small intestine. This may then feedback through satiety signals (Dunshea *et al.* 2001). There may also be other factors involved as suggested by van Nevel (2000) which include excessive volatile acid production in the hindgut and the presence of bitter saponins which may inhibit feed intake.

The hypothesis that the backfat of pigs immunized against GnRF will decrease as the concentration of *Lupinus albus* in the diet increases was supported. Backfat decreased linearly as the concentration of albus lupins in the diet increased. To minimise the backfat thickness the predicted concentration of albus lupins in the diet is 138 g/kg. In the current experiment this decreased backfat thickness by approximately 9% (~1.2 mm) compared to the control diet. Van Nevel *et al.* (2000), Moore *et al.* (2016b) and Moore *et al.* (2017) also found that backfat was reduced when albus lupins were included in finisher diets. The reduced backfat in van Nevel *et al.* (2000) was attributed to the slower growth rate of the pigs fed albus lupins. The reduction in backfat in the present experiment provides further support to the use of albus lupins in the diets of immunocastrated males when these pigs are marketed where producers are penalized for excessive backfats.

After taking all factors into consideration including growth performance parameters, carcass parameters, feed costs and carcase returns a concentration of 130 g/kg albus lupins fed for 14 days pre-slaughter is proposed as the optimum inclusion concentration. This will allow daily gain to be maximised whilst minimizing feed intake and backfat. It will also allow an optimum price/kg to be obtained. Including albus lupins in the diet two weeks after the second immunization against GnRF will avoid the large increase in feed intake and fat deposition associated with the production of immunocastrated male pigs. In addition, it provides a means whereby immunocastrated male pigs can be kept for at least four weeks after the second immunization GnRF to allow the other benefits (apart from elimination of boar taint) of these pigs to be realised. Other benefits of the production of immunocastrated males include less non-violent social and aggressive behaviours compared to entire males approximately one to two weeks after the second immunization against GnRF (Cronin *et al.* 2003; Rydhmer *et al.* 2010). The decrease in aggression also results in less carcass lesions at slaughter (Dunshea *et al.* 2011).

This study was partly undertaken due to conflicting results found in the magnitude of the reduction in feed intake and growth rate when albus lupins were included at 20% in the diet of immunocastrated males for 14 days pre-slaughter in Moore *et al.* (2016b) and Moore *et al.* (2017). In the 14-day period pre-slaughter Moore *et al.* (2016b) found that feed intake was decreased by 20% compared to the control diet whilst in Moore *et al.* (2017) the reduction was approximately 25%. In the present study the inclusion of albus lupins at 20% decreased feed intake by 15% compared to diets with no albus lupins. The large decrease in feed intake in Moore *et al.* (2017) was attributed to increased acceptability issues with the albus lupin diet or that the large increase in feed intake that is generally observed approximately 2 weeks after the second immunization against GnRF could not be exhibited in pigs that had only just began to receive the albus diet. However, there was not a large reduction in feed intake in the present study and so it is possible that the large decrease in feed intake in Moore *et al.* (2017) was more likely related to diet manufacture than the potential increase in feed intake.

There was no difference in dressing percentage when pigs were fed varying concentrations of albus lupins. This is supported by Moore *et al.* (2017) who when feeding 20 g/kg albus lupins for 14 days pre-slaughter found no difference in the dressing percentage when compared to IC males fed the control diet. In contrast when IC males were fed a diet with 200 g/kg albus lupins (Moore *et al.* 2017) or 20-30 g/kg albus lupins (Moore *et al.* 2016b) for 28 days pre-slaughter the dressing percentage was decreased compared to those receiving the control diet.

The albus lupins used in this experiment were food grade and so had a price premium compared to if the lupins were classed as feed grade. At the time of this experiment (March 2018) the albus lupins were priced at $440/T. If feed grade albus lupins were available then this may improve the potential cost related benefits associated with feeding albus lupins. Another consideration is the quantity of albus lupins currently produced in Western Australia. Over the last five years the average lupin production in Australia has been 750,000 Tonnes of which 20% are albus lupins. The majority of albus lupins are grown in New South Wales but small amounts are grown in Western Australia. The cultivars of albus lupins which have been mainly used are susceptible to anthracnose and this previously resulted in the reduction of albus lupins planted in Western Australia. It has recently been detected (October 2016) in the plantings of albus lupins in New South Wales and an eradication program is currently in place (GRDC GrowNotes Lupins, 2018). However, the albus cultivar, Amira which was used in this experiment has been shown to be moderately resistant to anthracnose (Department of Primary Industries and Regional Development, 2018). This may possibly lead to an increase in the area planted to albus lupins in Western Australia and therefore increase the quantity of albus lupins available for inclusion in pig diets.

Conclusions

Albus lupins can be included in the diets of immunocastrated male pigs for 14 days pre-slaughter and two weeks after the second immunization against GnRF to decrease feed intake and subsequently backfat. The suggested inclusion concentration to optimize growth performance, carcass characteristics and economic considerations is 130 g/kg albus lupins.

References

Cronin, G.M., Dunshea, F.R., Butler K.R., McCauley I., Barnett, J.L., & Hemsworth, P.H., 2003. The effects of immuno- and surgical-castration on the behaviour and consequently growth of group-housed, male finisher pigs. *Applied Animal Behaviour Science,* **81**, 111–126. doi: 10.1016/S0168-1591(02)00256-3

Department of Primary Industries and Regional Development, 2018. *Amira: an anthracnose resistant albus lupin for Western Australia*. https://www.agric.wa/lupins/amira-anthracnose-resistant-albus-lupin-western-australia. Accessed 19 June 2019.

Dunshea, F.R., Calantoni, C., Howard, K., McCauley, I., & Jackson P. 2001a. Vaccination of boars with a GnRF vaccine (Improvac) eliminates boar taint and increases growth performance. *Journal of Animal Science*, **79**, 2524–2535.

Dunshea, F.R., Cronin, G.M., Barnett, J.L., Hemsworth, P.H., Hennessy, D.P., Campbell, R.G., Luxford, B., Smits, R.J., Tilbrook, A.J., King, R.H. & McCauley, I. 2011. Immunisation against gonadotrophin-releasing hormone (GnRH) increases growth and reduces variability in group-housed boars. *Animal Production Science*, **51**, 695-701.

Dunshea, F.R., Gannon, N.J., van Barneveld, R.J., Mullan, B.P., Campbell, R.G. & King, R.H. 2001b. Dietary lupins (*Lupinus angustifolius* and *Lupinus albus*) can increase digesta retention in the gastrointestinal tract of pigs. *Australian Journal of Agricultural Research,* **52**, 593-602.

GRDC GROWNOTES^{TM} Lupins, Northern April 2018, https://grdc.com.au/__data/assets/pdf_file/0021/314508/GRDC-GrowNotes-Lupins-Northern.pdf, Grains Research & Development Corporation. Accessed 19th June 2019.

Lealiifano AK, Pluske JR, Nicholls RR, Dunshea FR, Campbell RG, Hennessy DP, Miller DW, & Mullan BP. 2011. Reducing the length of time between harvest and the secondary GnRF immunization improves growth performance and clears boar taint compounds in male finishing pigs. *Journal of Animal Science*, **89**, 2782-2792.

Moore, K.L., Mullan, B.P., Kim, J.C. & Dunshea, F.R. 2016c. Standardized ileal digestible lysine requirements of male pigs immunized against gonadotrophin releasing factor. *Journal of Animal Science*, **94**, 1982-1992. doi: 10.2527/jas.2015-9622

Moore, K.L., Mullan, B.P., Kim, J.C., Payne, H.P. & Dunshea F.R. 2016a. Effect of feed restriction and initial body weight on growth performance, body composition and hormones in male pigs immunized against gonadotrophin releasing factor. *Journal of Animal Science*, **94**, 3966-3977. doi: 10.2527/jas.2016-0403

Moore, K.L., Mullan, B.P., Kim, J.C. & Dunshea, F.R. 2016b. The Effect of *Lupinus albus* and Calcium Chloride on Growth Performance, Body Composition, Plasma Biochemistry and Meat Quality of Male Pigs Immunized Against Gonadotrophin Releasing Factor. *Animals*, **6**, 78. doi:10.3390/ani6120078

Moore, K.L., Mullan, B.P., Kim, J.C. & Dunshea, F. 2017. The Effect of *Lupinus albus* on Growth Performance, Body Composition and Satiety Hormones of Male Pigs Immunized against Gonadotrophin Releasing Factor. *Animals*, **7**, 15. doi:10.3390/ani7030015.

National Health Medical and Research Council. Australian code for the care and use of animals for scientific purposes. 8th ed. Canberra, Australia, 2013.

Nutrient Requirements of Swine, 2012. National Research Council of the National Academies, 11th Edition, United States of America.

Rydhmer, L., Lundstrom, K. & Andersson, K. 2010. Immunocastration reduces aggressive and sexual behaviour in male pigs. *Animal*, **4**, 965-972.

Van Nevel, C., Seynaeve, M., Van De Voorde, G., De Smet, S., Van Driessche, E. & de Wilde, R. 2000, Effects of increasing amounts of *Lupinus albus* seeds without or with whole egg powder in the diet of growing pigs on performance. *Animal Feed Science and Technology*, **83**, 89-101.

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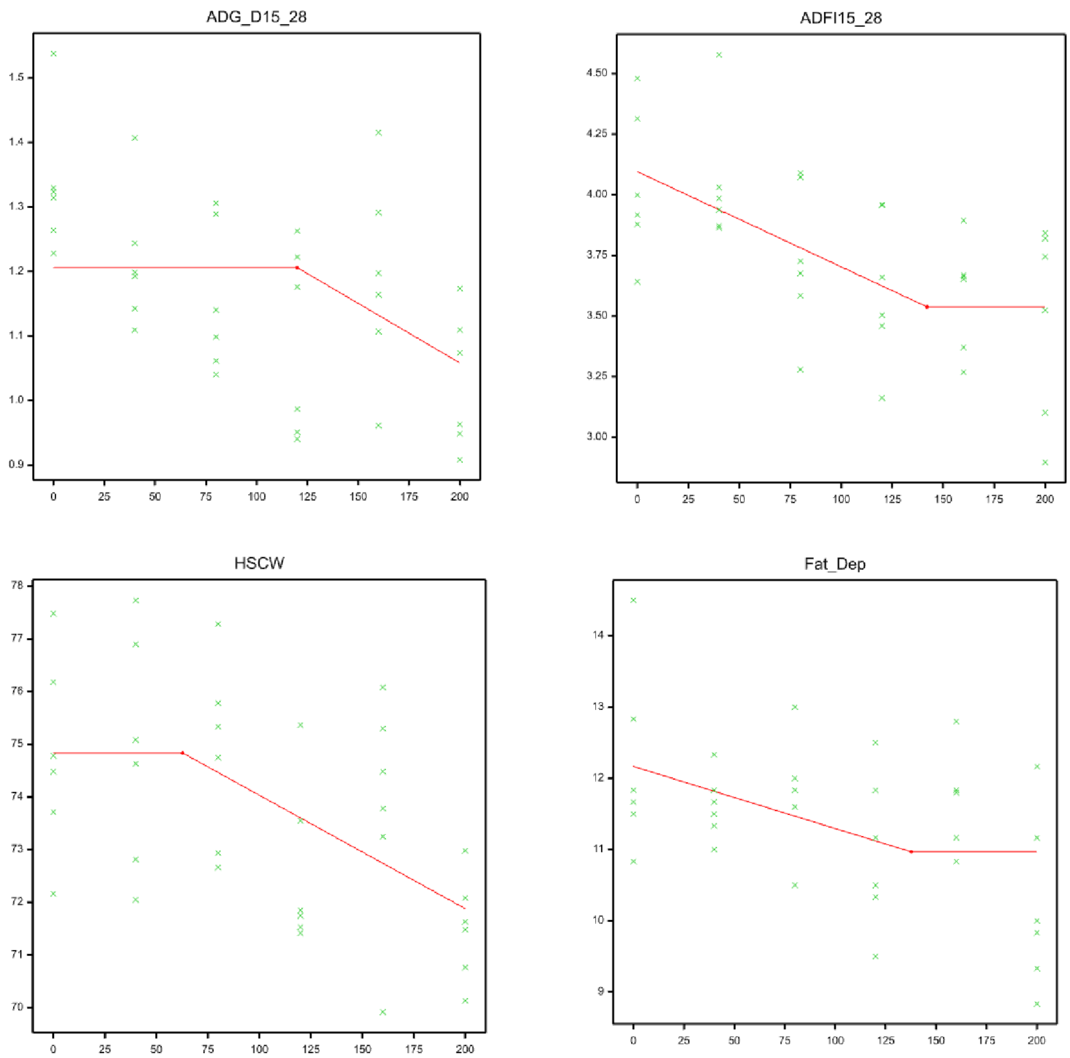
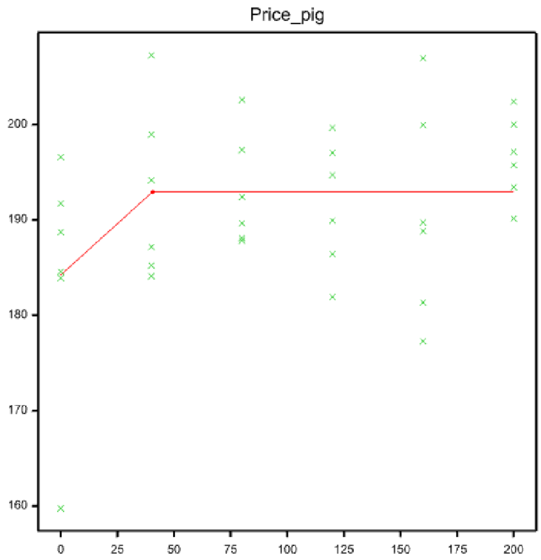
Appendix A

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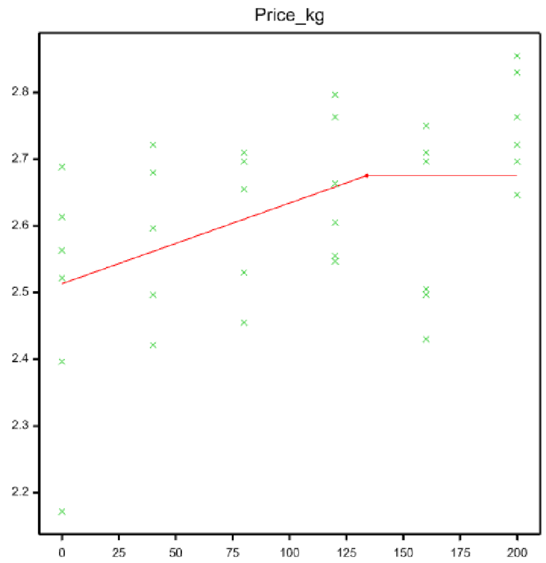
125
150
175
200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100
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150
175
200