THE USE OF HIGH FIBRE DIETS TO MANIPULATE CARCASS TISSUE DISTRIBUTION IN FINISHER PIGS, WITH PARTICULAR EMPHASIS ON REDUCING BELLY FAT
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Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

By

Megan Trezona, Roland Nicholls and Bruce Mullan

Department of Agriculture and Food WA
Locked Bag 4, Bentley Delivery Centre WA 6983
mtrezona@agric.wa.gov.au

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Executive Summary

The objective of this project was to use dietary interventions to manipulate the composition of the belly primal without negatively impacting upon growth performance and carcass quality. Two experiments were conducted; the first investigated the effect of dietary energy level and the inclusion of straw in finisher diets, and the second the inclusion of straw, lucerne and lupin hulls in finisher diets.

Overall there was no effect of treatment on belly primal composition and very little difference in growth performance, or the quality and composition of the carcass. P2 backfat depth was significantly higher for pigs fed a low energy diet without straw (14.2 mm) compared to those fed a high energy commercial diet with or without straw (12.6 and 12.0 mm, respectively) and a low energy diet with straw (12.8 mm). The results suggest that the addition of straw to the low energy diet contributed to reduced fat deposition at the P2 site, indicating that the straw had a direct effect on the pig rather than an indirect effect via dilution of dietary nutrients. Although the objective of manipulating tissue distribution within the carcass was not met, the similarity in growth performance and carcass quality between treatments suggests that straw, lucerne and lupin hulls may be used as alternative ingredients in finisher diets.

Diets that contained the fibrous ingredients, and were formulated to have equivalent energy levels to the commercial finisher diet, were more expensive than the commercial diet. Considering the results of the experiments it would not be economically beneficial to use these ingredients unless consistent carcass benefits were found to occur. Alternatively, without the constraints of feed costs, lucerne, lupin hulls or straw could be added at levels of up to 10% without negatively impacting upon growth performance and carcass quality of finisher pigs.

The low energy diet was $28 per tonne cheaper than the conventional finisher diet and pig growth performance and carcass composition did not differ. Group housed pigs tend to have lower voluntary food intake than individually housed pigs, therefore in a commercial environment it is likely pigs fed a low energy diet would grow slower and therefore be fatter at slaughter. Although carcass composition, as analysed by dual x-ray absorptiometry, did not differ between high energy and low energy fed pigs, average P2 depth was highest in the pigs fed the low energy diet which attracted penalties in the carcass payment schedule.

Future investigations into the inclusion of straw, lucerne or lupin hulls in finisher diets should include feeding to group housed pigs. Increasing the content of the fibrous ingredients in the diet is likely to affect growth performance and carcass tissue distribution, however increasing the content to above 10% will reduce the integrity of the pellet leading to increased feed wastage. Straw and lupin hulls are potential alternative ingredients for finisher diets. Due to cost, lucerne is not likely to be a realistic ingredient in pig diets unless there are significant production benefits.

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1. Introduction

Variability in fat distribution within finished pork carcasses is an issue that has been highlighted by the increasing demand for (and value of) the pork belly. Historically in Australia fresh pork bellies have not been viewed as valuable cuts, however, with the development of the pork export market to Asian countries the belly primal has become more valuable (pers comm. R Penn, PPC). In the domestic market there is new interest in pork belly cuts which have become a fashionable dish in restaurants and more readily available in supermarkets. Feedback from export buyers indicates that although carcasses are selected for leanness according to backfat depth, fatness within the belly can be variable. Backfat depth at the P2 site is a poor predictor of belly primal composition. Trezona (2008) found that P2 depth explained just 21% of the variability in percent belly fat. The new interest in pork bellies in both the export and domestic markets, combined with the existing base of potential consumers in Australia's large Asian-Australian population, provides an opportunity for Australian pork producers to increase the value of pork carcasses by ensuring the consistent supply of high quality, lean, pork bellies. Increasing lean tissue in pork bellies through genetic improvement will take time, therefore it would be useful to have management tools available which can be implemented immediately.

Increases in dietary fibre (DF) intake of pigs can lead to specific changes to the composition of the belly. Recently Whitney *et al*. (2006) found that when DF was increased via the inclusion of distiller's dried grains with solubles at 10, 20 and 30% of the diet, the thickness of the belly primal was significantly reduced from 3.15cm to 3.00, 2.84 and 2.71cm, respectively, indicating reduced fatness. Restrict-fed pigs supplemented with *ad libitum* access to roughage have also been shown to have reduced fat content in the belly primal compared to *ad libitum*-fed pigs (Hansen *et al*., 2006). Partanen *et al*. (2002) found that although growth performance, backfat thickness and percent carcass lean did not differ between pigs fed medium- (NDF grower: ~188g/kg DM; finisher: ~196g/kg DM) and high-fibre (NDF grower: ~240g/kg DM; finisher: ~285g/kg DM) diets. Pigs fed the high-fibre diets had significantly lower side-fat depth (15.6 vs. 14.3 mm). In a recent experiment conducted with group-housed grower-finisher pigs at the Medina Research Station, when grower-finisher pigs were fed diets diluted with 9% wheat straw (NDF grower diet = 22.5%; finisher diet = 23.5%), growth rates were similar to pigs fed commercial diets (NDF grower diet = 17.6%; finisher diet 18.7%). Live weight for age was significantly higher in pigs fed the 9% straw diet (115.1 vs. 110.4 kg LW) and carcass quality and composition were similar between treatment groups.

It has been demonstrated that the extent of fibre digestibility depends predominantly upon the origin of the fibre source, and to a lesser extent on the amount of fibre in the diet (Stanogias and Pearce, 1985). Lindberg and Anderson (1998) compared the depression in total gastrointestinal tract digestibility of energy in pigs fed high forage fibre diets and high cereal fibre diets. Results from the study indicated that pigs may have the capacity to utilise forage fibre to a greater extent than cereal fibre.

There is a need to investigate the effect the consumption of fibrous material by growing pigs has on fat distribution in the whole carcass and the belly primal, and whether the effect is specific to fibre source or is simply related to the dilution of dietary energy density. Determining the effect fibrous feedstuffs have on pork belly composition may provide information to aid in the development of management strategies to manipulate tissue distribution in growing pigs, and provide useful information for the abattoir to consider when allocating pork carcasses to specific markets.

Objectives

1. Manipulate tissue distribution in the carcass through the use of additional fibre in the diet, potentially reducing percent fat in the belly primal.
2. Maintain or reduce the cost of production by reducing diet cost whilst maintaining or improving feed conversion efficiency.

2. Methodology

Experiment 1 - Increasing the level of dietary fibre in finisher diets to manipulate belly fat in finisher pigs - Investigating the effect of straw

Introduction:

The proportion of fat deposited in the belly primal increases significantly with age relative to the amount of fat deposited in other primals (Figure 1), therefore changes to fat deposition during the finisher period are likely to have a greater effect on fat accretion in the belly relative to other carcass sites. Increasing DF in pig diets can result in less carcass fat (Stahly and Cromwell, 1986; Håkansson *et al*., 2000; Kreuzer *et al*., 2002) and reduced P2 depth (CRC Project 2B101).

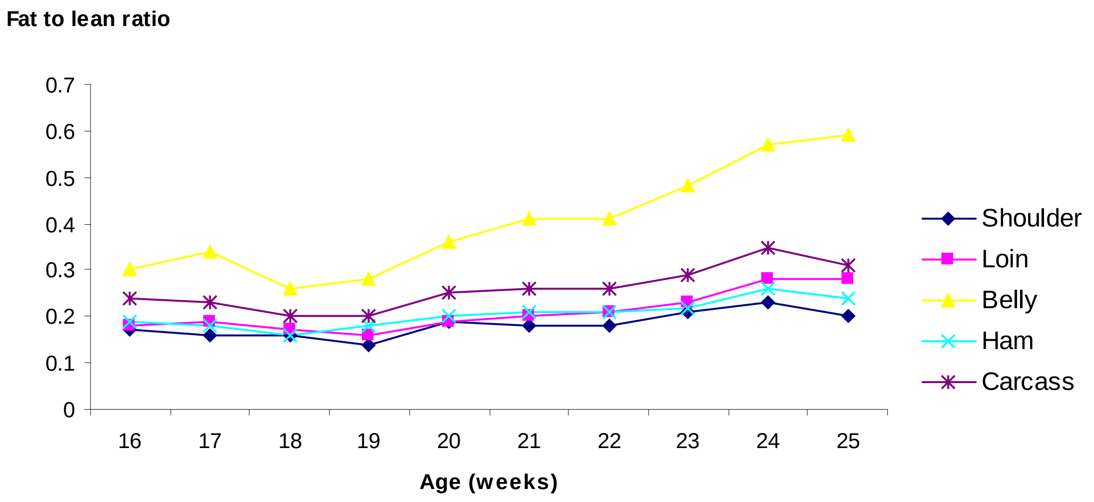

Figure 1 - Fat to lean ratio of the carcass and primal cuts of female pigs 16 to 25 weeks of age (from data of D'Souza *et al*., 2004)

Previous studies conducted at DAFWA have indicated that pigs housed in straw-bedded deep-litter systems had differences in carcass fat distribution compared to pigs raised in conventional intensive housing systems, in particular a reduction in the proportion of fat:lean in the belly primal (Trezona, 2008). Staals *et al*. (2007) concluded that significant amounts of straw are consumed by pigs housed on bedding and van Barneveld *et al*. (2003) quantified consumption as being up to 10% of the total dietary intake. Common bedding materials such as wheat and barley straw are highly lignified and are not readily fermentable, therefore have little nutritive value to growing pigs.

The experiment was designed to determine whether the effects of straw consumption on pig carcass composition were caused directly by the consumption of straw itself or indirectly via the dilution of dietary nutrients caused by the inclusion of straw in the diet.

Hypotheses:

1. Feeding finisher pigs diets containing 10% cereal straw will alter carcass fat distribution and reduce fat levels in the belly primal without negatively affecting pig growth performance
2. Feeding pigs lower energy diets during the last four weeks of finishing will reduce the proportion of fat in the belly primal to a greater extent than other carcass primals

Objectives:

1. Reduce the proportion of fat in the belly primal of pigs by adding straw to the finisher diet and determine the effect on pork quality and growth performance
2. Reduce the proportion of fat in the belly primal of pigs by reducing the energy density of the finisher diet during the finisher growth period and determine the effect on pork quality and growth performance

Experimental Design:

The experiment was conducted as a 2x2 factorial to explore the effects of straw and energy density on the growth, total carcass fat and belly fat of finisher pigs

- 2 levels of straw (0 or 10%)
- 2 levels of energy density (13 .5 or 12.5)
- N=60, n=15

The experiment was approved by the ARC (09MD15) and AEC (1-09-02) committees of the Department of Agriculture and Food Western Australia.

Detailed Methods:

Sixty female pigs weighing approximately 60 kg LW ± 5 kg (~15 weeks of age) were transported to Medina Research Centre from a high health status commercial farm. On arrival all pigs were identified with a unique ear tag and weighed. Pigs were sorted by LW from heaviest to lightest and allocated to groups of four (e.g. four heaviest pigs in group 1, next heaviest in group 2 etc.). Each group were housed randomly within the shed within four adjacent pens. Within each group treatments randomly were allocated. A standard finisher diet was fed for seven days to allow pigs to acclimatise to their new environment after which treatment diets were fed *ad libitum* until slaughter at 100 ± 5 kg LW. Cool, fresh water was available *ad libitum*. Individual food intake and LW were measured weekly to determine growth performance. Pigs were slaughtered at 100 ± 5 kg LW.

Treatment diets:

- **HE:** Control finisher diet (formulated to contain13.5 DE MJ/kg, 0.56g available lysine, 18.7% neutral detergent fibre (NDF), 7.8% acid detergent fibre (ADF);
- **LE+S:** Control diet diluted by the addition of 10% chopped straw (12.5 DE MJ/kg, 0.52g available lysine, 23.5% NDF, 11.2% ADF);

- **HE+S:** Control diet diluted by 10% chopped straw with added fat (so the energy density of the diet is equivalent to the control diet). (13 DE MJ/kg; 23.5% NDF, 11.2% ADF)
- **LE:** Low energy diet (energy density equivalent to that of treatment 2 but no added straw) (12 DE KJ/kg, 18.7% NDF, 7.8% ADF)

The diets were manufactured in a commercial feed mill and were pelleted to avoid ingredient separation (Table 1.1). The aim was to have the energy levels of the HE and HE+S diets as similar as possible, however, given the diet requirements and the manufacturing restrictions placed on the amount of tallow mixer that could be incorporated without degrading the integrity of the pellet this was not possible. Pellet integrity was an important consideration in the test diets as we wanted to be sure the straw component would not be easily separated from the rest of the pellet.

Table 1.1- Diet formulations

Ingredient (%)	**Experimental Diet**			
	HE	**LE+S**	**HE+S**	**LE**
Barley	54.33	48.53	6.00	63.48
Wheat	2.99	2.99	38.89	5.00
Groats (11%)	2.99	2.69	9.30	2.00
Straw (wheaten)	-	9.99	10.00	-
Lupins (32%)	-	-	-	10.01
Dehulled Lupins (38%	29.99	27.04	27.95	11.26
Soybean Meal (48%)	4.99	4.50	3.00	3.00
Tallow	1.49	1.35	1.50	0.50
Lysine	0.080	0.070	0.155	0.078
Methionine Alimet MHA	0.10	0.09	0.10	0.10
Threonine	-	-	-	0.078
Vitamins and mineral premix	0.25	0.25	0.25	0.25
Limestone	1.19	1.10	1.05	1.15
Dicalcium Phosphate	1.29	1.15	1.55	2.75
Salt	0.21	0.19	0.23	0.30
Choline Chloride (60%)	0.013	0.011	0.013	0.013
Calculated Analysis				
DE (MJ/kg)	**14.00**	**12.78**	**13.45**	**12.90**
NE (MJ/kg)	9.76	8.88	9.44	9.22
Protein (%)	20.04	18.43	18.92	16.26

Ingredient (%)	Experimental Diet			
	HE	LE+S	HE+S	LE
Fat (%)	4.95	4.58	5.18	3.29
Crude Fibre (%)	4.13	7.53	6.40	5.33
Av Lysine (%)	0.819	0.743	0.780	0.647
Lysine (%)	0.962	0.874	0.908	0.776
Calcium (%)	0.889	0.847	0.918	1.19
Phosphorus (%)	0.771	0.698	0.772	0.893
ND Fibre (%)	15.02	20.70	17.79	16.83

At 100 ±5 kg LW pigs were transported to a commercial abattoir for slaughter. Carcass weight and P2 backfat depth (PorkScan) were measured on the hot carcass by abattoir staff. At 45 minutes post slaughter the pH of the *longissimus dorsi* (*l. dorsi*) was measured adjacent to the P2 site using a portable pH/temperature meter (Jenco Electronic Ltd, model 6009), fitted with a polypropylene spear-type gel electrode (Ionode IJ42S, Brisbane QLD) and a temperature probe.

Twenty four hours after slaughter approximately 1kg of the *l. dorsi* muscle (with fat and skin attached) was removed from the left side of the carcass in a posterior direction from the point of the last rib, and measurements of objective pork quality were carried out. pH of the *l. dorsi* was determined using a portable pH/temperature meter (described above). Percent drip loss was calculated using the suspension method described by Hokinel (1998) where an 80g sample of meat devoid of skin and significant fat deposits was cut in duplicate from the *longissimus dorsi*. The sample was placed in netting and suspended in a sealed plastic container. The samples were refrigerated for 24 hours then removed from the container, gently blotted dry and weighed to determine drip loss. Surface lightness (L*), redness (a*) and yellowness (b*) were measured using a Minolta Chromameter CR-400. Cook loss was determined by cooking a pre-weighed sample of *l. dorsi* at 80^{o}C for one hour, cooling for 30 minutes, then reweighing the sample. Shear force of the cooked sample was then measured using a Warner Bratzler shear blade fitted to an Instron Universal testing machine.

The right side of each carcass was broken down into the four quarter primals (shoulder, loin, belly and ham). The shoulder primal was removed from the middle as a straight cut level with the junction 4th and 5th thoracic vertebrae, as described by Giles *et al.* (1983). The hind primal was removed from the middle with a straight cut between the last and second last lumbar vertebrae (Suster *et al.*, 2004). The middle was cut parallel to the dorsal edge at the point of the last rib, to give the loin and belly primals. The primals were boxed and frozen for later determination of carcass and primal composition by dual X-ray energy absorptiometry (DXA).

Statistical Analysis

The data were analysed as a 2x2 factorial, blocked by group, using procedures of the Genstat Program. A statistical difference was determined when the probability was less than 0.05. Trends were identified when P<0.100.

Experiment 2 - The use of high fibre finisher diets to reduce belly fat in finisher pigs – investigating different fibre sources

Introduction

Results from the previous experiment investigating the effect of straw inclusion in pig diets during the final weeks of finishing found little effect on the quality, composition and tissue distribution of the carcass and quarter primals. Pigs received the treatment diets for an average of 4 weeks (ranging from 3 to 5 weeks) which may not have been a sufficient length of time to show a response in carcass tissue distribution. Therefore for this experiment the duration for which pigs were fed treatment diets was increased to an average of 6 weeks. Increasing the inclusion of fibrous ingredients in the finisher diet to above 10% may not be practical as there may be a negative effect on growth performance as well as causing issues with the structure/integrity of the feed pellet which would increase the amount of feed wastage.

Straw inclusion significantly reduced average daily gain, however, the value of the carcasses from pigs fed the high energy + straw diet was greater than that of carcasses from pigs fed the commercial high energy diet ($229 vs. $223). The higher carcass value was because a greater proportion of carcasses from pigs fed the HE+S diet fell within the premium live weight and P2 range of the abattoir payment schedule.

Research has indicated that pigs have the capacity to utilise forage fibre to a greater extent than cereal fibre (Stanogias and Pearce, 1985; Lindberg and Anderson, 1998). Recent research has found the forage fibre lucerne can be included in finisher diets at a rate of up to 150g/kg without detrimental effects on pig performance (Thacker and Haq, 2008). Lupin hulls are a recognised fibre source, however, these are not commonly used in grower finisher diets. Compared to fibre originating from cereals the fibre fraction of legumes is more easily digested by pigs (Fernández and Jørgensen, 1986), however, there is little information available describing the effects on carcass composition of feeding grower-finisher pigs diets with added lupin hulls. It has been demonstrated that when lupin hulls were added at 5% to diets containing soya bean meal there was no adverse effects on growth (Ferguson *et al.* 2003). Fernandez and Batterham (1991) found that the addition of 10% lupin hulls to diets containing soya bean meal improved daily gain, however the researchers concluded that part of this response may have been associated with the lupin hulls contributing to the lysine content of the diet.

There is a need to investigate the specific effects of the consumption of fibrous ingredients on fat distribution in the whole carcass and the belly primal of growing pigs, and whether the effects are specific to fibre type. Determining the effect of fibrous feedstuffs on pork belly composition may provide information to aid in the development of management strategies to manipulate tissue distribution in growing pigs, as well as provide useful information for the abattoir to consider when allocating pork carcasses to specific markets. Pork quality is affected by diet, therefore it is essential to test that dietary interventions to manipulate carcass composition do not negatively impact the quality of fresh pork. In pigs, the fatty acid (FA) profile of fat tissue largely reflects the FA pattern of the diet (Smith *et al.*, 1996), and feeding pigs increased levels of dietary fibre has been shown to alter the properties of fat tissue in the carcass (Kreuzer *et al.*, 2001; Whitney *et al.*, 2006). The FA profile of the fat tissue influences pork quality (appearance, shelf life) and eating quality (flavour), therefore it is important to determine what effects the treatment diets may have on the FA profile of fat tissue.

Hypotheses:

1. Feeding finisher pigs diets containing 10% straw, lupin hulls or lucerne for 6 weeks prior to slaughter will alter carcass fat distribution and reduce fat levels in the belly primal compared to when pigs are fed a control finisher diet
2. Pigs fed diets containing 10% lucerne or lupin hulls will have improved growth performance and differences in carcass fat distribution compared to pigs fed diets containing 10% cereal straw
3. Consumption of the different fibre types will be reflected in differences in the fatty acid profile of fat tissue

Objective:

Reduce the proportion of fat in the belly primal of pigs by adding fibrous ingredients to the finisher diet and determine the effect on pork quality and growth performance.

Experimental Design:

The experiment was conducted to explore the effects of different fibre sources on the growth, total carcass fat and belly fat of finisher pigs

- 4 treatment diets
- N=64, n=16

The experiment was approved by the ARC (09MD32) and AEC (5-09-28) committees of the Department of Agriculture and Food Western Australia.

Detailed Methods:

Seventy Large White x Landrace female pigs from the same genetic source as experiment 1 weighing approximately 45 kg LW ± 5 kg (~14 weeks of age) were transported to the Medina Research Centre. On arrival all pigs were identified with a unique ear tag, weighed and sorted by weight. Pigs were allocated to groups of four according to weight and each group of pigs were individually housed in four adjacent pens. Within each group, treatments were randomly allocated. Pigs were fed the control finisher to allow them to acclimatise to their pens until reaching an average of 55 kg LW, after which treatment diets began. Pigs received the diets *ad libitum* until they reached a slaughter weight at 92 ± 5 kg LW. Cool, fresh water was available *ad libitum*. Individual food intake and LW were measured weekly to determine growth performance.

The diets were formulated to contain equivalent calculated levels of digestible energy (13.5 DE MJ/kg) and lysine (0.56 g available lysine). Additional tallow was used in the lucerne, lupin and straw diets to adjust digestible energy level. Fibrous ingredients were ground in a tub grinder and passed through a series of screens with the final screen being a mesh of 5mm diameter. The diets were manufactured in a commercial feed mill and were pelleted to avoid ingredient separation. Diet formulations were as presented in Table 2.1.

Treatment diets:

- **Control:** Control finisher diet
- **Straw:** Control diet diluted by the addition of 10% chopped straw
- **Lupin:** Control diet diluted by the addition of 10% lupin hulls
- **Lucerne:** Control diet diluted by the addition of 10% lucerne

Table 2.1 – Experimental diet formulations

	Experimental Diet			
Ingredient (%)	**Control**	**Straw**	**Lupin Hulls**	**Lucerne**
Barley	35.0	30.33	32.86	35.71
Wheat	37.92	25.0	25.0	25.0
Straw (wheaten)	-	10.0	-	-
Lupin Hulls	-	-	10.0	-
Lucerne	-	-	-	10.0
Lupin Kernel	20.65	27.20	24.85	22.95
Tallow Press	1.5	4.05	4.05	3.30
Lysine	0.30	0.20	0.19	0.22
Methionine Alimet MHA	0.100	0.105	0.105	0.090
Threonine	0.112	0.066	0.061	0.051
Vitamins and mineral premix	0.25	0.25	0.25	0.25
Limestone	1.10	1.00	0.90	0.75
Dicalcium Phosphate	2.75	1.55	1.50	1.45
Salt	0.3	0.24	0.22	0.22
Choline Chloride (75%)	0.013	0.013	0.013	0.013
Calculated Analysis				
DE (MJ/kg)	**13.59**	**13.37**	**13.59**	**13.68**
NE (MJ/kg)	9.71	9.51	9.59	9.55
Protein (%)	15.70	16.21	17.1	16.68
Fat (%)	3.24	7.04	7.21	6.51
Crude Fibre (%)	3.45	6.52	6.94	6.60
Av Lysine / DE	0.056	0.055	0.055	0.055
Lysine (%)	0.812	0.804	0.820	0.835
Calcium (%)	0.996	0.887	0.878	0.878
Phosphorus (%)	0.819	0.741	0.814	0.714
ND Fibre (%)	14.54	19.44	17.03	18.25
Dietary Fibre (%)	10.84	7.75	7.75	7.75

At 92 ± 5 kg LW pigs were transported to a commercial abattoir for slaughter. Carcass weight and P2 backfat depth (PorkScan) were measured on the hot carcass by abattoir staff. Twenty four hours after slaughter approximately 1kg of the *l. dorsi* muscle (with fat and skin attached) was removed from the left side of the carcass in a posterior direction from the point of the last rib and measurements of objective pork quality were carried out as described in experiment 1.

The right side of each carcass was broken down into the four quarter primals (shoulder, loin, belly and ham) as described in Experiment 1. A sample of belly fat was collected and frozen for later determination of fatty acid profile (Manning and Harvey, 2002). The primals were boxed and frozen for later determination of carcass and primal composition by dual X-ray energy absorptiometry (DXA).

Statistical Analysis

The data were blocked by group and analysed using general ANOVA procedures of the Genstat Program. A statistical difference was determined when the probability was less than 0.05. Trends were identified when P<0.100.

3. Outcomes

Experiment 1 - Increasing the level of dietary fibre in finisher diets to manipulate belly fat in finisher pigs – Investigating the effect of straw

Growth Performance

For most measurements of growth performance there was no effect of feeding pigs diets containing high versus low energy diets, with and without the addition of 10% cereal straw (P>0.05) (Table 1.2). There were no interactions between energy level and the addition of straw (P>0.05). Average daily gain (ADG) was affected by treatment where pigs fed diets containing straw had significantly lower ADG compared to pigs fed diets that did not contain straw (P=0.025). There was a trend for pigs fed the diets containing straw to have the highest feed conversion (therefore poorest efficiency) (P=0.082). As the negative effects of straw on ADG and FCR were seen for pigs fed high and low energy diets, the results show that the presence of straw in the diet negatively impacted upon the utilisation of dietary nutrients by pigs.

Table 1.2. Growth performance of finisher pigs fed high (HE) or low (LE) energy diets, with (+S) or without 10% straw included in the diet.

	HE	HE+S	LE	LE+S	SEM	P-value Energy	Straw	E*S
Live weight (kg) day 0	55.3	56.1	56.4	55.8	1.70	0.808	0.961	0.667
Final Live weight (kg)	96.6	95.8	98.3	96.8	0.88	0.126	0.189	0.714
Days on Experiment	27	28	27	29	1.1	0.511	0.130	0.276
Total LW gain (kg)[1]	34.2	32.1	34.4	33.2	0.99	0.502	0.102	0.685
Average Daily Gain (kg/day)	1.28[ab]	1.18[b]	1.30[a]	1.14[b]	0.039	0.959	0.025	0.563
Food Intake (FI) (kg/pig)	85.2	86.5	88.5	94.2	3.60	0.136	0.338	0.547
Daily FI (kg/pig/day)	3.16	3.14	3.34	3.19	0.083	0.163	0.338	0.417
FCR (kg feed/kg LW gain)	2.52	2.79	2.63	2.84	0.135	0.552	0.082	0.837

[1]adjusted for days on experiment

The low energy diets cost less per tonne than the high energy diets, with the HE+S diet being the most expensive (Table 1.3). The average feed cost per pig was highest for pigs fed the diets containing straw however the average feed cost per kg of LW gain was similar for pigs fed the HE diet and the diets containing straw, and lowest for pigs fed the LE diet. Average carcass value was highest for pigs fed the HE+S diet as a greater proportion of carcasses from this treatment group fell within the premium categories of backfat depth and carcass weight.

Table 1.3. Average diet cost and carcass value according to treatment

	HE	HE+S	LE	LE+S
Diet cost ($/tonne)	418	437	390	396
Average Feed cost/pig ($)	35.61	37.78	34.56	37.29
Average Feed cost/kg LW gain ($)	1.18	1.16	1.07	1.14
Average Carcass value ($)	223.10	228.60	219.20	220.90

Carcass

Most carcass measures were not significantly affected by dietary treatment (Table 1.4). For P2 backfat depth, however, there was a trend for pigs fed the low energy diets to have higher P2 depth (P=0.78). A significant interaction between energy and straw, however, showed pigs fed the LE diet had the highest P2 depth compared to pigs fed the other treatment diets (P=0.046). This suggests that the inclusion of straw in the low energy diet reduced the deposition of fat at the P2 site during the final weeks of finishing. There was a trend for pigs fed diets without straw to have thicker belly fat at the caudal end of the belly primal (P=0.081), however this appears to be mostly due to the thicker belly fat in pigs fed the low energy diet. The thicker fat depth at the P2 site and on the belly primal from carcasses of pigs fed the LE diet may be explained in part by the lower protein levels within the LE diet compared to the other treatment diets (16.26 % compared to 18.43%, 18.92% and 20.04%). When pigs are fed diets where the ratio of protein to energy is imbalanced and protein levels are below requirements the excess dietary energy is deposited as fat (Campbell *et al*., 1984; Tuitoek *et al*., 1997).

There was a trend for the interaction between diet energy level and straw to affect hot carcass weight (HCWT) (P=0.066). Hot carcass weight was highest for pigs fed the LE diet and lowest for pigs fed the LE+S diet. Though not significant (P>0.05) average LWT before slaughter and carcass dressing percentage were slightly higher for LE fed pigs compared to LE+S fed pigs, and this therefore contributed to the difference in HCWT between the two treatment groups.

Table 1.4 - The effect of treatment diets on carcass parameters

						P-value		
	HE	HE+S	LE	LE+S	SEM	Energy	Straw	E*S
Belly fat thickness (cranial) (mm)	19.8	19.7	21.3	19.2	1.04	0.604	0.349	0.325
Belly fat thickness (caudal) (mm)	31.8	30.3	35.7	31.4	1.56	0.111	0.081	0.376
Hot carcass weight (kg)	63.8	64.1	64.9	62.7	0.65	0.877	0.187	0.066
P2 depth (mm)	12.0[a]	12.6[ab]	14.2[b]	12.8[ab]	0.67	0.078	0.301	0.046
Dressing %	66.0	67.0	66.0	64.8	0.80	0.165	0.994	0.178

**number of experimental days as covariate in analysis*

Dietary treatment did not affect carcass or primal composition. There was a trend for the percentage of fat in the shoulder primal to be highest in carcasses from pigs fed the LE+S diet (P=0.081). There was no difference between treatments in the percentage of fat tissue in the belly primal (Table 1.5).

Table 1.5 - Carcass composition

						P-value		
	HE	HE+S	LE	LE+S	SEM	Energy	Straw	E*S
% Carcass fat	18.7	18.7	19.8	19.1	1.06	0.484	0.751	0.784
% Carcass lean	79.0	79.0	77.8	78.6	1.05	0.441	0.746	0.703
% Carcass bone	2.2	2.3	2.4	2.3	0.06	0.258	0.942	0.081
% Shoulder fat	17.4	16.0	17.0	18.7	0.85	0.183	0.921	0.076
% Shoulder lean	79.9	80.0	79.7	78.2	0.89	0.338	0.561	0.303
% Loin Fat	22.6	22.7	23.0	22.3	1.46	0.992	0.854	0.759
% Loin lean	75.2	75.1	74.7	75.4	1.48	0.940	0.851	0.763
% Belly fat	24.7	25.8	25.2	24.5	1.14	0.754	0.831	0.448
% Belly lean	75.0	74.0	74.5	75.2	1.13	0.762	0.861	0.444

	HE	HE+S	LE	LE+S	SEM	P-value Energy	Straw	E*S
% Ham Fat	22.7	23.6	25.0	23.4	1.40	0.445	0.830	0.386
% Ham lean	74.9	73.9	72.4	74.2	1.41	0.411	0.822	0.332

**number of experimental days as covariate in analysis*

Most pork quality measurements were not affected by dietary energy level or straw inclusion (P>0.05) (Table 1.6). There were also no significant interactions between energy and straw (data not presented). Pork from pigs fed the low energy diets lost significantly less moisture during cooking than pork from pigs fed the high energy diet (P=0.016). Higher percentages of intramuscular fat (IMF) can explain lower cook losses and the trend for higher P2 backfat depth of pigs fed the low energy diets (P=0.075) may indicate increased fatness and therefore higher levels of IMF. There were no corresponding differences in percentages of total carcass fat, however there may have been an effect of treatment in proportions of fat deposited between the various fat depots.

Table 1.6 - Effect of dietary treatments on objective pork quality of the *longissimus dorsi*

	Treatment diets					P-value	
	HE	HE+S	LE+S	LE	SED	Energy	Straw
pH_{45}	6.16	6.16	6.24	6.20	0.075	0.281	0.749
pH_u	5.57	5.55	5.63	5.62	0.057	0.120	0.943
Shear Force (kg)	5.80	5.72	6.12	5.54	0.558	0.884	0.539
L*	52.1	53.3	52.1	53.4	1.10	0.888	0.939
a*	5.66	6.05	5.35	8.86	2.656	0.481	0.413
b*	2.33	2.83	2.17	2.49	0.336	0.311	0.700
% Drip loss	5.22	5.82	4.58	5.19	0.581	0.132	0.987
% Cook loss	36.06^{a}	35.33^{ab}	34.64^{b}	34.99^{b}	0.507	0.016	0.136

Experiment 2 - The use of high fibre finisher diets to reduce belly fat in finisher pigs – investigating different fibre sources

Growth performance

Pig growth performance was not affected by treatment (P>0.05), indicating that when energy density is maintained the addition of the fibrous ingredients (lucerne, straw and lupin hulls) did not have a negative impact on growth and feed efficiency (Table 2.2).

Table 2.2 - Growth performance of finisher pigs fed experimental diets

	Control	Lucerne	Lupin	Straw	SEM	P-value
Live weight (kg) day 0	54.4	54.0	53.7	54.3	0.45	0.690
Final Live weight (kg)	94.0	91.5	92.7	92.3	1.26	0.540
Days on Experiment	39	37	37	38	1.25	0.560
Total LW gain (kg)*	39.1	38.1	39.3	37.6	1.07	0.620
Average Daily Gain (kg/day)	1.03	1.02	1.05	1.00	0.029	0.676
Food Intake (kg/pig)*	107.3	103.7	112.0	105.3	2.59	0.137

Daily FI (kg/pig/day)	2.86	2.87	3.09	2.83	0.099	0.243
FCR (kg LW gain/kg feed)	2.75	2.83	2.94	2.84	0.135	0.596

*adjusted for number of days on experiment

The diets with added lucerne, lupin hulls or straw were more expensive than the control finisher diet as additional lupin kernel and tallow were used to increase the energy density of the diets to equal the control diet. There was a $3.25 difference in feed cost per pig, with the lucerne diet having the lowest feed cost/pig and the lupin hull diet having the highest cost. In this experiment pigs fed the lucerne diet had the highest average carcass value whilst carcass value of pigs fed the lupin hull and straw diets was an average of $15 lower.

Table 2.3 - Average diet cost and carcass value according to treatment

	Control	Lucerne	Lupin	Straw
Diet cost ($/tonne)	425.70	437.80	433.40	432.30
Feed cost/pig ($)	46.17	44.94	48.19	45.8
Feed cost/kg LW gain ($)	1.17	1.24	1.27	1.23
Average Carcass value ($)	219	225	211	210

Carcass

Treatment diets did not affect carcass quality (P>0.05). Carcass dressing percentages were equivalent to those from experiment 1. P2 depth was lower for the current experiment as pigs were slaughtered at a lower LW than those in the previous experiment.

Table 2.4 - The effect of treatment diets on carcass parameters

	Control	Lucerne	Lupin	Straw	SEM	P-value
Hot carcass weight (kg)	62.9	61.5	62.6	59.8	1.48	0.461
P2 depth (mm)	12.1	10.8	11.9	11.1	0.86	0.674
Dressing %	67.1	66.7	67.4	65.1	1.33	0.632

**number of experimental days as covariate in analysis*

Treatment diets did not successfully manipulate carcass composition or the distribution of fat within the carcass. Over all, percent fat in the carcass and primals was lower in the current experiment compared to the previous experiment as pigs were slaughtered at lighter weights (~4 kg lighter). The difference in carcass composition demonstrates how rapid the rate of fat accretion occurs during late finishing.

With low pig numbers per treatment (n=16) and no significant differences in carcass quality parameters and carcass composition, the effect of the lucerne diet on increased carcass value was likely not a real effect. Also in this experiment the carcass value from pigs fed the straw diet was less than carcasses from the control fed pigs, whereas in the previous experiment the average carcass value from pigs fed a high energy straw diet was higher than carcasses from pigs fed the conventional high energy diet. More data would need to be collected in order to determine if there is a real and repeatable effect of the fibrous ingredients tested on carcass value.

Table 2.5 - Carcass composition

	Control	Lucerne	Lupin	Straw	SEM	P-value

% Carcass fat	17.3	15.4	17.1	15.8	1.09	0.541
% Carcass lean	80.4	82.3	80.5	81.9	1.09	0.518
% Carcass bone	2.3	2.3	2.4	2.3	0.05	0.340
% Shoulder fat	15.5	16.7	15.4	15.8	1.06	0.801
% Shoulder lean	81.3	80.2	81.4	80.0	1.06	0.866
% Loin Fat	19.5	16.7	17.8	17.1	1.37	0.485
% Loin lean	78.3	81.1	79.9	80.7	1.37	0.485
% Belly fat	21.4	19.2	19.8	18.3	1.32	0.403
% Belly lean	78.3	80.5	79.9	81.4	1.32	0.419
% Ham Fat	22.0	18.8	22.0	19.7	1.33	0.235
% Ham lean	75.5	78.8	75.4	77.7	1.34	0.218

Number of experimental days as covariate in analysis

Pork Quality

There was no effect of treatment diet on pork colour, cook loss or tenderness (P>0.05) (Table 2.6). There was a significant effect of diet on percentage drip loss where pork from pigs fed the lucerne or lupin diets had a higher drip loss than pork from pigs fed the control diet. Percentage drip loss is the amount of moisture/fluid that exudes from the raw meat whilst in storage/packaging. Higher levels of drip loss can result in tougher, drier cooked meat. A high ratio of saturated fatty acids to polyunsaturated fatty acids can improve most aspects of pork quality (Teyes *et al.*, 2006) and this may explain why drip loss was lowest in pork from control fed pigs which had the highest ratio (3.14), whilst pork from pigs fed the lucerne and lupin diets the lowest ratio (2.70).

There was a trend for $pH_{u\ 24h}$ to be highest in straw fed pigs (P=0.086), however as this difference was less than 0.1 of a pH unit, and there were no corresponding differences in pork colour and shear force, this trend did not affect objective pork quality.

Table 2.6 - Effect of dietary treatments on objective pork quality of the *longissimus dorsi*

		Control	Lucerne	Lupin	Straw	SEM	P-value
pHu (24 hours)		5.46	5.48	5.48	5.53	0.018	0.086[1]
Colour	L*	58.8	53.3	54.4	52.8	0.81	0.560[1]
	A*	5.77	6.40	6.22	5.71	0.236	0.115
	B*	3.57	3.94	3.93	3.40	0.217	0.215[1]
% drip loss		5.92[a]	7.59[b]	7.36[b]	6.37[ab]	0.426	0.023
% cook loss		32.5	32.6	35.6	32.2	0.44	0.929[1]
WB Shear Force (kg)		5.55	5.01	5.49	5.24	0.363	0.703

[001]significant effect of slaughter day (P<0.05)

Pigs fed the control diet had significantly higher levels of C16:0 in belly fat compared to pigs fed lupin and straw diets (Table2.7). Pigs fed the control diet had significantly lower levels of C18:3 in belly fat than pigs fed the fibrous diets. These differences led to belly fat from straw fed pigs being significantly lower in saturated fatty acid and higher in unsaturated fatty acid content than pigs fed the control diet and the lucerne diet.

Table 2.7 - Effect of dietary treatments on fatty acid profile

	Control	Lucerne	Lupin	Straw	SEM	P-value
C14:0	1.70	1.66	1.64	1.61	0.041	0.489
C16:0	26.3[a]	25.1[ab]	24.6[b]	24.3[b]	0.44	0.012
C16:1	2.58	2.20	2.28	2.32	0.158	0.117
C18:0	14.3	14.0	13.8	13.2	0.49	0.418
C18:1	39.6	39.6	40.6	41.6	0.66	0.102
C18:3n3	1.18[a]	1.36[b]	1.33[b]	1.32[b]	0.048	0.049
C18:2n6	11.4	12.7	12.5	12.4	0.44	0.156
C18:3n6	0.059	0.064	0.064	0.074	0.006	0.334
C20:0	0.22	0.19	0.19	0.19	0.008	0.101
C20:1	0.74	0.83	0.76	0.78	0.036	0.299
C20n6	0.26	0.28	0.28	0.29	0.014	0.470
SFA (%)	43.3[a]	41.8[a]	41.1[ab]	40.0[b]	0.738	0.027
UFA (%)	56.7[a]	58.2[a]	58.9[ab]	60.0[b]	0.738	0.027
PUFA (%)	13.8	15.5	15.2	15.2	0.528	0.109
SFA:UFA	0.77[a]	0.73[a]	0.70[ab]	0.67[b]	0.023	0.032

There was an effect of treatment on subcutaneous fat colour (Table 2.8). The fat from pigs fed the lucerne and straw diets had higher b* values than fat from pigs fed the control diet (P=0.028). This indicates that fat from lucerne and straw fed pigs was less yellow than pigs fed the control diet. This result fits with the differences in the fatty acid profile of belly fat between treatment groups where pigs fed the lucerne and straw diets had a lower percentage of saturated fatty acids in belly fat than did pigs fed the control diet. As the proportion of saturated fatty acids increase in fat tissue it appears more yellow. Even though measurement with the chromameter detected a significant difference in colour, the difference was small and therefore difficult to detect with the naked eye and would not be detected by the consumer.

Table 2.8 - Effect of diet on subcutaneous fat colour

		Control	Lucerne	Lupin	Straw	SEM	P-value
Colour	L*	78.12	77.32	77.34	77.29	0.468	0.534
	a*	4.69	5.30	5.48	5.32	0.302	0.283
	b*	5.58[a]	6.54[b]	5.93[ab]	6.55[b]	0.260	0.028

4. Application of Research

Application of the research findings in the commercial world.
Opportunities uncovered by the research
Commercialization/Adoption Strategies

- *Potential benefits to cost of production*
- *Ease of adoption by producers*
- *Impact of the research*

5. Conclusion

In Experiment 1, the hypotheses were not supported.

Feeding finisher pigs diets containing 10% cereal straw did not alter carcass fat distribution and reduce fat levels in the belly primal .

Feeding pigs lower energy diets during the last four weeks of finishing did not reduce the proportion of fat in the belly primal to a greater extent than other carcass primals.

The addition of 10% straw to the finisher diets reduced pig average daily gain, however, there was no effect of diet energy level on growth performance.

Given that pigs fed the LE diet had significantly thicker backfat at the P2 site than pigs fed the other treatment diets, the inclusion of straw may have contributed to reducing the P2 depth of pigs fed the LE+S diet.

In this experiment pigs fed the LE diet had similar growth performance to those fed the HE commercial diet. The LE diet cost $28/tonne less than the HE diet, suggesting it could be more profitable to feed the cheaper diet as growth performance was not compromised. However, the effects of high energy versus low energy diets on pig growth and carcass composition are well documented.

In a commercial environment *ad libitum* fed pigs often have lower food intake, and higher maintenance energy requirements, compared to pigs housed individually in a controlled experimental environment. Hence the effects of the treatment diets may have been more evident if pigs were group housed under commercial conditions.

In experiment 2, there was no difference in growth performance, carcass quality and carcass and primal composition between pigs fed the conventional control diet and those fed the diet with added lucerne, lupin hulls or straw. Therefore the hypothesis that carcass fat would be reduced and belly composition manipulated in pigs fed the treatment diets was not supported. Similarly the hypothesis that there would be better growth performance and differences in carcass tissue distribution for pigs fed the diets containing the forage and leguminous fibre sources, lucerne and lupin hull, diets compared to the straw diet was not supported.

Diet did affect percent drip loss in fresh pork however as the other parameters were not affected it is likely that the effect of treatment on over all pork quality was small. The hypothesis that consumption of the different fibre types would result in differences in the fatty acid profile of tissue was confirmed. The addition of straw to the diet resulted in pork fat that had a significantly lower ratio of saturated- to unsaturated-fatty acids compared to fat from pigs fed the control diet. The colour of backfat was influenced by treatment diet with pigs fed the straw and lucerne diets having fat that was less yellow in colour than in pigs fed the control diet. Although significant, the difference in colour was not obvious to the naked eye and would not have been detected by the consumer. Although the fatty acid profile was determined for belly fat and fat colour was measured in subcutaneous backfat, it is likely that the effect of diet on fat colour was explained by the difference in the ratio of saturated to unsaturated fatty acids.

Feed costs were highest for the diets with added lucerne, lupin hulls and straw because higher percentages of energy rich ingredients were required to increase the energy density of the diets to make them equivalent to the control diet. The results from this experiment indicate that, without economic constraints, pigs can be fed finisher diets containing 10% lucerne, lupin hulls or straw without compromising growth performance or carcass quality.

6. Limitations/Risks

To the application of the research findings

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

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