Strategies to improve market value of pig carcases

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Selection for profitability

Genetic improvement of pig performance is a primary tool in enhancing profitability in pig enterprises. The first step of genetically improving livestock is the development of a breeding objective which combines all economically important traits that can be improved by selection. These traits are given economic values that are defined as the increase in profit with a single unit change in each trait while keeping all other traits constant. Breeding objectives should include all traits that affect profitability even if they cannot be directly measured. This can be achieved by using knowledge of genetic parameters for traits that that breeders wish to improve (breeding objective traits) and traits that have no economic importance but are genetically correlated with traits in the breeding objective (selection criteria). Some traits may be prohibitively difficult or expensive to measure such as feed conversion ratios while others like carcase attributes can only be measured on animals after slaughter.

Historically, only average daily gain and backfat depth have been recorded on farm. However, there are many other traits that influence the profitability of both the production enterprise and subsequent processing and sales facilities. The economic benefits of considering weight of primal cuts were discussed at the last workshop (Mérour and Hermesch, 2008) and since then genetic parameters have been obtained for these traits from the analyses of the French data (Mérour and Hermesch, 2009). Belly composition is important for some markets providing a further avenue to increase the market value of the carcase in addition to backfat at a given carcase weight which is the basis of current payment systems in Australia.

It was the aim of these index calculations to evaluate the benefits of including measures of muscle depth, belly fat and length on live animals as well as measures of carcass and meat quality attributes on related animals of the selection candidate by comparing response to selection and accuracies for different scenarios. Recommendations are provided based on results from these index calculations.

Breeding objective and genetic parameters

The breeding objective included average daily gain, backfat depth, feed conversion ratio, belly and loin weight, belly fat percentage and drip loss percentage. Economic weights for these traits were updated from previous values (Cameron and Crump, 2001 and Hermesch, 2005) using cost parameters expected to be relevant for the Australian industry in the next three to five years (Table 1). Improvements in market value of the carcase arise from higher weight of the loin and reduced belly fat percentage. Economic weights for primal cut weights are defined for a fixed carcase weight and represent the price difference between individual cuts at the farm gate level. Middles achieve a higher price mainly due to the higher economic importance of loin weight. Economic weights were also expressed per genetic standard deviation of each trait showing the relative importance of feed conversion ratio. Backfat has been reduced considerably and further reduction has little economic benefit and keeping backfat constant is often the aim of current pig breeding programs.

Genetic parameters for these traits have been estimated for the four breeds that are part of the national pig breeds, Landrace, French Large White dam and sire lines, and Pietrain (Mérour and Hermesch, 2009; Mérour *et al*. 2009). Genetic and phenotypic correlations for all traits used in this evaluation were the mean of the genetic and phenotypic correlations found for the three white breeds. French Pietrain pigs were judged to be an extreme genotype not representative of Australian pig breeds. Therefore genetic parameters for this breed were excluded when deriving mean genetic parameters. Genetic parameters for drip loss percentage and belly fat percentage were from Hermesch *et al*. (2000a, b) and Hermesch (2008). The selection index program developed by Julius Van der Werf of the University of New England was used (http://www-personal.une.edu.au/~jvanderw/) to evaluate different scenarios. This program also provided a tool for bending of non-positive matrices since the original matrix was outside the parameter space and had to be modified (Table 2).

Table 1. Heritabilities (h^2), genetic standard deviations (GSD), economic weights (EW, $/pig) also expressed per genetic standard deviation ($/GSD) and as a percentage of the overall breeding objective (BO%).

Trait name	h^2	GSD	EW	$/GSD	BO%
Breeding objective traits					
Average daily gain (g/day)	0.29	26.39	0.10	2.64	19
Backfat (mm)	0.57	0.39	-0.70	-0.70	5
Feed conversion ratio (kg/kg)	0.36	0.13	-28.0	-3.53	25
Belly weight (kg)	0.27	0.39	1.20	0.47	3
Loin weight (kg)	0.42	0.68	3.60	2.45	18
Belly fat percentage (%)	0.34	10.96	-0.20	-2.19	16
Drip loss percentage (%)	0.23	0.84	-2.25	-1.89	14
Selection criteria					
Live animal measures					
Live loin muscle depth (mm)	0.30	1.93			
Live animal length (mm)	0.51	17.29			
Carcase measures					
Carcase loin muscle depth (mm)	0.31	2.68			
Carcase fat depth (mm)	0.58	2.35			
Boning room measures					
Weight of back leg (kg)	0.44	0.50			
Weight of shoulder (kg)	0.21	0.31			
pH 24 hours post mortem (scale)	0.20	0.66			

Sources of information

The effect of using additional sources of information on response in the breeding objective and accuracies were evaluated. Adding measures on the live animal are most beneficial since information is available prior to selection. However, the benefits of using live animal measures for improved carcase composition depend on the magnitude of genetic correlations between traits.

It was assumed that traits recorded prior to selection on the live animal were available for the selection candidate, its parents, six fullsibs and 30 halfsibs. Traits recorded in the abattoir or in the boning room were assumed to be recorded on two fullsibs and ten halfsibs at the point of selection. Benefits of measuring feed conversion ratio were also evaluated given the importance of feed conversion ratio in the breeding objective. In scenarios where feed conversion ratio was recorded, it was assumed that it was available for the selection candidate, its sire, two fullsibs and ten halfsibs.

The response to selection is shown per generation assuming a selection intensity of one. The actual annual response to selection will depend on the selection intensities and generation intervals achieved. The response per year is obtained by multiplying the response per generation with the selection intensity achieved divided by the generation interval. Although a selection intensity of 2.101 (average of 2.665 (top 1% of boars) and 1.554 (top 15% of gilts) can be achieved, a selection intensity of 1.667 (average of 2.063 (top 5% of boars) and 1.271 (top 25% of gilts) is more realistic in practice. A generation interval of 18 to 20 months (1.5 to 1.667 years) can be assumed. Given these assumptions in regard to selection intensity and generation interval, the response per generation shown in the Tables below corresponds well to potential genetic gains per year. In practice, often only 25 to 50% of the potential annual genetic gain is achieved indicating the opportunities for improvement.

Table 2. Correlation structure between traits; phenotypic correlations are above diagonal, genetic correlations are below diagonal.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.10	-0.20	0.13	0.03	-0.12	-0.04	0.20	-0.14	-0.05	0.18	-0.06	0.12	0.06	0.06
2	0.01	1	0.35	0.04	-0.10	-0.30	-0.15	0.15	-0.25	-0.06	0.45	0.45	0.08	-0.08	0.01
3	-0.14	0.50	1	0.08	-0.02	-0.11	0.03	0.02	-0.14	-0.03	0.20	0.20	0.01	-0.08	0.01
4	-0.05	-0.04	0.01	1	-0.15	-0.01	0.00	-0.01	-0.03	0.12	0.02	-0.01	0.09	-0.10	-0.01
5	-0.01	-0.19	-0.10	-0.38	1	-0.07	0.00	-0.06	0.25	-0.12	-0.25	-0.14	-0.17	0.04	-0.04
6	-0.08	-0.45	-0.30	0.24	-0.18	1	-0.05	-0.11	-0.08	0.07	-0.22	-0.21	-0.02	-0.13	0.00
7	0.16	-0.25	-0.10	-0.05	-0.01	0.05	1	-0.13	-0.14	-0.03	-0.03	-0.04	-0.07	0.04	0.01
8	0.16	0.35	0.25	-0.36	0.03	0.25	-0.33	1	-0.29	-0.02	0.11	0.20	0.01	-0.001	0.00
9	-0.15	-0.50	-0.40	0.24	0.25	0.20	-0.10	-0.51	1	0.05	-0.37	-0.20	0.29	0.03	-0.02
10	-0.02	-0.18	-0.23	0.38	-0.29	0.15	-0.27	-0.29	0.45	1	-0.13	-0.05	0.22	0.01	0.04
11	0.04	0.65	0.45	-0.01	-0.30	-0.48	-0.28	0.30	-0.54	0.20	1	0.01	0.08	-0.08	-0.01
12	0.16	0.65	0.45	-0.06	0.10	-0.35	-0.13	0.37	-0.40	0.02	0.65	1	0.01	-0.04	-0.01
13	0.35	0.18	-0.10	0.26	-0.29	0.10	-0.25	0.03	0.23	0.70	0.19	0.01	1	-0.07	0.02
14	0.11	-0.20	-0.42	0.20	0.01	0.25	-0.09	-0.08	0.04	0.21	-0.10	-0.04	0.10	1	-0.30
15	-0.03	0.17	0.14	-0.17	0.001	-0.17	-0.01	0.16	-0.15	-0.17	-0.10	0.20	-0.15	-0.60	1

Traits:

1: Average daily gain (g/day); 2: Backfat (mm); 3: Feed conversion ratio (kg/kg); 4: Dressing percentage (%); 5: Carcase length (mm); 6: Weight of back legs (kg); 7: Weight of shoulders (kg); 8: Weight of belly (kg); 9: Weight of loin (kg); 10: Carcase muscle depth (mm); 11: Carcase fat depth (mm); 12: Belly fat percentage (%); 13: Live muscle depth (mm); 14: Drip loss percentage (%); 15: pH at 24 hours *post mortem.*

Using measurements on the live pig only

The base index included measurements of growth and backfat only, which gives a response per generation of $ 4.08 per pig (Base index in Table 3). Adding muscle depth recorded on the live animal raised response per generation to $ 4.26 per pig (IndexL1). In contrast, recording length of the animal did not increase response to selection due to the low genetic correlations between length of the animal and breeding objective traits (IndexL2). Genetic gain can be increased considerably if measurements on the live pig can be developed that are genetically correlated with belly fat percentage of the carcase (IndexL3) even when muscle depth is already recorded (IndexL4). Finally, recording feed conversion ratio increased response to selection to $ 4.54 per pig (IndexL5). However, the costs of performance recording are considerably larger for feed conversion ratio in comparison to ultrasound measures of muscle depth and belly fat percentage, which resulted in only a slightly lower response of $ 4.47 per pig.

Table 3. Sources of information included in the selection index along with genetic response to selection in breeding objective and accuracies after one generation assuming a selection intensity of one – ***adding measures on the live animal***.

Trait name	Base	IndexL1	IndexL2	IndexL3	IndexL4	IndexL5
Breeding objective (BO) traits						
Average daily gain (g/day)	X	X	X	X	X	X
Backfat (mm)	X	X	X	X	X	X
Feed conversion ratio (kg/kg)						X
Belly weight (kg)						
Loin weight (kg)						
Belly fat percentage (%)				X	X	
Drip loss percentage (%)						
Selection criteria						
Live animal measures						
Live loin muscle depth (mm)		X			X	
Live animal length (mm)			X			
Response in BO ($/pig)	**4.08**	**4.26**	**4.08**	**4.34**	**4.47**	**4.54**
Relative response in BO	100	104	100	106	109	111
Accuracy of BO	0.594	0.619	0.594	0.632	0.651	0.660

Incorporating carcase measurements

Response in the breeding objective was $ 4.23 (IndexC1 in Table 4) when information about carcase muscle depth and fat depth was available. This response is slightly lower than the response obtained from measuring muscle depth on the live animal despite stronger genetic correlations between carcase muscle depth and primal cut weights in comparison to muscle depth recorded on the live animal. Genetic parameters are likely to be influenced by the accuracy of the measurement technology. For example, muscle depth recorded with the Hennessy Chong machine on the carcase was not heritable in a previous Australian study (Hermesch, 2000a). In addition, it is often difficult to retrieve data for individual pigs from abattoirs and it is recommended that breeders focus on accurately measuring muscle depth on farm.

Recording breeding objective traits directly (primal cut weights) led to more response in the breeding objective ($ 4.30 Index C2) than indirect fat and muscle depth measures ($ 4.19 Index C1). Obtaining direct information about economically important traits should always be attempted since it allows close monitoring of these traits for purposes of genetic improvement and management practices. In comparison, less response was obtained by adding a belly fat measure recorded on the carcase ($ 4.19, Index C3). The same genetic parameters were assumed for the live and carcase belly fat measure, which demonstrates the benefits of recording traits on the live animal prior to selection. Minimal additional genetic gain was achieved by recording meat quality traits (Index C4).

Table 4. Sources of information included in the selection index along with genetic response to selection in breeding objective and accuracies after one generation assuming a selection intensity of one – ***using carcase measures***.

Trait name	Index C1	Index C2	Index C3	Index C4
Breeding objective (BO) traits				
Average daily gain (g/day)	X	X	X	X
Backfat (mm)	X	X	X	X
Feed conversion ratio (kg/kg)				
Belly weight (kg)		X		
Loin weight (kg)		X		
Belly fat percentage (%)			X	
Drip loss percentage (%)				X
Selection criteria				
Abattoir measures				
Carcase loin muscle depth (mm)	X			
Carcase fat depth (mm)	X			
Boning room measures				
Weight of back leg (kg)		X		
Weight of shoulder (kg)		X		
pH 24 hours post mortem				X
Response in BO ($/pig)	**4.23**	**4.30**	**4.19**	**4.10**
Relative response in BO	104	105	103	100
Accuracy of BO	0.615	0.626	0.610	0.632

Using live-animal and carcase measurements

By using muscle depth recorded on the live animal and primal cut weights the response per generation increased to $ 4.39 (Index A1 in Table 5). This is an improvement of $ 0.31 per pig in comparison to the base index which included growth and backfat only. However, the difference to IndexL1 which included muscle depth on the live pig in addition to growth and backfat was only $ 0.13 per pig, highlighting the benefits of using ultrasound muscle depth on the live animal prior to selection.

Genetic gain in breeding objective increased continuously when additional measurements were used. The response in breeding objective per generation increased to $4.46, $4.63 and $4.93 when carcase fat and muscle depth, belly fat percentage recorded on the live pig and feed conversion ratio were added (Indexes A2, A3 and A4).

Table 5. Sources of information included in the selection index along with genetic response to selection in breeding objective and accuracies after one generation assuming a selection intensity of one – ***using measures on the live pig and the carcase***.

Trait name	Base	Index A1	Index A2	Index A3	Index A4
Breeding objective (BO) traits					
Average daily gain (g/day)	X	X	X	X	X
Backfat (mm)	X	X	X	X	X
Feed conversion ratio (kg/kg)					X
Belly weight (kg)		X	X	X	X
Loin weight (kg)		X	X	X	X
Belly fat percentage[1] (%)				X[1]	X[1]
Drip loss percentage (%)					
Selection criteria					
Live animal measures					
Live loin muscle depth (mm)		X	X	X	X
Abattoir measures					
Carcase loin muscle depth (mm)			X	X	X
Carcase fat depth (mm)			X	X	X
Boning room measures					
Weight of back leg (kg)		X	X	X	X
Weight of shoulder (kg)		X	X	X	X
pH 24 hours post mortem					
Response in BO ($/pig)	**4.08**	**4.39**	**4.46**	**4.63**	**4.93**
Relative response in BO	100	108	109	113	121
Accuracy of BO	0.594	0.639	0.648	0.632	0.717

[1] recorded on the live animal

Response in individual traits

Response in growth rate and backfat decreased from the base index to Index A4 due to inclusion of additional carcase traits and feed conversion ratio (Table 6). Only Index L1 led to an increase in response in growth rate due to the positive genetic correlation between muscle depth on the live pig and growth rate (Table 2). Index A1 which included muscle depth on the live pig and weight of primal cuts resulted in the highest genetic gain in loin weight. High response was achieved in both backfat and belly fat percentage due to the high genetic correlation between fatness traits. However, these high genetic responses might not be desirable.

Feed conversion ratio has generally favourable genetic correlations with leanness and muscularity which resulted in higher response in feed conversion ratio for the more complex indexes. Overall, feed conversion ratio contributed most as an individual trait to the response in the breeding objective (Table 7) due to its economic importance.

There were little differences between indexes for responses in belly weight and weight of back leg or shoulder reflecting the low or zero emphasis on these traits and their low genetic relationships with breeding objective traits. Negative response was observed for belly weight and drip loss percentage for all indexes. Selection for more efficient lean meat growth and carcase composition will lead to lighter bellies and inferior meat quality (Table 6).

Table 6. Response in individual traits for different indexes

Trait name	Base	Index L1	Index A1	Index A2	Index A3	Index A4
Breeding objective (BO) traits						
Average daily gain (g/day)	7.14	7.63	7.17	7.22	5.99	5.38
Backfat (mm)	-0.76	-0.72	-0.70	-0.69	-0.68	-0.64
Feed conversion ratio (kg/kg)	-0.05	-0.05	-0.05	-0.06	-0.06	-0.08
Belly weight (kg)	-0.09	-0.09	-0.10	-0.10	-0.11	-0.11
Loin weight (kg)	0.23	0.27	0.31	0.31	0.31	0.31
Belly fat percentage (%)	-4.92	-4.96	-4.87	-5.15	-6.33	-6.23
Drip loss percentage (%)	0.15	0.16	0.15	0.15	0.12	0.18
Selection criteria						
Live animal measures						
Live loin muscle depth (mm)	-0.08	0.29	0.28	0.27	0.28	0.29
Abattoir measures						
Carcase loin muscle depth (mm)	0.35	0.27	0.74	0.62	0.51	0.59
Carcase fat depth (mm)	-1.13	-1.04	-1.11	-1.22	-1.27	-1.25
Boning room measures						
Weight of back leg (kg)	0.16	0.17	0.17	0.17	0.17	0.16
Weight of shoulder (kg)	0.07	0.05	0.05	0.06	0.05	0.05
pH 24 hours post mortem	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Response in BO ($/pig)	**4.08**	**4.26**	**4.39**	**4.46**	**4.63**	**4.93**

Table 7. Economic response in each breeding objective trait

Trait name	Base	Index L1	Index A1	Index A2	Index A3	Index A4
Breeding objective traits						
Average daily gain (g/day)	0.71	0.76	0.72	0.72	0.60	0.54
Backfat (mm)	0.53	0.50	0.49	0.49	0.47	0.45
Feed conversion ratio (kg/kg)	1.48	1.52	1.54	1.55	1.59	2.12
Belly weight (kg)	-0.10	-0.11	-0.12	-0.12	-0.13	-0.13
Loin weight (kg)	0.83	0.96	1.13	1.12	1.11	1.12
Belly fat percentage (%)	0.98	0.99	0.97	1.03	1.27	1.25
Drip loss percentage (%)	-0.35	-0.36	-0.34	-0.33	-0.28	-0.42
Response in BO ($/pig)	**4.08**	**4.26**	**4.39**	**4.46**	**4.63**	**4.93**

Recommendations

The breeding objective should be as complete and accurate as possible. However, little information was available about economic importance of primal cut weights and belly fat percentage. Economic weights for these traits differ between markets and breeders should develop breeding objectives relevant for their medium to long term production and market systems.

As a first priority, breeders should use muscle depth on the live animal for selection of higher weights in the more valuable primal cuts. Muscle depth has been investigated in a number of studies in Australia. In each study, muscle depth measures were based on real time ultrasound equipment which provided images of the scan to an experienced and validated operator.

The economic importance for belly composition depends on market requirements. If belly composition is an economically important trait in the breeding objective, then a measure for belly composition on the live animal should be used So far, no measure of belly composition has been investigated in a genetic analysis in Australia.

If it is possible to obtain information from the abattoir or boning room, then the focus should be on primal cut weights rather than fat and muscle depth measures that can be recorded on the live animal.

There was little value in recording length of the animal or the carcase for selection of primal cut weights in the current study due to low genetic correlations with primal cut weights. However, it may be possible to obtain higher genetic correlations between length and loin weight for alternative measures of length and loin weight as was available from the French data.

The majority of response in the breeding objective was due to high genetic gain in feed conversion ratio. Juvenile IGF1 is a selection criterion for feed conversion ratio available to Australian breeders. Genetic correlations between juvenile IGF1 and primal cut weights are currently not available.

Selection for efficient lean meat growth and conformation leads to inferior meat quality and might have undesirable effects on survival and disease resistance. Survival and disease resistance were ignored in the current index calculations since their genetic relationships with performance are poorly understood.

Undesired effects of selection for increased leanness, carcase conformation and feed efficiency might be overcome by shifting the emphasis away from improvement of the mean towards reduction in variation. Variation *per se* has an economic value (Hermesch, 2005) and should be considered in pig breeding programs.

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