final report

Project code: B.SBP.0111

Prepared by: Dr Malcolm McPhee, Dr Brad Walmsley, Dr Hutton Oddy, Dr Todd Andrews and Dr Boyd Gudex

NSW Department of Primary Industries

Date published: 12 February 2016

ISBN: 9781741919868

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Enhancing BeefSpecs systems for improving market compliance of pasturefed beef in southern Australia

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This project has enhanced the BeefSpecs tools to assist pasture fed beef producers improve compliance rates and 'meet market specifications' before slaughter. The new enhancements include a new input for muscle score and the prediction of denuded lean meat yield (%), MSA marbling score and MSA index of live animals. The development of the BeefSpecs drafting tool initiated during the former Beef CRC has now been developed for the web and is available on the NSW DPI web site (http://beefspecs.agriculture.nsw.gov.au/drafting/). A prototype pasture-fed BeefSpecs optimisation tool to optimise profitability of beef herds has been developed that can be customized, as required, to large pastoral companies. Growth trait EBVs were evaluated and confirmed that the inclusion of EBVs provides value in terms of increasing predictive accuracy. A BeefSpecs prototype economic calculator based off a generic grid has been developed and predicts total value of consignment. Workshop material has been developed and four pilot workshops are in the pipe line with a focus on the management changes that are required to assist producers meet market specifications.

Executive summary

The project is driven by the need and opportunity to link decisions affecting production along the supply chain as well as the final product (carcass traits). This affects product compliance at progressive stages and facilitates value based trading/payment at any point. BeefSpecs has already emerged as a vital part of a system integrating performance, marketing and carcass feedback data by virtue of its prediction capabilities.

Rates of compliance to market specifications are an industry issue. Up to 28% of short-fed feedlot cattle do not conform to carcase weight specifications resulting in lost returns of $5.50/head and 16% miss P8 fat specifications reducing returns by $17.70/head. An MLA funded study of non-compliance in pasture-fed cattle conducted by NSW DPI (B.SBP.0108) found non-compliance of pasture fed cattle can vary from 15% to 88% for HSCW and 0.7% to 58% for P8 fat.

Significant potential exists to assist producers to improve compliance rates in pasture-fed cattle and improve net farm income. A tool to provide predictions on live cattle of yield, marbling grade, and MSA index would assist the industry move forward to a value based trading system.

The objectives of this project were:

1. Incorporate Retail Beef Yield (RBY), MSA marbling grade and MSA ossification predictions in the BeefSpecs calculator;
2. BeefSpecs predictions linked quantitatively to the MSA index;
3. Develop a BeefSpecs optimisation tool for use in pasture-based systems (based on the current feedlot tool);
4. Test new additions to BeefSpecs using BIN data and other available data sources;
5. Develop linkages between visual imaging systems, BeefSpecs, and the livestock data link (LDL) database;
6. Further develop methods for including genetic information in the form of EBVs integrated into BeefSpecs predictions; and
7. Review existing training materials and produce new BeefSpecs training material.

In this study a serial slaughter was conducted on *Bos taurus* heifers (n = 49) and steers (n=78) using the low and high muscling herd established in 1992 at the Glen Innes Research Station. Live animal data including ultrasound scanning of P8 fat (mm) and intramuscular fat (%) were collected. The left side of an untrimmed carcase was boned out and primals were transported to the University of New England (UNE) Meat Science laboratory. Computer tomography (CT) scans were made on all primals (~2,540) to estimate total lean and fat in all carcases. Statistical analysis indicated differences exist between sex and muscle score categories.

BeefSpecs equations were modified to include muscle score and predict lean meat yield (%). Equations for intramuscular fat (%) and MSA marbling score were developed. An ossification equation (Adj R^2 = 0.54; SE = 14.23) using live animal data was developed for use in the MSA index prediction. All models were evaluated with independent *Bos taurus* data and ossification also evaluated with *Bos indicus* data. Results using the validation dataset 1 (data from MLA projects B.BSC.0339 and B.SBP.0108) indicated that muscle weight (n = 77), P8 fat (n=77), carcase weight (n = 77), bone weight (n = 77), MSA marbling score (USMB) (n = 77), and intramuscular

fat (%) (n = 40) were predicted within 15.7 kg, 4.1 mm, 20.1 kg, 4.1 kg, 65.7, and 1.2 %, respectively. Results from validation dataset 2 (Beef CRC 1 data) indicated that carcase weight (n = 594), P8 fat (n = 594), and intramuscular fat (%) (n =527) were predicted within 16.6 kg, 3.7 mm, and 1.4%, respectively. In the ossification study results from dataset 1 (n = 74), the 2007 NSW DPI muscle herd (n = 81), dataset 2 *Bos taurus* data (n = 1,304), and dataset 2 *Bos indicus* data (n = 959) indicated that ossification was predicted within 10.5, 11.3, 24.1, and 48.3 units, respectively.

This research project has revised the BeefSpecs tools to assist producers improve compliance rates and 'meet market specifications'. The new enhancements include a new input for muscle score and the prediction of denuded lean meat yield (%), MSA marbling score and MSA index of live animals. The development of the BeefSpecs drafting tool initiated during the former Beef CRC has now been developed for the web and is available on the NSW DPI web site (http://beefspecs.agriculture.nsw.gov.au/drafting/). A prototype pasture-fed BeefSpecs optimisation tool has been developed that can be customized, as required, to large pastoral companies to optimise profitability of a herd. Growth trait EBVs were evaluated and confirmed that the inclusion of EBVs provides value in terms of increasing predictive accuracy but further investigations into how carcase fat EBVs influence fat partitioning and the inclusion of IMF EBVs using the BIN data (cohort 3 of SBMP) from the Angus society are required. A BeefSpecs prototype economic calculator based off a generic grid has been developed and predicts total value of a consignment. Workshop material has been developed and four pilot workshops are in the pipe line with a focus on 'meeting market specifications'. All pilot workshops are engaging with industry and working with carcase feedback from abattoirs.

Conclusions:

- Enhanced BeefSpecs includes predictions of:
    - Lean Meat Yield (%)
    - MSA marbling score
    - MSA index
- BeefSpecs drafting tool (*ver* 1.0.0) is available on the NSW DPI web site.
- Pasture-fed optimisation tool has been developed.
- Five pilot workshops are being conducted using the BeefSpecs drafting tool

Recommendations

Future work should focus on the following key areas of research.

- Develop a fast, effective and cheap real time method to predict P8 fat and muscle score from live animals.
- A compositional study on *Bos indicus*, *Bos indicus* crosses and European cattle.
- A focus meeting with key MLA staff and both the feedlot and large pastoral companies to discuss how the BeefSpecs Feedlot and Pasture-fed optimisation tools could be used.
- Collection of data to expand/strengthen the intramuscular fat (%) and MSA marbling score, and EBV relationships within BeefSpecs.
- A workshop with the LDL team to discuss the evaluation of feedback from the 4 pilot workshops to pave a way forward for developing a conversation between producers and processors.

Table of Contents

Background....7
Project objectives....9
1 Incorporate Retail Beef Yield (RBY), MSA marbling grade and MSA ossification predictions in the BeefSpecs calculator....10
1.1 Prediction of lean meat yield and MSA marbling....10
1.1.1 Introduction....10
1.1.2 Materials and methods....10
1.1.2.1 Study animals....11
1.1.2.2 Model refinement/development data....12
1.1.2.3 Model evaluation data sets....13
1.1.2.4 Statistical analysis for model development and evaluation of serial study....13
1.1.2.5 Statistical evaluation....14
1.1.3 Results and discussion....14
1.1.3.1 Serial slaughter study....14
1.1.3.2 BeefSpecs calculator equations....15
1.1.3.3 Model evaluation of refined and new equations....18
Beef CRC data (dataset 2)....24
1.1.4 Conclusion....28
1.2 Prediction of Ossification....29
1.2.1 Introduction....29
1.2.2 Materials and methods....29
1.2.3 Results and discussion....29
1.2.4 Conclusion....34
2 BeefSpecs predictions linked quantitatively to the MSA index....35
3 Further develop methods for including genetic information in the form of EBVs integrated into BeefSpecs predictions....38
3.1 Introduction....38
3.2 Materials and methods....39
3.2.1 Incorporation of Rib and P8 Fat EBVs:....39
3.3 Results and discussion....44
3.3.1 Incorporation of Growth Trait EBVs:....46
3.3.2 Incorporation of IMF EBVs:....56
3.4 Conclusions....56
4 Test new additions to BeefSpecs using BIN data and other available data sources....57
5 Develop a BeefSpecs optimisation tool for use in pasture-fed systems (based on the current feedlot tool)....57
5.1 Introduction....57
5.2 Discussion....57
5.3 Conclusion....61
6. Develop linkages between visual imaging systems, BeefSpecs, and the livestock data link (LDL) database....61
6.1 Linking BeefSpecs with visual imaging systems....62
6.2 Development of a BeefSpecs generic grid to link with LDL....62
6.3 Conclusions....63
7 Review existing training material and produce new BeefSpecs training material....63

8 General discussion 65
9 Achieved objectives. 66
10 Conclusion and recommendations. 67
11 Acknowledgements 68
12 References 69
13 Appendix 1. On-farm data, carcase traits, preliminary statistics and summary of dataset1 71
14 Appendix 2. BeefSpecs Drafting Tool 88
15 Appendix 3. BeefSpecs Workshop 95
16 Appendix 4. BeefSpecs Drafting Tool 104

1. Background

Rates of compliance to market specifications are an industry issue. Slack-Smith et al. (2009) demonstrated that 28% of short-fed feedlot cattle did not conform to carcase weight specifications resulting in lost returns of $5.50/head and 16% missed P8 fat specifications reducing returns by $17.70/head. More recently, results from an MLA funded study of non-compliance in pasture-fed cattle conducted by NSW DPI ("Assessment of compliance in pasture-fed cattle and evaluation of increasing accuracy of BeefSpecs inputs and impact on compliance rates" B.SBP.0108) found non-compliance of pasture fed cattle varied from 15% to 88% for HSCW and 0.7% to 58% for P8 fat. Therefore significant potential exists to improve compliance rates in cattle.

BeefSpecs has already emerged as a key element in efforts to improve compliance rates by virtue of its capabilities to predict carcase outcomes (P8 fat depth and carcase weight). Further development of a system that integrates real-time objective measurement of live animal traits (e.g., P8 fat, frame score, and muscle score) with BeefSpecs would further assist producers 'meet market specifications'. Creation of such capability would assist linking of information and decisions along the supply chain, facilitating product compliance and value-based trading/payment at any point.

This enhancing BeefSpecs project will increase BeefSpecs capabilities by including predictions of denuded lean meat yield, MSA marble score (USMB), MSA ossification, and a live animal prediction of MSA index. The enhanced BeefSpecs system has the capability to assess the costs and profitability of changing livestock management for improved compliance. Other desirable outcomes from the project include:

- a freely available web based version of the BeefSpecs drafting tool;
- a BeefSpecs pasture-based optimisation tool available for large pastoral companies;
- BeefSpecs drafting tool workshop material.

Table 1. provides a glossary of terms used throughout this report.

Table 1. Glossary of terms

Term	Meaning	Units
ADG	Average daily gain	kg/day
BoneWt	Bone weight	kg
Cwt	Carcase weight	kg
CT	Computer tomography	
DressPC	Dressing percentage	%
EBW	Empty body weight	kg
EBFW	Carcase empty-body fat weight	kg
EBFFW	Empty body fat-free mass	kg
EMA	Eye muscle area	cm^2
FBW	Full body weight	kg
FFM	Fat-free mass	kg
FFMat	Fat free mass at maturity	kg
FFW	Fat-free weight	kg
FS	Frame score	
HSCW	Hot standard carcase weight	kg
IMF	Intramuscular fat	%
LDL	Livestock data link	
LMY	Lean meat yield (denuded)	kg
MS	Muscle score	
MSEP	Mean square error of prediction	
MusWt	Muscle weight	kg
P8 fat	Rump fat thickness	mm
PropEBW	Proportion of EBW	
RBY	Retail Beef Yield	%
SE	Standard error	
SBMP	Sire Bench Marking Program	
RMSE	Root mean square error	
USMB	MSA marbling score	

2. Project objectives

1. Incorporate Retail Beef Yield (RBY), MSA marbling grade and MSA ossification predictions in the BeefSpecs calculator;
2. BeefSpecs predictions linked quantitatively to the MSA index;
3. Develop a BeefSpecs optimisation tool for use in pasture-based systems (based on the current feedlot tool);
4. Test new additions to BeefSpecs using BIN data and other available data sources;
5. Develop linkages between visual imaging systems, BeefSpecs, and the livestock data link (LDL) database;
6. Further develop methods for including genetic information in the form of EBVs integrated into BeefSpecs predictions; and
7. Review existing training material and produce new BeefSpecs training material.

1 Incorporate Retail Beef Yield (RBY), MSA marbling grade and MSA ossification predictions in the BeefSpecs calculator

1.1 Prediction of lean meat yield and MSA marbling

1.1.1 Introduction

An outcome from a Southern Beef production meeting, held in Sydney with MLA staff and research scientists from NSW DPI and Murdoch University (WA), was the incorporation of lean meat yield (LMY; %) rather than retail beef yield (RBY) into the BeefSpecs calculator. Hence, lean meat yield is referred to throughout this report.

BeefSpecs predicts changes in rump fat thickness (P8 fat) using on-farm assessments of animal characteristics (e.g. frame size, liveweight, fatness, breed-type and sex) and production system parameters (e.g. growth rate, feed type, growth hormone implant status). To better account for conformational differences between cattle, this project has incorporated muscle score as an input parameter to BeefSpecs. A serial slaughter study was conducted to collect data that included muscle score for both steers and heifers and this data was used to refine existing models.

The model underpinning BeefSpecs (Walmsely et al, 2014) permits partitioning of fat and fat free components of empty body weight into carcase and non-carcase components. The new work conducted in this project required development of the relationships between whole body composition and composition of the body parts. Re-analysis of data from Haecker (1920) and Moulton (1922) demonstrated that the basic relationships between carcase and non-carcase fat and fat free (lean) mass were best described by simple linear part/whole equations. These equations are used to partition fat and fat free mass between non-carcase and carcase (separating bone and flesh) to derive a method to estimate total denuded yield. As part of this modelling a method was devised to estimate intramuscular fat content for re-inclusion in the estimate of yield (due to the difficulties of separating intramuscular fat). However, ongoing research is being conducted (Laurensen et al. unpublished) to develop a technique to estimate IMF from Computer Tomography (CT) images. Therefore, IMF% was estimated from existing data sets that reported chemical fat from the *M. longissumus lumborum* (Striploin) and consequently a relationship to estimate MSA marble score (USMB) was developed.

Using this approach a stand-alone estimator of lean mean yield (LMY) and IMF% has been developed. It is envisaged BeefSpecs will complement abattoir feedback, and directly empower on-farm management actions to maximize the chances of meeting market specifications. These predictions can be readily incorporated into existing BeefSpecs tools with little change to the user interfaces.

The modelling methodology used in this report is broken into 2 phases: (1) model development and (2) model evaluation. These 2 phases and the techniques used are described below in the materials and methods.

1.1.2 Materials and Methods

The following sections provide detail on: study animals, model refinement/development data, model evaluation datasets, statistical analysis, and statistical evaluation for the incorporation of LMY, MSA marbling grade and MSA ossification predictions into BeefSpecs.

1.1.2.1 Study animals

The NSW DPI muscling herd was established in 1992 from an unselected Hereford herd that was mated to high or low muscled Angus bulls (McKiernan and Robards, 1997). The female progeny from these mating's and subsequent generations were selected based on visual muscle score (**high** or **low**) for mating with Angus bulls selected from industry also using visual muscle score (Figures 1(a) to 1(c)). In ~1998 a third line (**MYO** - carrying one copy of the gene) was formed after the myostatin 821 del11 mutation was inadvertently introduced into the high muscling line. Further details concerning the establishment and management of the muscling herd are described by Walmsley and McKiernan (2011); Cafe et al. (2014). Several MLA projects have supported the low and high muscling herd to gain additional data (B.BFG.0049), inform maternal productivity modelling (B.SBP.0085) and more recently an Angus bin project has been established with the herd.

Figure 1(a). Low muscle line (D muscle score).

Figure 1(b). High muscle line (C+ muscle score)

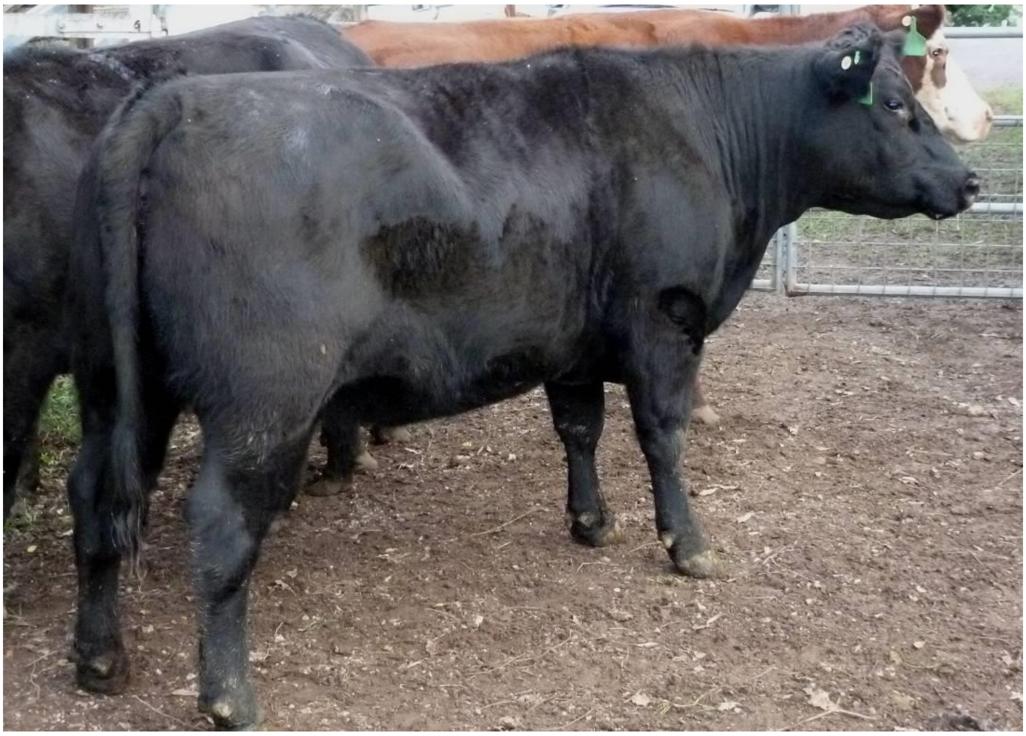


Figure 1(c). High muscle line heterozygous for myostatin (B muscle score)

1.1.2.2 Model refinement/development data.

Four serial slaughters on heifers and steers covering three pasture endpoints and one feedlot endpoint have been conducted (heifers: n= 12, 12, 13, and 12; steers: n= 20, 20, 19, and 19 across kills 1 to 4, respectively) to refine the existing BeefSpecs equations (Appendix 1). Table 1(a) provides detail on the ration provided to finish cattle at the UNE Tullimba feedlot facility for the final stage (kill 4).

Table 1(a). Ingredients of feedlot ration offered to finish steers

	Finished
Feedlot period, d	82
Ingredient, % as fed	
Barley	75
Cotton seed	10
Hay	6
Liquid Supplement	5
Water	4
Nutritional value	
DM, % as fed	86.5
NDF, % DM	25
ADF, % DM	12
Ash, % DM	5
CP, % DM	11.8
Predicted ME, MJ/kg DM	12.7

Additional data from cohort 2 of the Angus Australia Sire Bench Marking Program (SBMP) has been used to extend the range of intramuscular fat (IMF; %) and USMB to better estimate the relationship between these traits.

1.1.2.3 Model evaluation data sets

Dataset 1

Data generated from two serial slaughters of muscle line steers [grass (n=33) and grain finished (n=34)] from the 'proof of concept' project (MLA B.BSC.0339) has been used to evaluate the models.

Dataset 2

Data were collected from experiments conducted within the CRC for Cattle and Beef Quality (CRC 1). The data obtained was taken from the straight breeding program that ran from 1993 to 1997 (Robinson, 1995; Upton et al. 2001). The CRC's straightbreeding program involved 7 breeds from 34 commercial herds throughout eastern Australia. Participation in the straightbreeding program was by invitation. Breeds included in the program were from biologically diverse types of cattle from environmentally diverse properties of origin: *Bos tarus*, *Bos indicus* and *Bos tarus x Bos indicus* breeds. Cattle were both pasture and feedlot finished. Grain finished cattle were targeted for feedlot entry weights of 300, 400 (short fed), and 400kg (long fed) for 400, 520, and 640 kg slaughter weights, respectively. The following measurements: liveweight (kg); body structural measurements (body condition score and muscle score), temperament (flight speed and crush score), scanning of carcase attributes [P8 fat, rib fat (mm) and EMA (cm^2)] were recorded at intervals of 6 months using ultrasound equipment by trained assessors.

1.1.2.4 Statistical analysis for model development and evaluation of serial study.

Minitab and the R statistical package have been used to develop prediction models of MSA marbling score and ossification. Genstat has been used to examine the serial slaughter data across kills.

The relationships between live animal measurements of the subjective measurements of muscle score and hip height and carcase traits that included ultrasound measurements of P8 fat (mm), rib fat (mm), and eye muscle area (cm^2; EMA) were evaluated:

1) at weaning
2) repeatedly for all traits across the duration of the experiemnt: and
3) just prior to slaughter

1.1.2.5 Statistical evaluation.

The R statistical package was used to develop graphs of the observed versus predicted with a line of unity (y=x) and a graph of the residuals (observed – predicted) *versus* predicted. The observed *versus* predicted graphs with the line of unity do not have regression lines because the accuracy of prediction is around how close a data set can lie on the line of unity rather than the strength of a R^2 value (Tedeschi 2006). The statistical techniques and the reasoning behind employing these techniques in this study are found in Bibby and Toutenburg (1977) and articulated by Tedeschi (2006). In brief the statistics presented include summary statistics of mean values of observed and predicted along with a mean bias. The b coefficient and correlation of a linear regression line are reported but do not indicate the accuracy of prediction. The reasoning behind this is reported by Tedeschi (2006) and highlighted below. A mean square error of prediction (MSEP) and a root mean square error of prediction (RMSEP) are reported. The MSEP is then partitioned into 3 components (bias, slope, and random) as a percentage of MSEP. The bias follows on from the mean bias reported above and the slope component provides information if there is a problem with a deviation in the slope and lastly the random is what is effectively left over.

1.1.3 Results and Discussion

1.1.3.1 Serial slaughter study

A summary of four serial slaughters, with data collected on live animals (Appendix 1: Tables 1 to 7) and carcases (Appendix 1: Tables 8 to 18) are reported. The data in Tables 1 to 18 have been used to help refine and develop the models reported in this report. Figures 1 to 16 in Appendix 1 (A 1.) provide least squared means and SE across kills for sex and muscle-line differences.

Differences in muscle-line were found for numeric muscle score (A 1. Figure 2), lean muscle, % (A 1. Figure 6), rib fat (A 1. Figure 10), marbling score (A 1. Figure 12), and EMA (A 1. Figure 14).

1.1.3.2 BeefSpecs calculator equations

Revised equation

The BeefSpecs calculator (Walmsley et al 2014) was revised as follows:-

To include muscle score without affecting mean P8 fat estimated from Frame score (in the original BeefSpecs) Fat Free Mass at maturity (FFMat) was derived as

$$FFMat = ((15.8*FS+3*MS)+265)*Sex \qquad (1)$$

where FS = Frame Score, MS = Muscle score (numeric from 1-15) and Sex = 1 Heifer, 1.3 Steer

Development/inclusion of new equations

To calculate carcase specific parameters, the following changes were made:-
Dressing percentage was calculated as described by McKiernan et al. (2007).
Carcase weight (Cwt) was calculated as

$$Cwt = (0.95*FBW*DressPC)/100 \qquad (2)$$

where FBW = full body weight (saleyard liveweights after a 12 hour curfew, which is 15 to 18 hours from muster to weighing or empty body weight), DressPC = Dressing % from McKiernan et al. (2007) and 0.95 a linear adjustment to account for realistic shrink between paddock and lairage.

Bone weight (BoneWt) was calculated from Haecker (1920) with an adjustment based on observations in the test data set as:-

$$BoneWt = (-0.0002*Cwt^2+0.2093*Cwt+4.7021)/0.8062 \; (R^2=84\%) \qquad (3)$$

Flesh, and its fat and lean components, are calculated as:-

$$Flesh = Cwt - BoneWt \qquad (4)$$

$$FleshFat = PropEBW * EBFW - 0.2093*BoneWt-1.263 \qquad (5)$$

where PropEBW is the proportion of EBW in the carcase and EBFW is carcase empty-body fat weight (kg)

$$Flesh\ FFM = PropEBW *EBFFW -0.7007*BoneWt+1.2635 \qquad (6)$$

where EBFFW is empty-body fat-free weight (kg)

And Lean Meat Yield (LMY) is predicted as:

$$LeanMeatYield = ((FleshFFM+0.135*FleshFat)/Cwt)*100 \qquad (7)$$

where 0.135 is the proportion of carcase fat in the IMF pool [modelled using the *M. longissumus lumborum* muscle IMF% from the serial slaughter data (Kills 2 to 4); parameter adjustments were made to fit to unity].

From this a simple calculation is used to estimate IMF%:-

$$IMF\% = ((0.135*FleshFat)/(FleshFFM+0.135FleshFat))*100 \quad (8)$$

and USMB marble score was developed using both the muscle herd kills and the Angus Australia SBMP data:-

$$USMB = 213.7 + 38.59*IMF\% -0.629*IMF\%^2 \quad (R^2 = 54\%) \quad (9)$$

Figures 2 and 3 illustrate the relationships encompassed in equations 3 and 9, respectively.

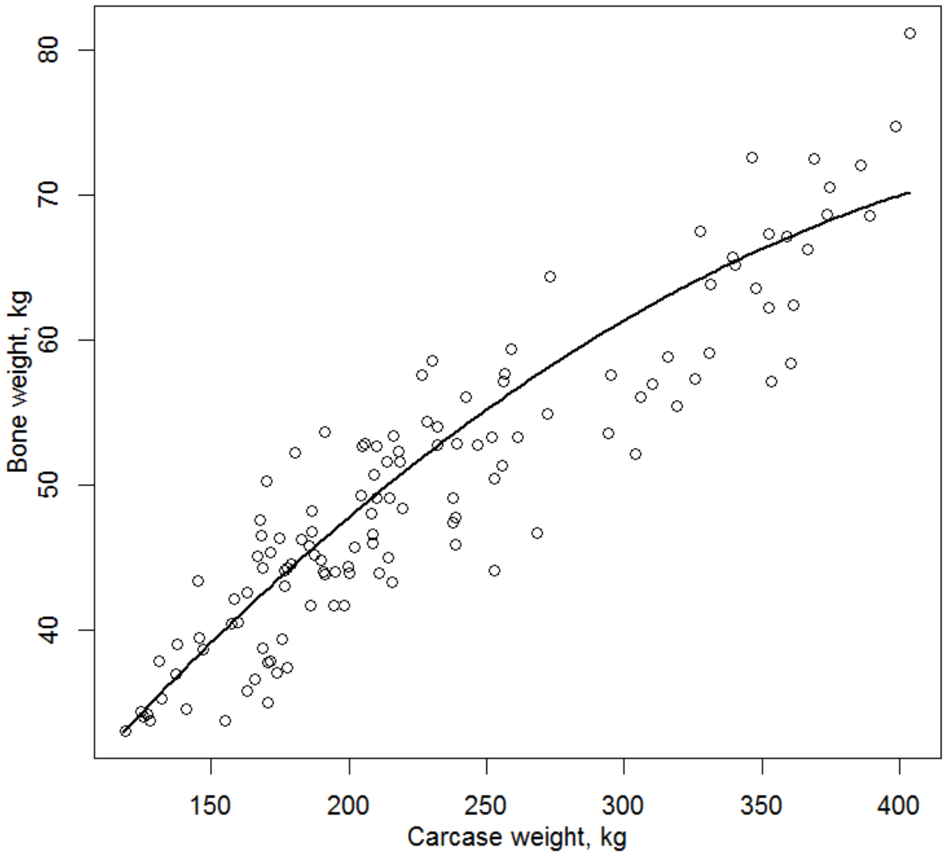


Figure 2. Relationship of bone weight (kg) and carcase weight (kg) and equation 3 (solid line)

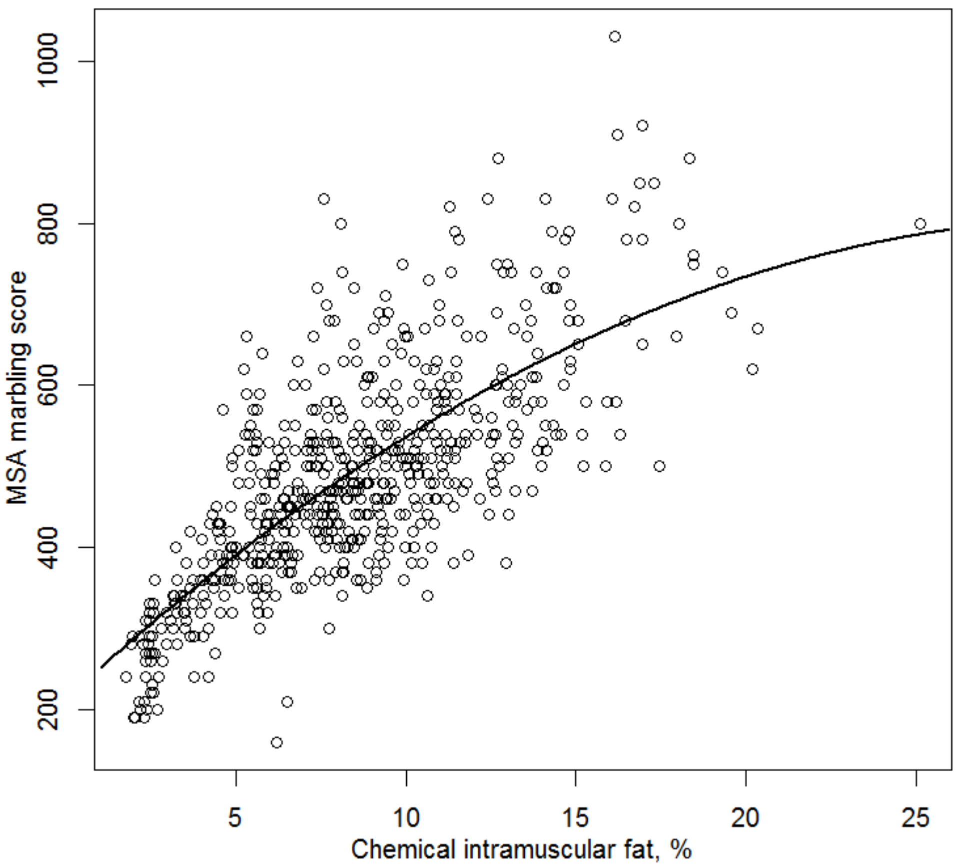


Figure 3. Relationship between MSA marbling score (USMB) and chemical intramuscular fat (%) and equation 9 (solid line)

1.1.3.3 Model evaluation of refined and new equations

Grass and grain data (dataset 1)

Figures 4 to 9 provide results for the observed *versus* predicted values and residuals (observed – predicted) covering a range of carcase traits: bone weight (kg), carcase weight (kg; Cwt), chemical intramuscular fat (IMF; %), muscle weight (kg) and P8 fat (mm).

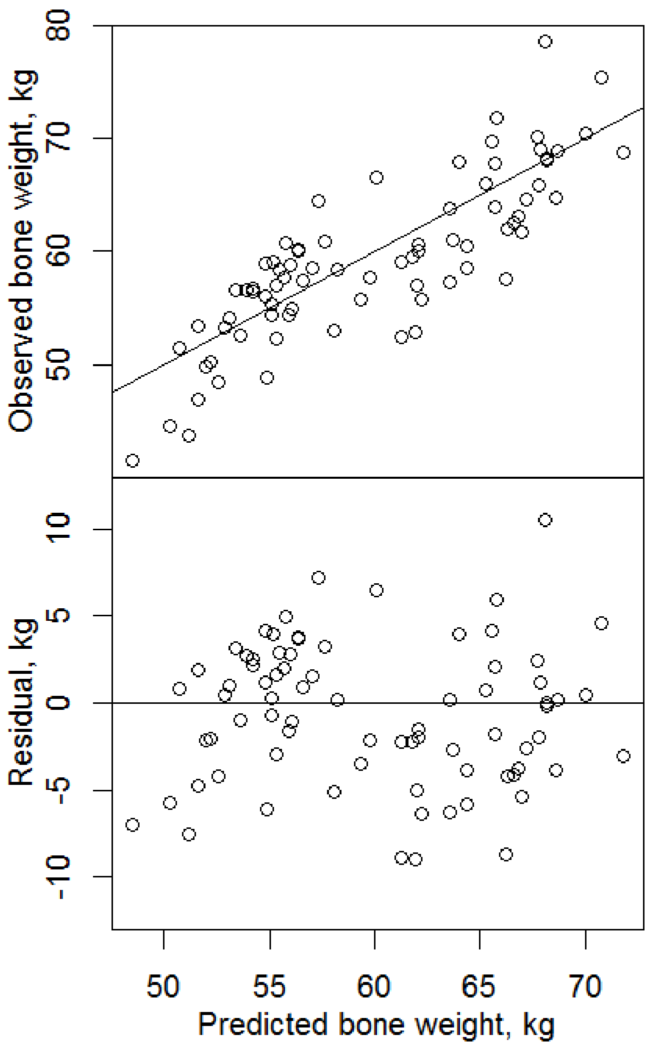


Figure 4. Relationship of bone weight (kg) between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

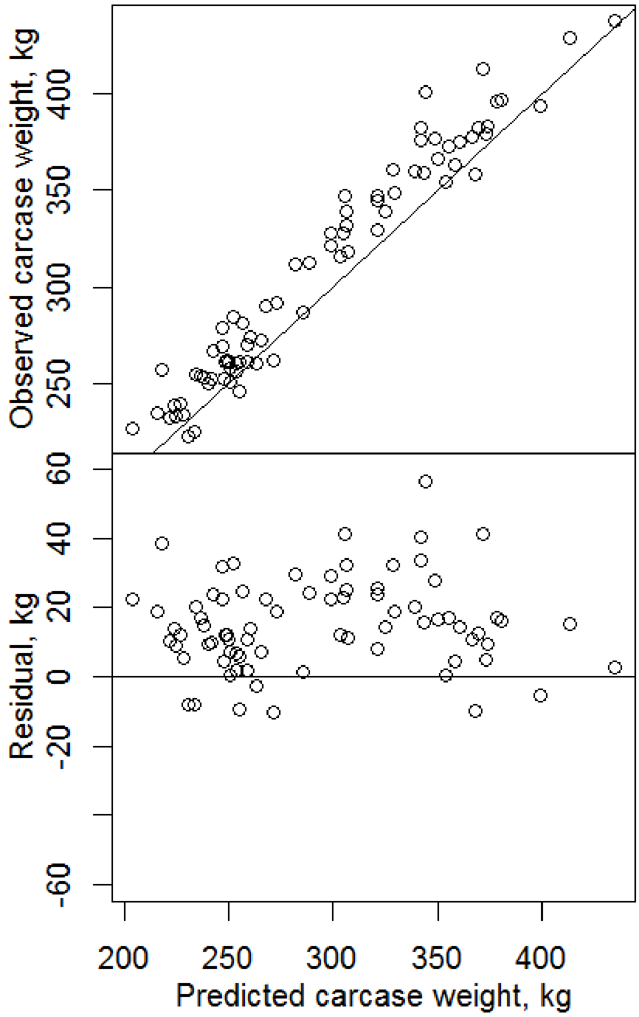


Figure 5. Relationship of carcase weight (kg) between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

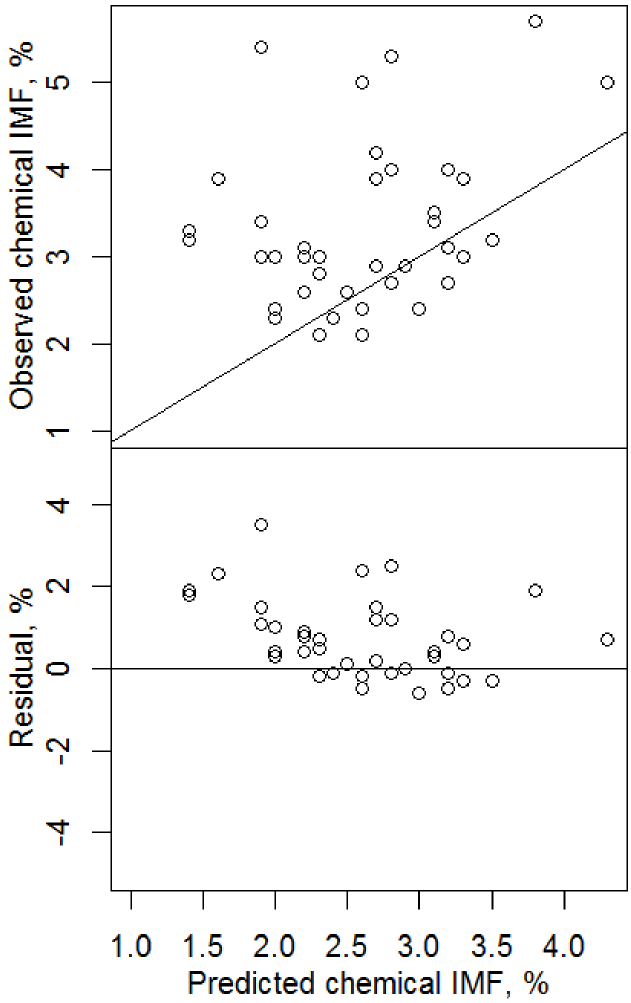


Figure 6. Relationship of intramuscular fat (%) between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

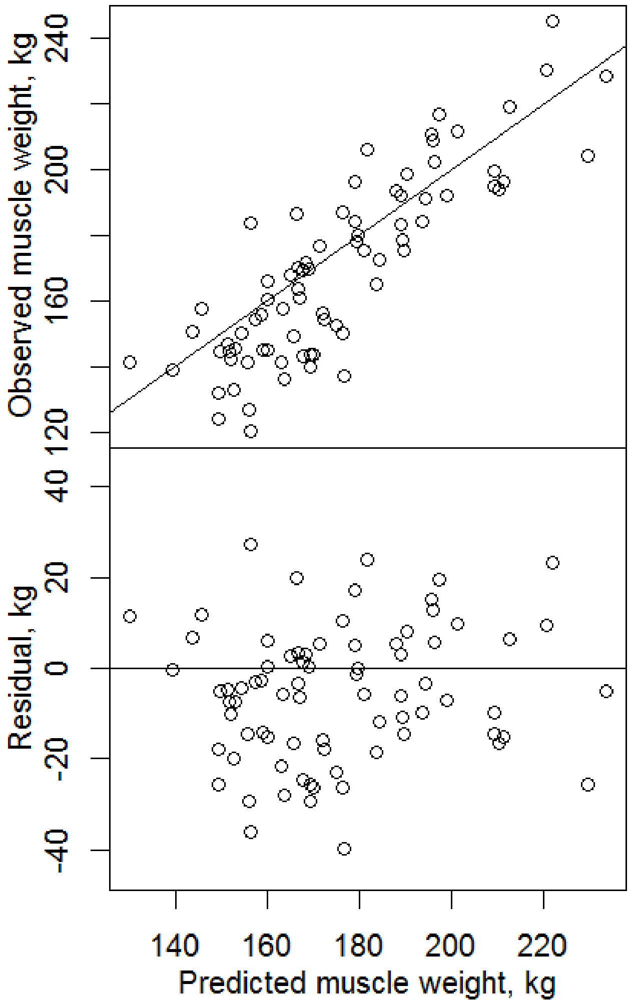


Figure 7. Relationship of muscle weight (kg) between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

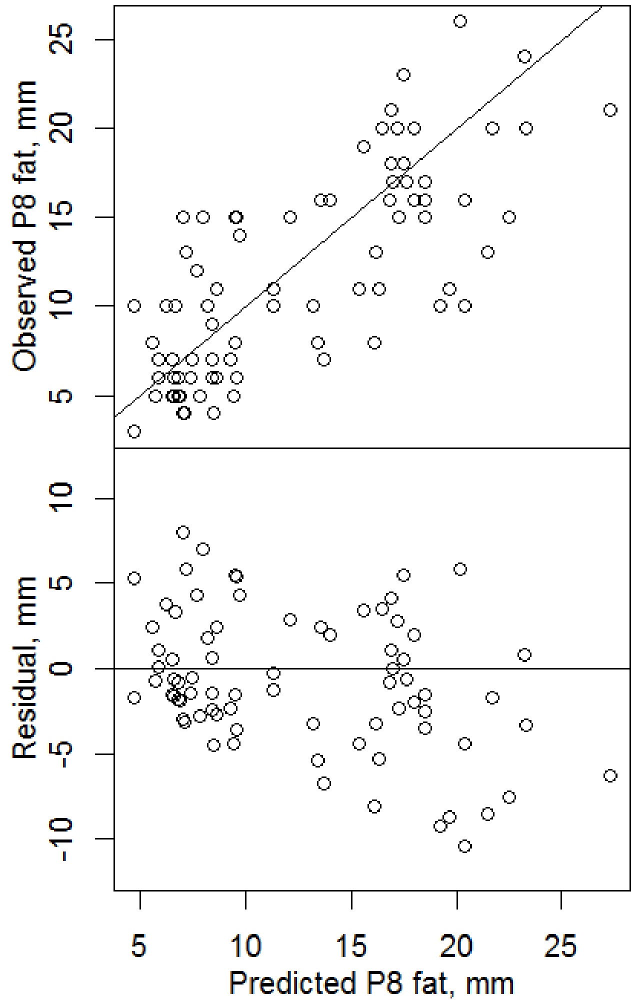


Figure 8. Relationship of P8 fat (mm) between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

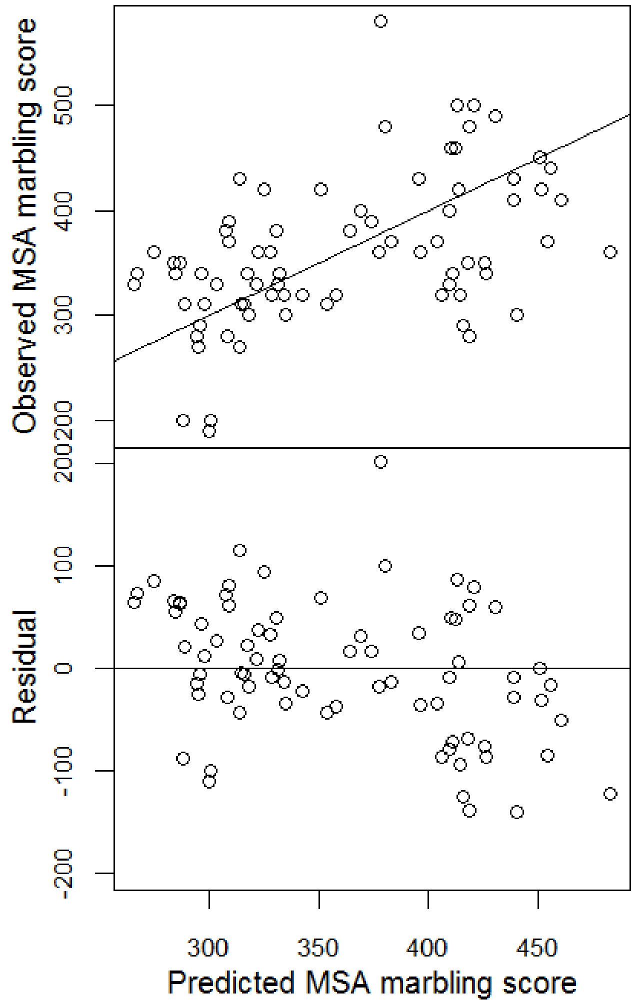


Figure 9. Relationship of MSA marbling score between observed and the residual (observed – predicted) *versus* predicted using dataset 1, solid line (y=x).

The model evaluation using dataset 1 is reported in Table 2. The techniques, as described above, are based on the Bibby and Toutenburg (1977) text that introduces the concept of partitioning the mean square error of prediction (MSEP) into the components of bias, slope and random. Bias indicates differences, slope provides a quantitative result of deviation from the perfect line of fit (i.e., y=x) and lastly, random is what is left over, hence where there is very little bias or slope the random component would be high The accuracy of prediction of muscle weight (wt), P8 fat , bone wt, and USMB marbling score was generally good, the root MSEP was 15.7, 4.1, 4.1, and 65.7, respectively. Bias in the mean differences for muscle wt occurred and a slope bias for P8 fat and USMB marble score were present. The carcase weight prediction was poor with a mean bias between observed and predicted different from zero (Table 2). The observed carcase weight was consistently greater than the predicted value because carcases, were untrimmed. The accuracy of predicting muscle weight (Table 2) indicated that the model could predict denuded LMY (%).

Table 2. Model evaluation using dataset 1 of muscle weight (MusWt; kg), P8 fat (mm), carcase weight (Cwt; kg), bone weight (kg), MSA marbling score (USMB), and intramuscular fat (IMF; %).

	MusWt (kg)	P8 Fat (mm)	Cwt (kg)	Bone Wt (kg)	USMB	IMF (%)
n	77	77	77	77	77	40[1]
mean obs	169.91	11.84	308.79	59.23	359.61	3.30
mean pred	175.46	12.58	293.58	59.91	359.80	2.60
Mean Bias	-5.55	-0.74	15.21	-0.67	-0.19	0.70
b coefficient	1.08	0.74	1.02	0.98	0.58	0.45
correlation, r	0.85	0.75	0.97	0.83	0.48	0.31
MSEP[2]	245.97	16.62	402.27	16.51	4321.80	1.38
Root.MSEP	15.68	4.08	20.06	4.06	65.74	1.17
Bias	12.53	3.28	57.49	2.72	0.00	35.67
Slope	1.32	12.76	0.39	0.09	13.85	8.66
Random	86.15	83.97	42.12	97.18	86.15	55.67
t-test p-value	0.00	0.11	0.00	0.15	0.98	0.00
t-test conf. int. 1	-8.90	-1.65	12.22	-1.59	-15.20	0.40
t-test conf. int. 2	-2.20	0.18	18.20	0.25	14.83	1.01

[1]Data lost on 1 slaughter (n=37)
[2]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

Further data is required to extend the range of IMF% values because the range of values reported in Figure 6 was limited (only between 1.5% and 4%). The Beef CRC has a large number of limited measurements; few have accurate measures of frame score, muscle score measurements. In addition, the measures of retail beef yield in the Beef CRC data were taken to a commercial end point (approximately 5mm trim). Moreover, the RBY for full bone outs ended early in the CRC and were replaced by alternate (less reliable) measures.

Beef CRC data (dataset 2)

Figures 10 to 12 provide results of the observed *versus* predicted and the residuals (observed – predicted) for a range of carcase traits; carcase weight (kg; Cwt), P8 fat (mm), and chemical intramuscular fat (IMF; %) using the Beef CRC data (dataset 2).

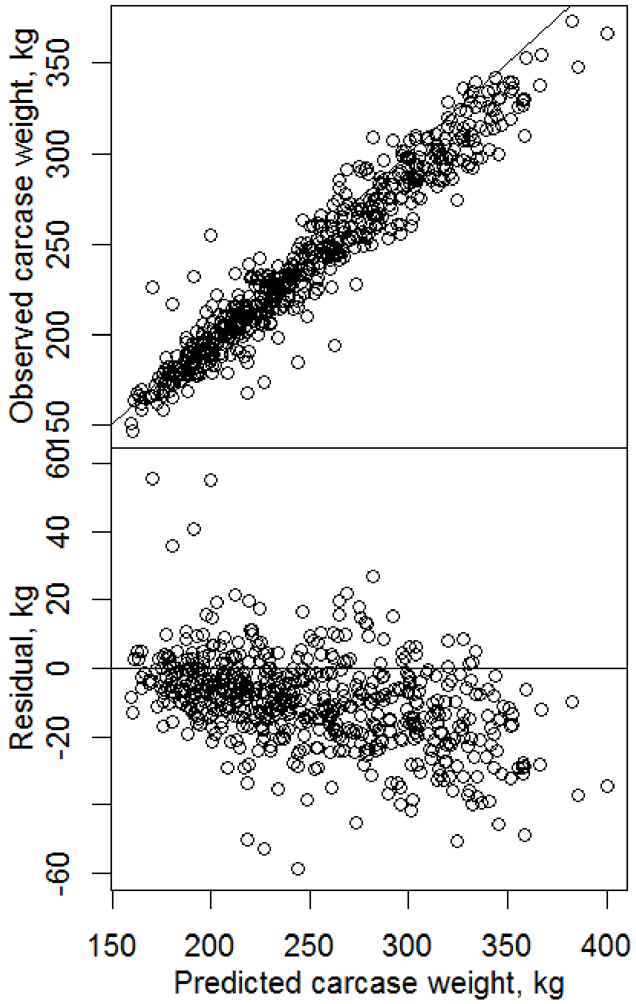


Figure 10. Relationship of carcase weight (kg) between observed and the residual (observed – predicted) *versus* predicted using dataset 2, solid line (y=x).

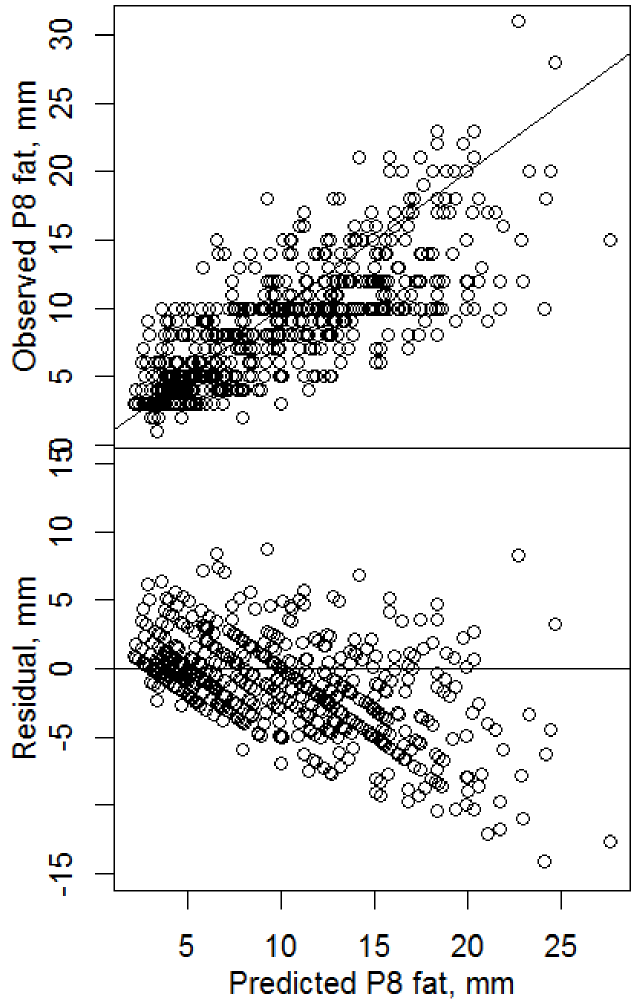


Figure 11. Relationship of P8 fat (mm) between observed and the residual (observed – predicted) *versus* predicted, solid line (y=x).

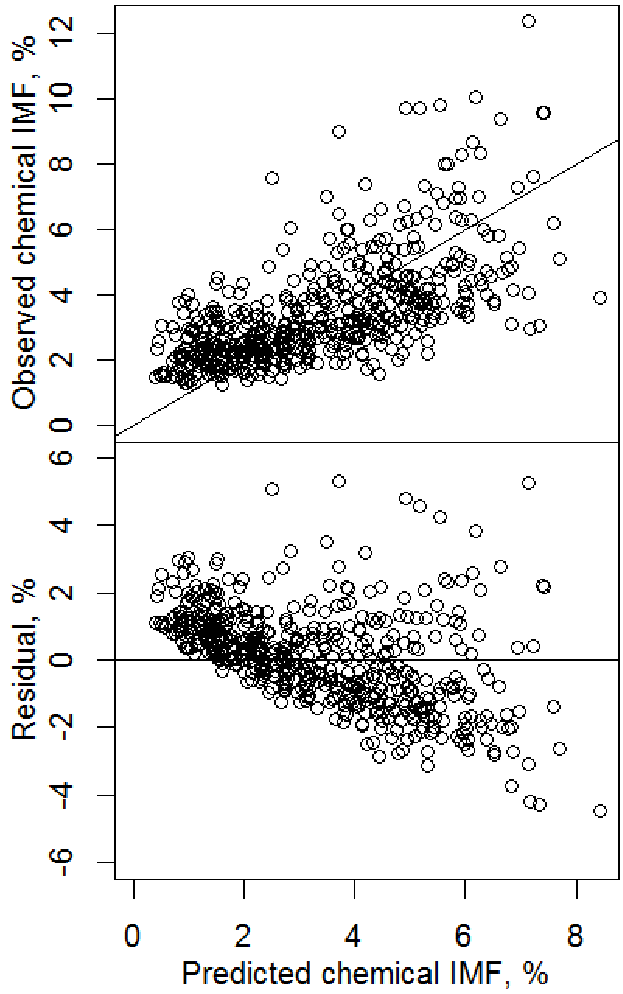


Figure 12. Relationship of chemical intramuscular fat (IMF; %) between observed and the residual (observed – predicted) *versus* predicted using dataset 2, (n = 527) calibrated to Soxhlet extraction Perry et al. (2001), solid line (y=x).

The model evaluation using dataset 2 is reported in Table 3. The techniques outlined by Bibby and Toutenburg (1977), described previously have been used. The accuracy of prediction for P8 fat and IMF % was generally good, the root MSEP was 3.7 mm and 1.4%, respectively. Bias in the mean differences for P8 fat occurred and a slope bias for IMF% was present. Carcase weight prediction was poor with a mean bias between observed and predicted different from zero (Table 3). The difference between the dataset 1 results (Table 2; Figure 5) and the CRC 1 data (Table 3; Figure 10) is that the dataset 1 did not have any slope bias (Figure 5) as compared to the CRC 1 data (Figure 10). The CRC 1 data slope bias may be attributed to the 3-5 mm variation in trim when compared to the carcase weight calculation (Equation 2; McKiernan et al., 2007).

Table 3. Model evaluation using CRC 1 data (dataset 2) of P8 fat (mm), carcase weight (Cwt; kg) and chemical intramuscular (IMF; %).

	P8 Fat (mm)	Cwt (kg)	IMF (%)
n	594	594	527
mean obs	8.89	240.39	3.44
mean pred	10.05	250.24	3.35
Mean Bias	-1.16	-9.85	0.09
b coefficient	0.64	0.89	0.60
correlation, r	0.75	0.97	0.64
MSEP[1]	13.70	276.84	2.08
Root.MSEP	3.70	16.64	1.44
Bias	9.76	35.04	0.39
Slope	25.79	10.86	23.55
Random	64.45	54.11	76.06
t-test p-value	0.00	0.00	0.15
t-test conf. int. 1	-1.44	-10.93	-0.03
t-test conf. int. 2	-0.87	-8.77	0.21

[1]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

1.1.4 Conclusion

The enhanced BeefSpecs model developed to predict total denuded lean meat yield (LMY; %) and IMF (%) was done so by building on the predictive capabilities of the previous model. Carcase weight and fatness are predicted within 20.1 kg and 4.1 mm and 16.6 kg and 3.7 mm for the dataset 1 and dataset 2, respectively. Intramuscular fat content was 1.2% and 1.4% for dataset 1 and dataset 2, respectively, and in turn USMB (MSA marbling score) were predicted within 66 units in dataset 1 (Table 2). For estimates from live animal assessment and growth, these are useful capabilities. They provide estimates of what to expect from post slaughter measurements. As such, the tool is useful in that it provides a framework for discussion with abattoirs concerning the data provided in carcase feedback. However, variation associated with estimates of growth rate and the associated variation around the live animal assessment of post slaughter measurements needs to be considered.

Finding suitable data sets to test the models (and further refine them beyond the data set used to calibrate them) is difficult. There is limited reliable data on muscle score in live animals where there are suitable carcase measurements. Although the Beef CRC data set has some of the data required, it does not have comprehensive measures of frame score (hip height) and muscle score. Retail beef yield data is limited where trim is documented and there is very little yield data with total denuded lean to compare predictions and observations. The use of CT scanning to obtain suitable data has been valuable, but the number of records and the range in yield covered is limited (125 records in the 2013 steer and heifer set, 77 in the 2012 steer data set). More data is required to fully evaluate the model over practical ranges of carcase weights, yield percentages and breeds.

Intramuscular fat content is reasonably well predicted (Tables 2 and 3). This prediction could be improved by including additional information on sire breeding values. There is currently limited data to independently test this. A working relationship with the Angus Australia has been established to obtain data that includes all necessary live animal and carcase measurements to complete this task.
The proportion of total carcase fat in the intramuscular fat pool used in the current model is 13.5%. It is not known if this varies with EBV within breed, or across breeds (although the evidence suggests that if such variation exists it is small). It is anticipated that through the relationship with Angus Australia sufficient data to determine if there is systematic variation in the proportion of carcase fat in the intramuscular pool can be determined. If the basis of such variation can be identified, it is anticipated the accuracy of estimating IMF will be increased.

1.2 Prediction of Ossification

1.2.1 Introduction

The enhancements of BeefSpecs include the prediction of beef eating quality via the Meat Standards Australia (MSA) model (Watson *et al.* 2008) and the newly developed MSA Index. Ossification is one input used by the MSA Index to predict meat quality and as such needs to be included in the BeefSpecs framework. To achieve this, an equation was developed that uses live animal inputs to predict ossification and would be accurate enough to be used effectively for predicting meat quality.

1.2.2 Materials and methods

Data (Appendix 1: Tables 17 and 18) from dataset 1 were used to develop this equation (37 heifers and 58 Angus steers). The animals were serially slaughtered in three groups at ages ranging from 422 to 650 days. Another group slaughtered as yearlings (average 364.4 days of age) were not analysed due to the absence of live animal records (ultrasound scan intramuscular fat) due to their younger age at slaughter. All animals were backgrounded on grass with the final slaughter group fed for 97 days at Tullimba prior to slaughter.

Live animal traits including P8 fat depth (mm), rib fat depth (mm), intramuscular fat (IMF, %) and eye muscle area (EMA, cm^3), measured by ultrasound scanning, live weight (kg) and muscle score were recorded between 3 and 5 times for each animal (animals killed at older ages had more opportunities for measurement). Upon slaughter, carcase weight (kg), EMA (cm^3), P8 fat depth (mm), rib fat depth (mm), ossification and MSA marbling score were recorded for each animal. Birth and recording dates were also collected so age at each recording (d) and average daily gain (kg/d) could be calculated.

1.2.3 Results and discussion

Linear regression analyses were conducted that fitted ossification as the dependant variable. Linear regressions were progressively developed, beginning with models that only contained age, sex and/or live/carcase weight (equations A to F in Table 4) and continued to a model that included either all live animal or carcase information sources (including all 2-way interactions). Information sources that were not significant ($P<0.05$) were removed to produce the prediction equations G and H in Table 4. The adjusted R^2 and standard error (SE) were used to assess model fit (Table 4).

Table 4: Ossification prediction equations from live animal or carcase traits; linear regression coefficients, adjusted R^2 (R^2_{adj}) and SE are presented.

Model	**Equation**	R^2_{adj}	**SE**
Live Animal			
A	$54.28 + 0.16 \times \text{Age}$	0.30	17.66
B	$27.84 + 41.1 \times \text{Sex} + 0.236 \times \text{Age} - 0.123 \times \text{Sex} \times \text{Age}$	0.66	12.38
C	$111.79 + 0.057 \times \text{Live Weight}$	0.08	20.23
D	$112.19 + 0.096 \times \text{Live Weight} - 30.78 \times \text{Sex}$	0.54	14.23
Carcase traits			
E	$113.42 + 0.109 \times \text{Cwt}$	0.08	22.06
F	$117.77 + 0.173 \times \text{Cwt} - 32.1 \times \text{Sex}$	0.53	15.97
G	$126.5 - 6.1 \times \text{Sex} + 2.35 \times \text{Carcase P8 Fat} - 1.3 \times \text{Sex} \times \text{Carcase P8 Fat}$	0.60	13.36
H	$106.1 + 16.6 \times \text{Sex} + 1.40 \times \text{Carcase P8 Fat} + 0.15 \times \text{Cwt} - 0.169 \times \text{Sex} \times \text{Cwt}$	0.61	14.31

[1] Sex (heifer = 0, steer = 1), Age = Animal Age in days, Weight = animal body weight in kilograms (kg), P8 Fat = rump fat thickness (mm)

Predictions using models B, G and H (Table 4) are demonstrated in Figures 13 to 15, respectively.

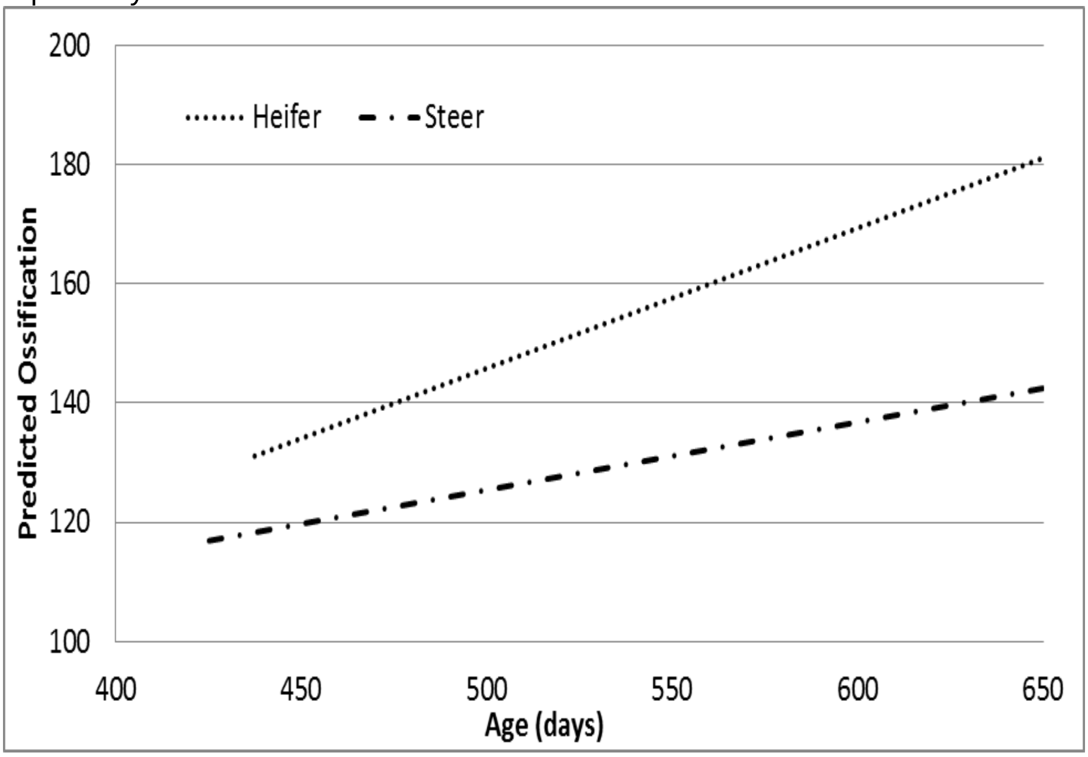


Figure 13. Predictions of ossification using Model B with age ranging from 436 to 649 days for heifers (….) and 422 to 650 days for steers(-.-.-.) .

Figure 14. Predictions of ossification using model G with carcase P8 fat ranging from 1 to 27 mm in heifers and 1 to 26 mm in steers.

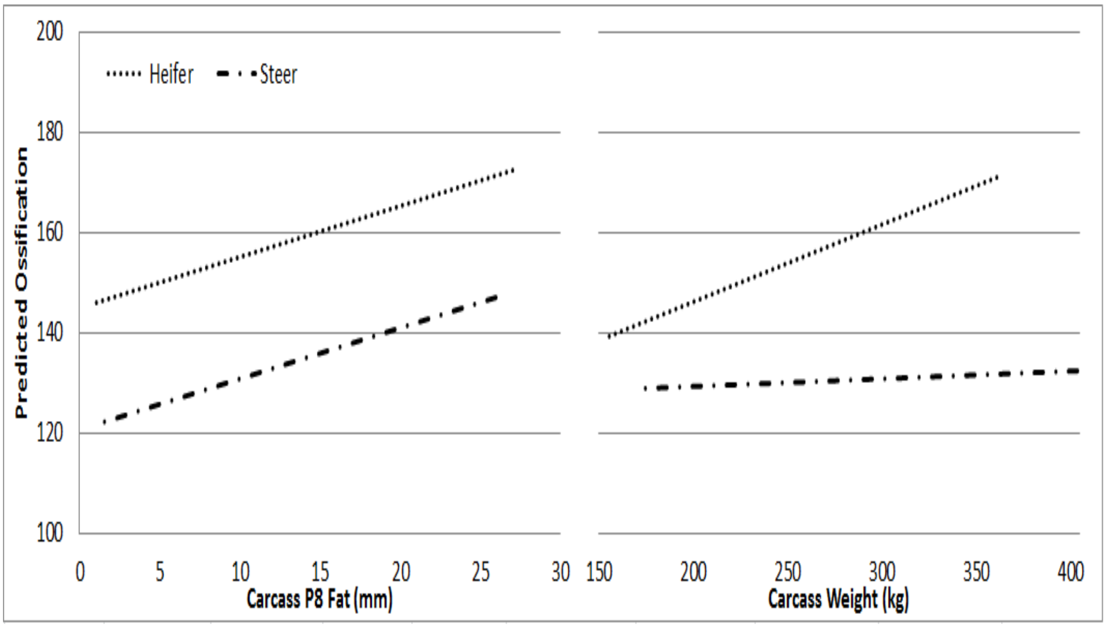


Figure 15. Predictions of ossification using model H with carcase P8 fat ranging from 1 to 27 mm and carcase weight from 155 to 361 kg in heifers, while P8 fat ranged from 1 to 26 mm and carcase weight ranged from 170 to 404 kg in steers.

The prediction equations with R^2_{adj} above 0.5 were challenged using three datasets [Tables 5(a) and (b)]. The models were evaluated using mean bias (average (observed ossification – predicted ossification)), mean square error of prediction (MSEP) and root-MSEP. The MSEP was decomposed into bias, slope, and random components as a proportion of MSEP to assess error structure following Bibby and Toutenburg (1977). The statistical significance of the mean differences between the observed and model-predicted ossification was evaluated using a paired *t*-test. The results from these evaluations are presented in Tables 6(a) and (b) and 7(a) and (b).

Table 5(a). Summary statistics for observed ossification in each of the evaluation datasets.

Evaluation Data	Year Born	n	sex	Min	Max	Avg	SD
Dataset 1	2011	74	Steers	100	150	134	10.8
NSW DPI muscle herd	2007	81	Steers	110	150	136	10.3
Dataset 2							
Bos tarus	1995-7	101	Heifers	140	250	180	26.0
		1,203	Steers	100	220	144	20.6
Bos indicus	1994-8	472	Heifers	120	390	189	51.1
		487	Steers	100	360	151	27.2

Table 5(b). Summary statistics for observed live weight in each of the evaluation datasets.

Evaluation Data	Year Born	n	sex	Min	Max	Avg	SD
Dataset 1	2011	74	Steers	391	736	538	87.3
NSW DPI muscle herd	2007	81	Steers	203	355	271	25.3
Dataset 2							
Bos tarus	1995-7	101	Heifers	342	614	484	74.2
		1,203	Steers	232	762	505	104.5
Bos indicus	1994-8	472	Heifers	172	678	441	82.1
		487	Steers	216	778	520	97.8

Table 6(a). Model evaluation of live and carcase trait models for ossification using data from the dataset 1.

	Live Traits		Carcase Traits		
Item	**B**	**D**	**F**	**G**	**H**
Mean observed	133.6	133.6	133.6	133.6	133.6
Mean predicted	137.8	133.2	136.0	133.7	134.2
mean bias	-4.2	0.4	-2.4	0.0	-0.6
P-value	0.000	0.731	0.058	0.989	0.664
MSEP[1]					
RMSEP	10.5	10.5	10.8	10.7	10.5
Bias, %	16.0	0.2	4.8	0.0	0.1
Slope, %	1.0	13.4	14.2	7.8	6.6
Random, %	83.0	86.5	80.9	92.2	93.3

[1]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

Table 6(b). Model evaluation of live and carcase trait models for ossification using data from the 2007 born NSW DPI muscle herd steers.

	Live Traits		Carcase Traits		
Item	**B**	**D**	**F**	**G**	**H**
Mean observed	136.3	136.3	136.3	136.3	136.3
Mean predicted	148.1	131.2	132.6	133.7	134.7
mean bias	-11.8	5.1	3.7	2.6	1.6
P-value	0.000	0.000	0.002	0.017	0.132
MSEP[1]					
RMSEP	15.6	11.3	10.9	9.9	9.8
Bias, %	57.6	20.1	11.8	6.9	2.8
Slope, %	0.3	2.2	4.0	0.0	0.9
Random, %	42.1	77.7	84.3	93.1	96.3

[1]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

Table 7(a). Model evaluation for ossification using data from *Bos taurus* recorded during Beef CRC 1.

	Live Traits		Carcase Traits		
Item	**B**	**D**	**F**	**G**	**H**
Mean observed	146.3	146.3	146.3	146.3	146.3
Mean predicted	143.3	132.2	135.3	132.4	133.0
mean bias	3.0	14.0	11.0	13.9	13.3
P-value	0.000	0.000	0.000	0.000	0.000
MSEP[1]					
RMSEP	19.6	24.1	22.2	24.7	24.4
Bias, %	2.3	34.0	24.5	31.5	29.9
Slope, %	11.9	0.0	0.2	1.5	0.1
Random, %	85.7	66.0	75.2	67.1	70.0

[1]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

Table 7(b). Model evaluation for ossification using data from *Bos indicus* cattle recorded during Beef CRC 1.

	Live Traits		Carcase Traits		
Item	**B**	**D**	**F**	**G**	**H**
Mean observed	169.5	169.5	169.5	169.5	169.5
Mean predicted	180.5	142.9	147.0	144.3	146.2
mean bias	-11.0	26.6	22.5	25.2	23.3
P-value	0.000	0.000	0.000	0.000	0.000
MSEP[1]					
RMSEP	37.5	48.3	46.0	47.5	46.0
Bias, %	8.6	30.4	24.0	28.1	25.6
Slope, %	8.9	1.8	2.4	1.4	1.3
Random, %	82.5	67.8	73.6	70.5	73.1

[1]MSEP = mean square prediction error; bias = MSEP decomposed into error attributable to overall bias of prediction; slope = MSEP decomposed into error attributable to deviation of the regression slope from unity; random = MSEP decomposed into error attributable to the random variation.

In the evaluation of models B and D that include live animal traits, model B predicted ossification more accurately than D in the two Beef CRC datasets, while D was superior in dataset 1 and the 2007 NSW DPI steer data. The evaluation of models F, G and H that include carcase traits revealed these models had similar predictive abilities. Models F, G and H were more accurate in dataset 1 and 2007 NSW DPI steer datasets, and models B and D were more accurate in the two BeefCRC datasets. All models predicted ossification more accurately in the *Bos taurus* than the *Bos indicus* data.

The results also show that variation in predictive accuracy exists between the four evaluation datasets (Tables 5 (a) and (b)). This could be due to the amount of variation between datasets in animal diversity and the age of the datasets. Three of the datasets used (the development dataset, dataset 1, and the 2007 NSW DPI steer datasets) represent different birth years from the NSW DPI muscling herd (2007, 2011 and 2012, respectively), whereas the remaining two datasets (BeefCRC I *taurus* and *indicus*) were older (1990's) and contained breeds other than those found in the development dataset. The presence of the Hereford, Murray Grey and Shorthorn breeds, in addition to the Angus breed in the dataset 2 could be a factor in reducing predictive accuracy given the NSW DPI muscling herd data is predominantly from the Angus breed. The Beef CRC *Bos indicus* dataset comprised Brahman and Santa Gertrudis animals.

1.2.4 Conclusion

Ossification is recorded commercially on the carcase on a scale between 100 and 590 in increments of ten units. The absolute mean bias for model D ranged from 0.2 to 14.0 in the three *Bos taurus* evaluation datasets which is acceptable when considering that ossification is recorded in ten unit increments. The absolute mean bias was larger in the *Bos indicus* evaluation (26.6).

Model D (Table 6 and Figure 16) was selected for inclusion in the BeefSpecs system on the basis of:

(1) accuracy, and

(2) having input variables that are routinely accurately recorded on farm (sex and live weight) thus allowing predictions directly from measured traits rather than from carcase traits predicted by the BeefSpecs system, and
(3) having the least amount of input variables. The selection of a model based on the number of inputs satisfies the principle of minimising the possible sources of recording error in the predictions.

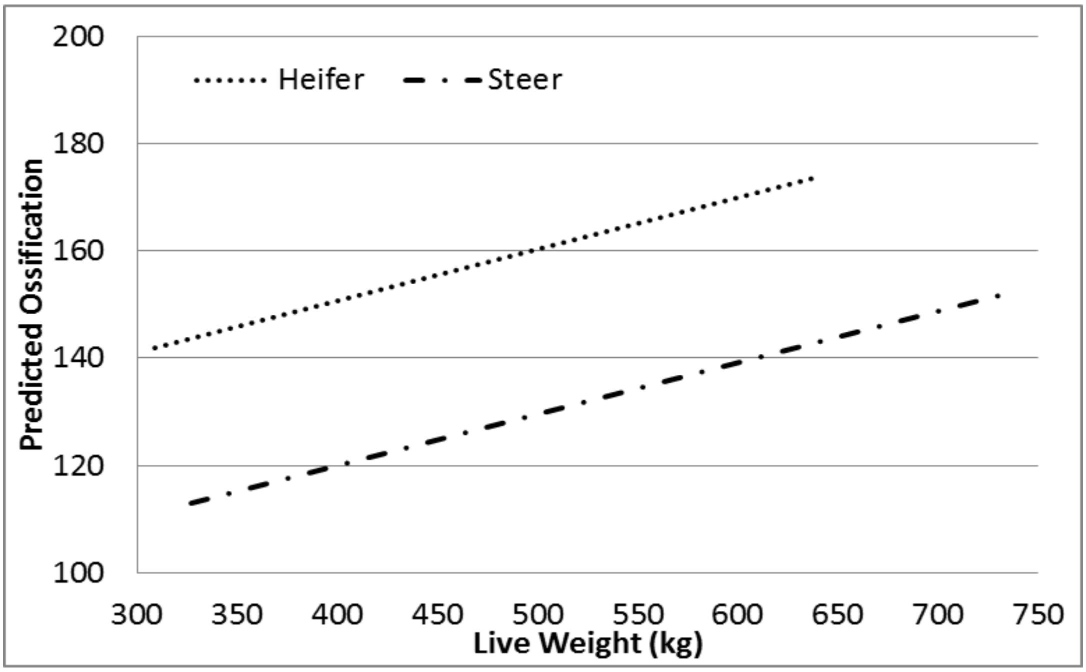


Figure 16. Predictions of Ossification using model D with live weight ranging from 309 to 640 kg in heifers and 327 to 740 kg in steers.

2 BeefSpecs predictions linked quantitatively to the MSA index

"The Meat Standards Australia (MSA) Index is a single number (30 to 80) and standard national measure of the predicted eating quality and potential merit of a carcase. It is independent of any processing inputs and is calculated using only attributes influenced by pre-slaughter production" (MLA tips & tools MSA 18). The MSA Index is a weighted average of the predicted MSA eating quality scores (MQ4) of 39 MSA cuts in a carcase. The BeefSpecs tools provide inputs to the MSA Index predicted from live animal measures.

The inputs used to predict the MSA Index include:

- Milk-fed vealer (Yes/No)
- Sold through saleyards (Yes/No)
- HGP use
- Sex
- Topical Breed Content (TBC)
- Hump height (for cattle greater than 0% TBC)
- Hot standard carcase weight (HSCW)
- Rib fat

- MSA marbling
- Ossification score

The enhanced BeefSpecs tools are able to provide seven of the inputs which are used to predict the MSA Index (see http://www.mymsa.com.au/msamobile/). Assumptions are made regarding the other three inputs that include: 1. Animals are assumed to not be milk-fed vealers; 2. Animals are assumed to not be sold through saleyards; and 3. No information is provided regarding hump height which is set to the minimum of 15cm in the MSA Index model. The percentage of *Bos indicus* content used as an input to BeefSpecs is used by the MSA index calculation.

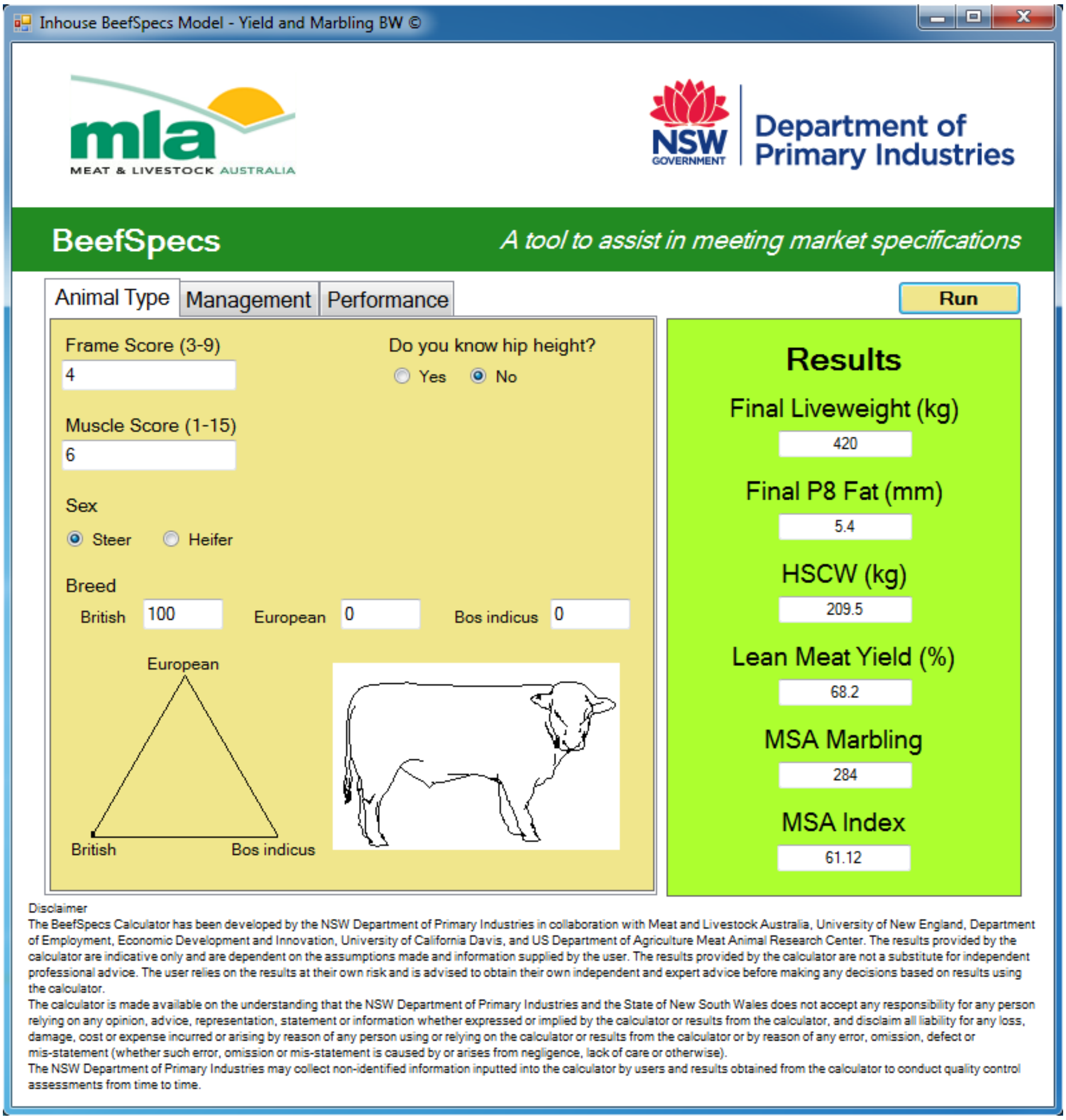


Figure 17. Layout of enhanced BeefSpecs Animal tab and the extra traits predicted by BeefSpecs are shown under the 'Results' heading.

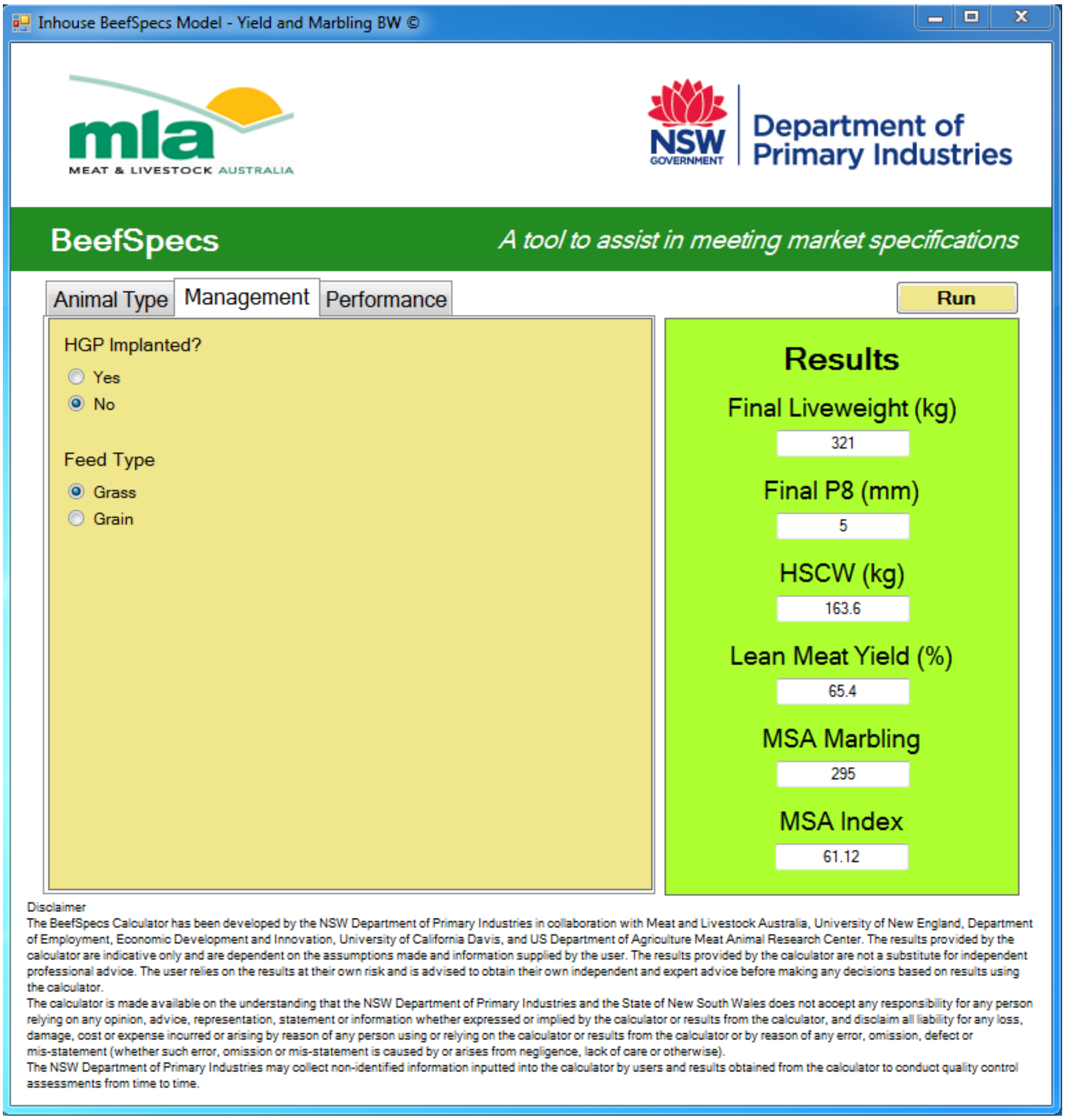


Figure 18. Layout of enhanced BeefSpecs Performance tab

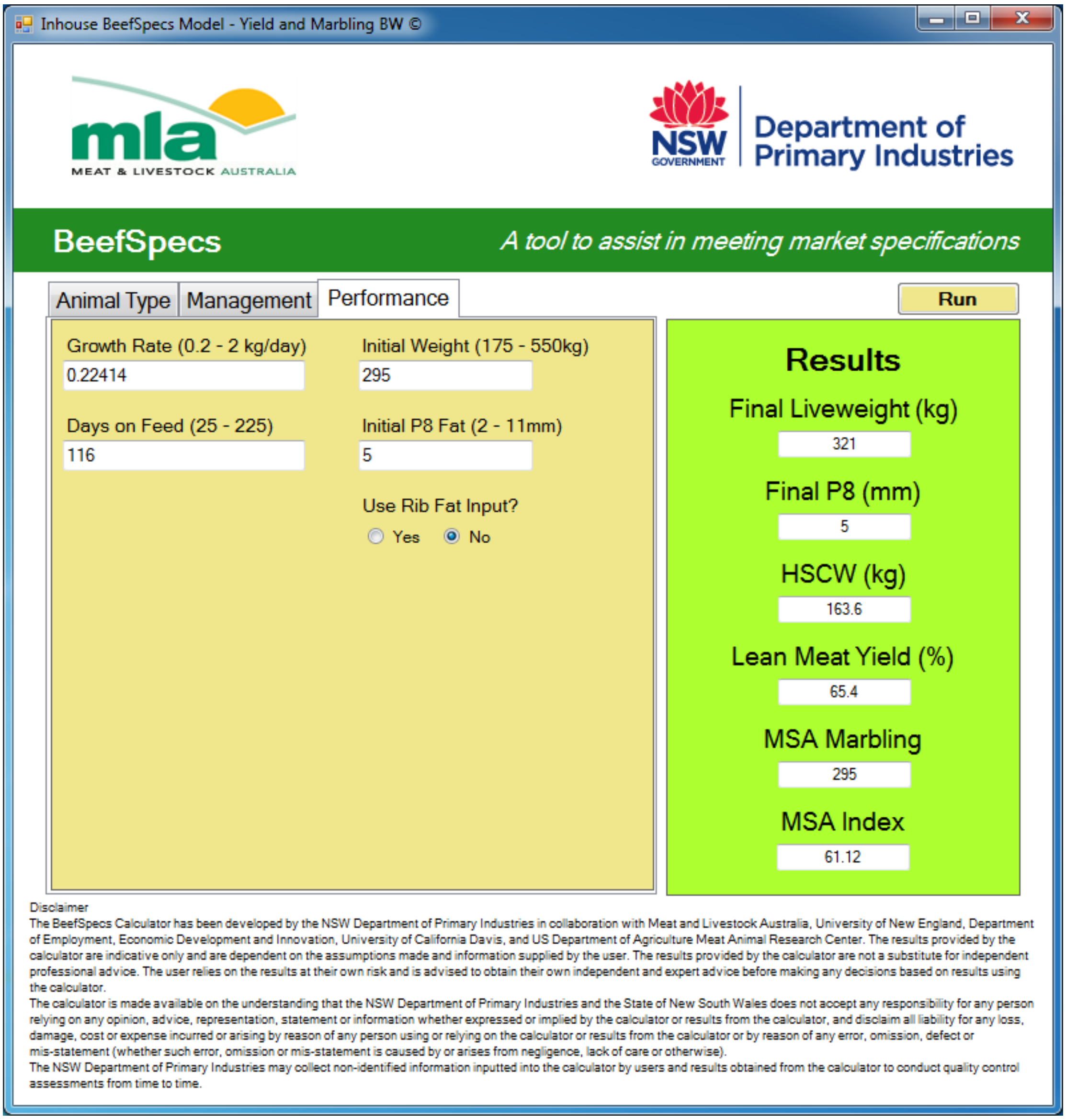


Figure 19. Layout of enhanced BeefSpecs Performance tab

3 Further develop methods for including genetic information in the form of EBVs integrated into BeefSpecs predictions

3.1 Introduction

Genetic merit and phenotypic performance are generally predicted independently. Achieving further gains in production efficiency requires genetic and non-genetic fields of expertise to work in an integrated manner to deliver new technologies. A preliminary evaluation of a method for incorporating genetic information into phenotypic prediction models has been undertaken (Walmsley *et al.* 2013). In the preliminary evaluation relationships between fat deposition parameters in a modified version of the Meat Animal Research Centre (MARC) model and Rib Fat EBVs from the Angus breed were explored. These relationships were incorporated into the

MARC model and subsequent predictions of P8 fat depth were compared to a scenario where Rib Fat EBVs were not used.

The current work has investigated the inclusion of additional genetic information in the form of EBVs that could potentially be integrated into BeefSpecs predictions. In particular, growth trait EBVs are explored and the way forward for further work on IMF EBVs is discussed. To place the study conducted within this project in context the incorporation of Rib and P8 Fat EBVs is briefly revisited.

3.2 Materials and methods

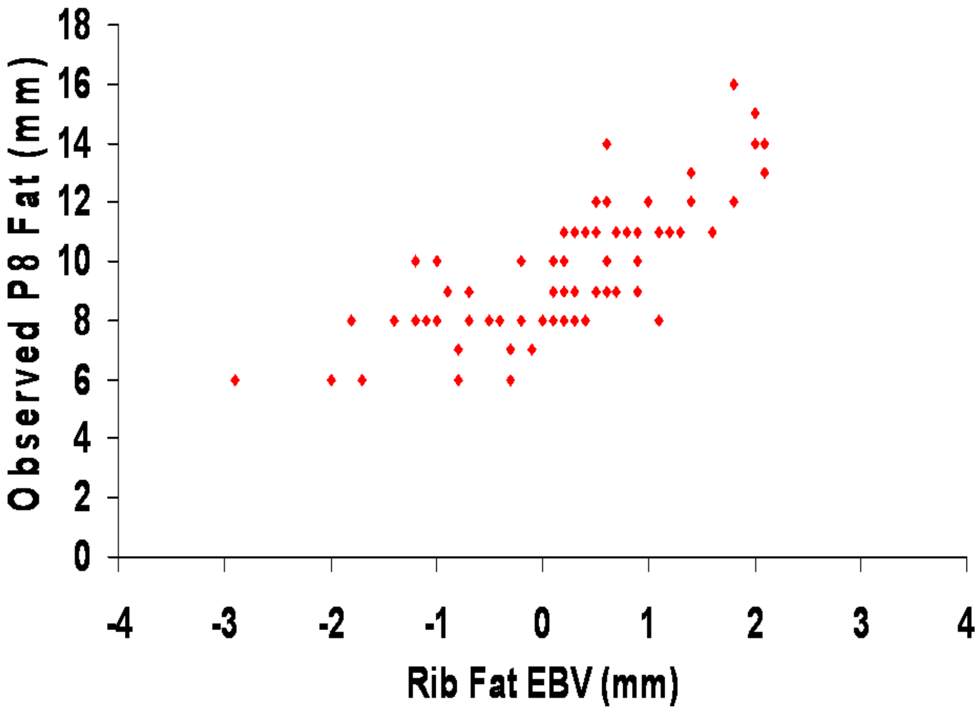
3.2.1 EBV study specific animals

The data used for this study came from the herd in dataset 1 (cohorts 2006/2007) and they were all steers. Cohort 2006 was backgrounded on pasture and cohort 2007 was feedlot finished for 100 days.

3.2.2 Incorporation of Rib and P8 Fat EBVs:

A single steer cohort from within the NSW DPI muscling herd (born 2006) was selected to test the inclusion of Rib and P8 (rump) fat EBVs in BeefSpecs. In this cohort, the correlation between observed P8 fat depth at slaughter and carcase rib fat EBV was found to be 0.75 while the correlation with rump fat EBV was 0.705. These relationships are depicted in Figure 20.

(a)



(b)

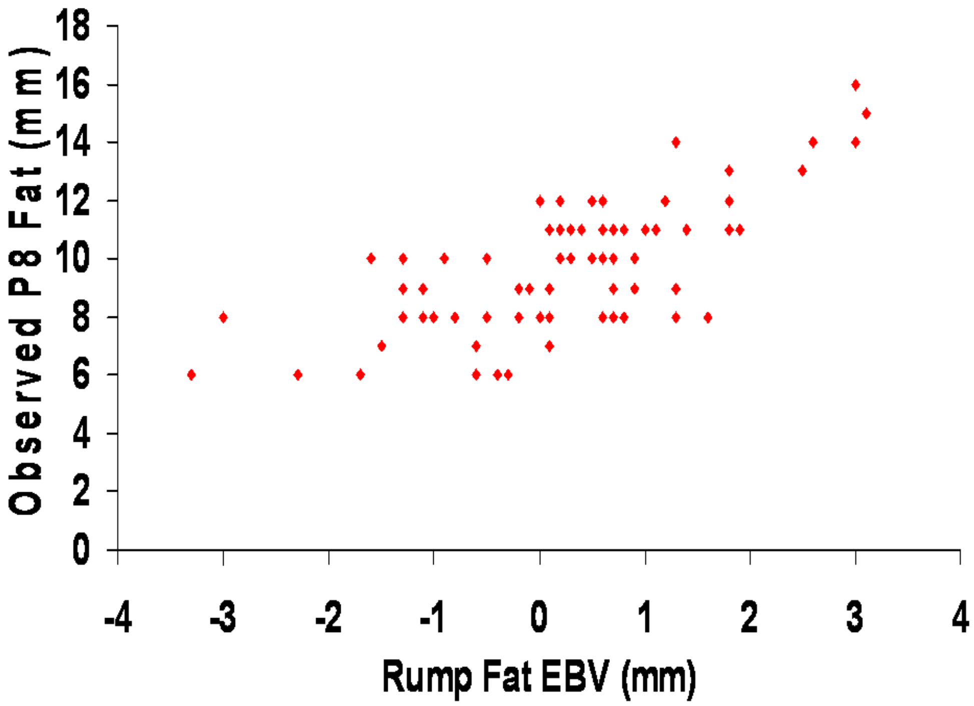


Figure 20. The relationships between observed (a) P8 fat depth at slaughter and rib fat EBVs and (b) P8 fat depth at slaughter and rump fat EBVs of a steer cohort from the NSW DPI muscling herd (born 2006).

The relationships demonstrated in Figures 20 (a) and (b) between carcase rib and rump fat EBVs and observed P8 fat depth suggest that these EBVs influence total animal body fat. Consequently, the relationships between the rib and rump fat EBVs, and the parameter regulating total body fat within the MARC model (THETA) were explored following the method outlined by Doeschl-Wilson et al. (2007) and Kinghorn (2012), using differential evolution (DEPrice and Storn, 1997). In this study, the correlations between THETA and the rib and rump fat EBVs were found to be -0.647 and -0.634, respectively. Linear regressions were used to describe the relationships between THETA and the rib and rump fat EBVs for incorporation into the BeefSpecs calculator. The regression of THETA on rib fat EBV (Equation 10) was:

$$\text{THETA} = 6.83 - (1.48 * \text{Rib EBV}) \qquad (R^2 = 0.41, \text{SE} = 1.72) \qquad (10)$$

The regression of THETA on rump fat EBV (Equation 10) was:

$$\text{THETA} = 6.84 - (1.14 * \text{Rump EBV}) \qquad (R^2 = 0.39, \text{SE} = 1.75) \qquad (11)$$

This evaluation was extended to also include the parameter (POBKF) that regulates the relationship between total body fat and rib fat depth (mm) within the MARC model (Walmsley *et al*. 2013). Results from these studies suggested further exploration of these relationships was required. Therefore, the study presented by Walmsley *et al.* (2013) was repeated with DE constrained to give greater consideration to parameter values which were closer to the default parameter values: 6.2 for THETA and 0.0025 for POBKF. Once again linear regressions were used to describe the relationships between model parameters (THETA and POBKF) and the rib and rump fat EBVs for incorporation into the BeefSpecs calculator.

The regression of THETA on rib fat EBV (Equation 12) when constraints were applied in DE was:

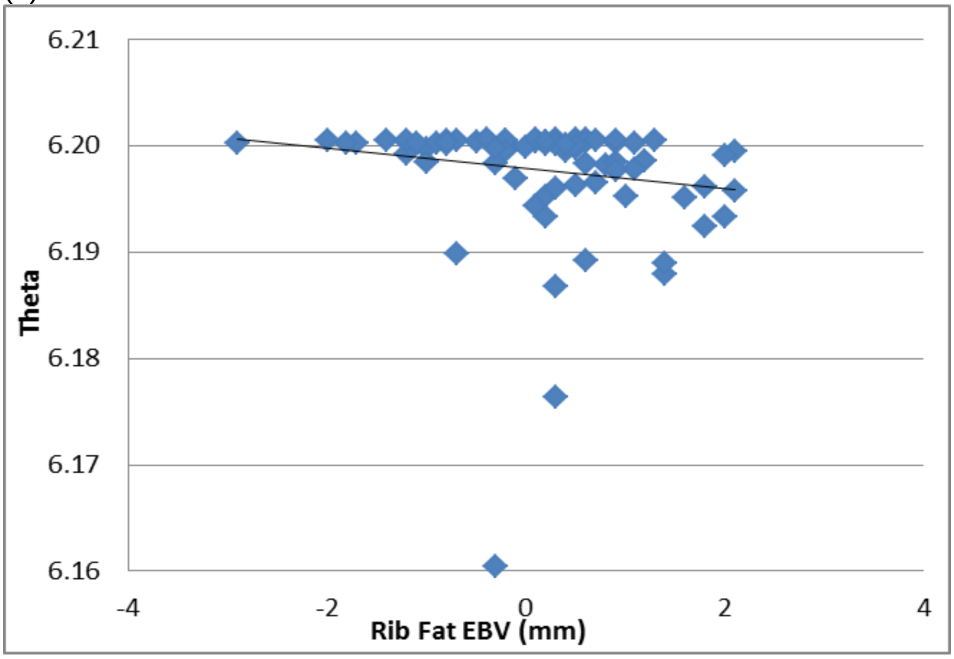
$$\text{THETA} = 6.200 - (0.001 * \text{Rib EBV}) \qquad (R^2 = 0.012, \text{SE} = 0.006) \quad (12)$$

The regression of THETA on rump fat EBV (Equation 13) when constraints were applied in DE was:

$$\text{THETA} = 6.200 - (0.001 * \text{Rump EBV}) \qquad (R^2 = 0.013, \text{SE} = 0.006) \quad (13)$$

These regressions are also depicted in Figure 21.

(a)



(b)

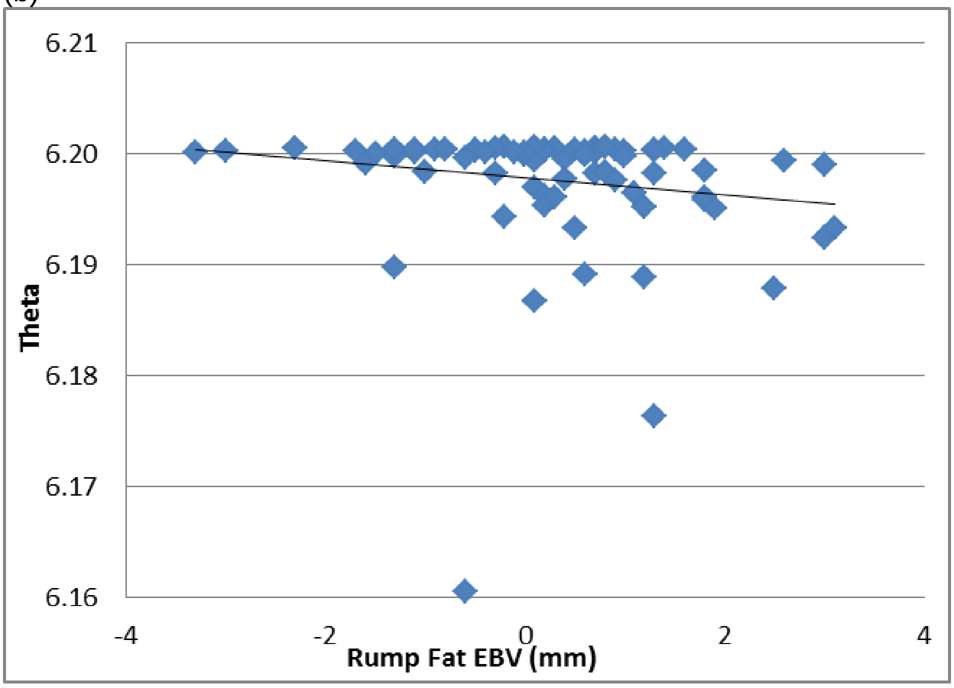


Figure 21. Relationship between the parameter regulating total body fat within the MARC model (THETA) and (a) rib and (b) rump fat EBVs of a cohort from the NSW DPI muscling herd (born 2006) when constraints were applied in differential evolution.

The regression of POBKF on rib fat EBV (Equation 14) when constraints were applied in DE was:

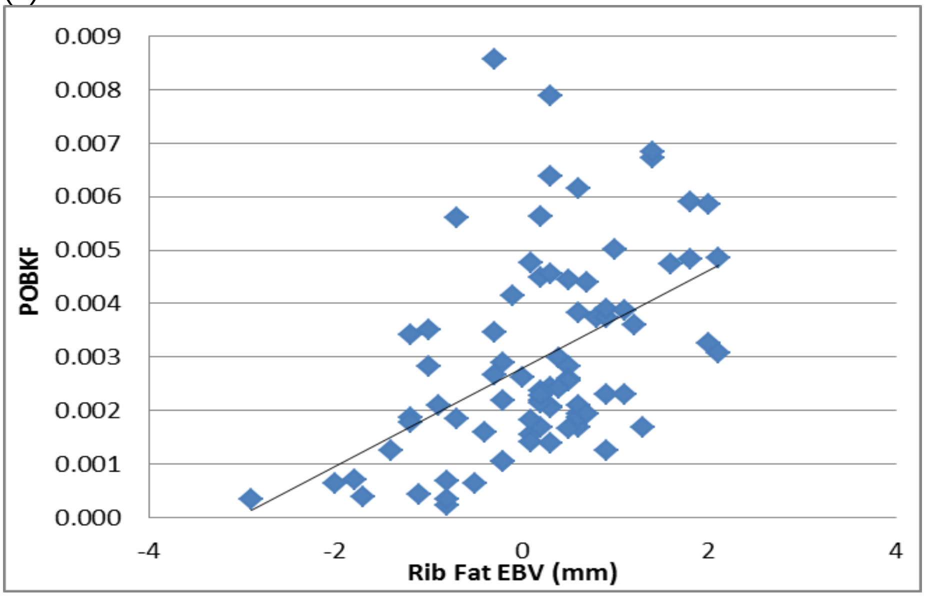
$$\text{POBKF} = 0.0028 - (0.0009 * \text{Rib EBV}) \qquad (R^2 = 0.23, \text{SE} = 0.002) \quad (14)$$

The regression of THETA on rump fat EBV (Equation 15) when constraints were applied in DE was:

$$POBKF = 0.0028 – (0.0007 * Rump\ EBV) \quad (R^2 = 0.21, SE = 0.002) \quad (15)$$

These regressions are also depicted in Figure 22.

(a)



(b)

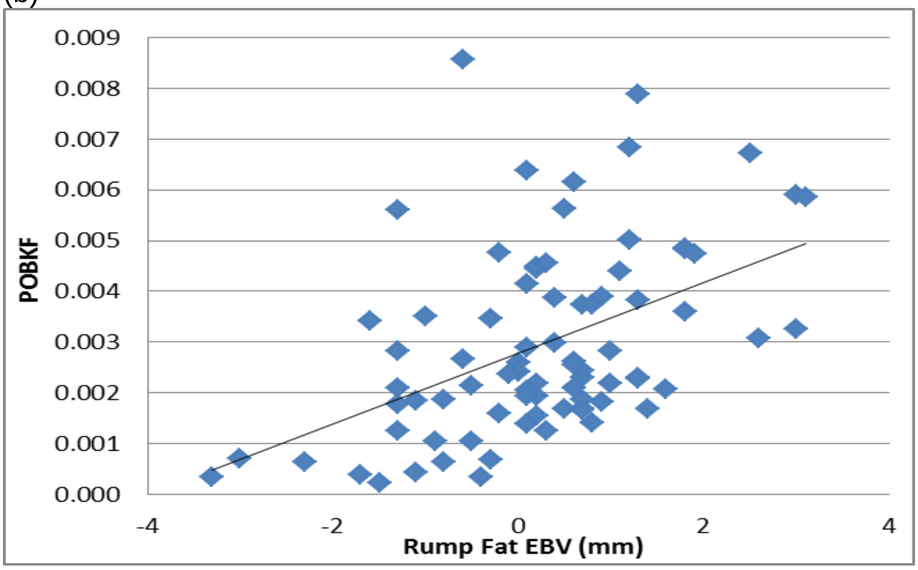


Figure 22. Relationship between the parameter regulating the relationship between total body fat and rib fat depth (mm) within the MARC model (POBKF) and (a) rib and (b) rump fat EBVs of a cohort from the NSW DPI muscling herd (born 2006) when constraints were applied in differential evolution.

3.3 Results and discussion

The predictive accuracy of including rib and rump fat EBVs was tested using the evaluation protocol that was used during the development of BeefSpecs (outlined in McPhee et al. (2008) and Walmsley et al. (2010)). These results were compared with the base scenario where no EBVs were used to assist prediction of P8 fat depth. The mean bias in the base scenario was very close to zero (0.06; Table 8). The inclusion of EBVs did not improve the mean bias (0.31 for both rib and rump EBVs) but did improve the Root Mean Square Error of Prediction (RMSEP) compared to the base scenario (1.36 and 1.37, respectively, vs 1.72). Using either EBV resulted in higher correlations between observed and predicted P8 fat depths. However, using either EBV also resulted in the regression slope between observed and predicted having a greater deviation from unity and a higher proportion of the Mean Square Error of Prediction (MSEP) being due to slope error (Table 7) compared with the base scenario. This repartitioning of error from the random to the slope component suggests the inclusion of either EBV is creating systematic bias in BeefSpecs predictions even though it is increasing average predictive accuracy (RMSEP). This is demonstrated for comparison in Figures 23 to 25.

Table 7. Assessment of differences between observed (n = 80; P8 fat = 9.68) and predicted P8 fat depths without using EBVs (Base Scenario) or when using carcase EBVs for rib (Rib EBV) and rump fat (Rump EBV) to assist prediction in a selected cohort of the NSW DPI muscling herd (born 2006).

	Base Scenario	Rib EBV	Rump EBV
Predicted P8 fat, mm	9.61	9.98	9.98
Mean Bias, mm	0.06	0.31	0.31
Slope of observed on predicted, b	0.78	0.77	0.78
Correlation between observed and predicted P8 fat, r	0.65	0.84	0.83
RMSEP[1], mm	1.72	1.36	1.37
Bias, %	0.13	5.03	5.06
Slope, %	5.77	15.99	13.68
Random, %	94.10	78.99	81.26

[1]RMSEP = root mean square prediction error, Bias = MSEP decomposed into error due to overall bias of prediction; Slope = MSEP decomposed into error due to deviation of the regression slope from unity, Random = MSEP decomposed into error due to the random variation.

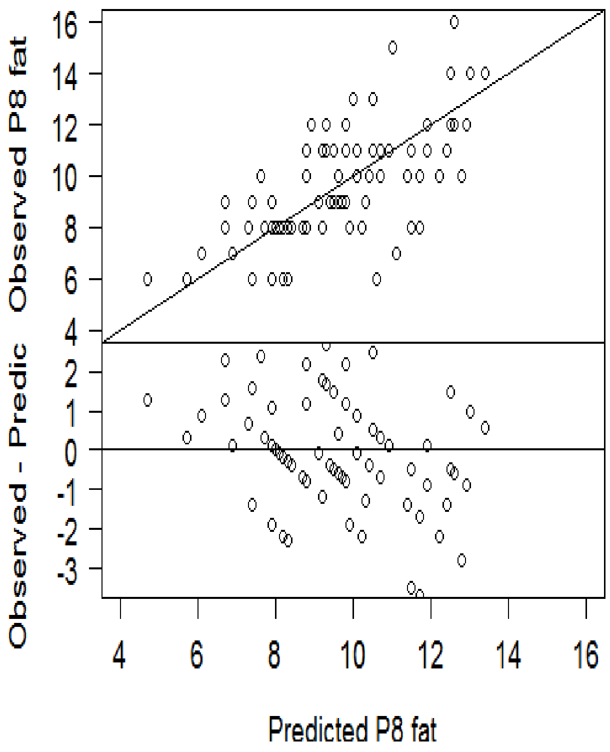


Figure 23. Relationship of P8 fat depth when not using EBVS to predict P8 fat depth of (a) observed *versus* predicted and (b) residual (observed – predicted) *versus* predicted P8 fat depth in a cohort of steers from the NSW DPI muscling herd.

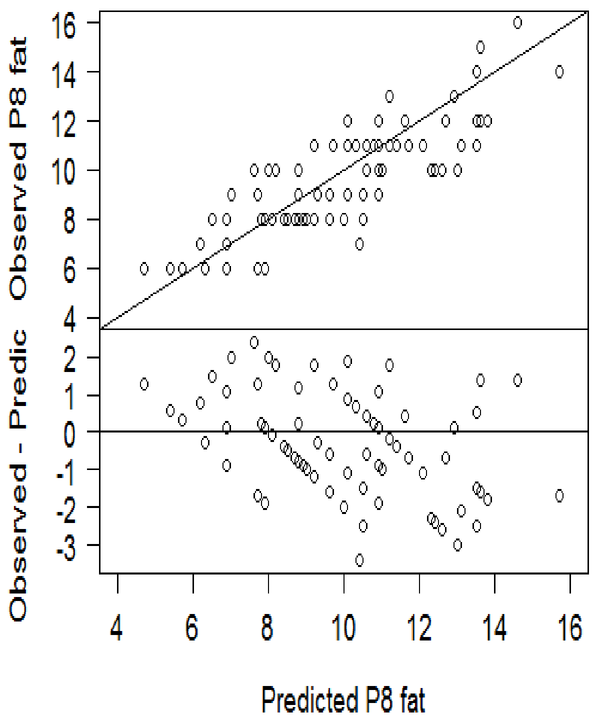


Figure 24. Relationship of P8 fat depth when using carcase rib fat EBV to assist predictions of P8 fat depth of (a) observed *versus* predicted and (b) residual (observed – predicted) *versus* predicted P8 fat depth in a cohort of steers from the NSW DPI muscling herd.

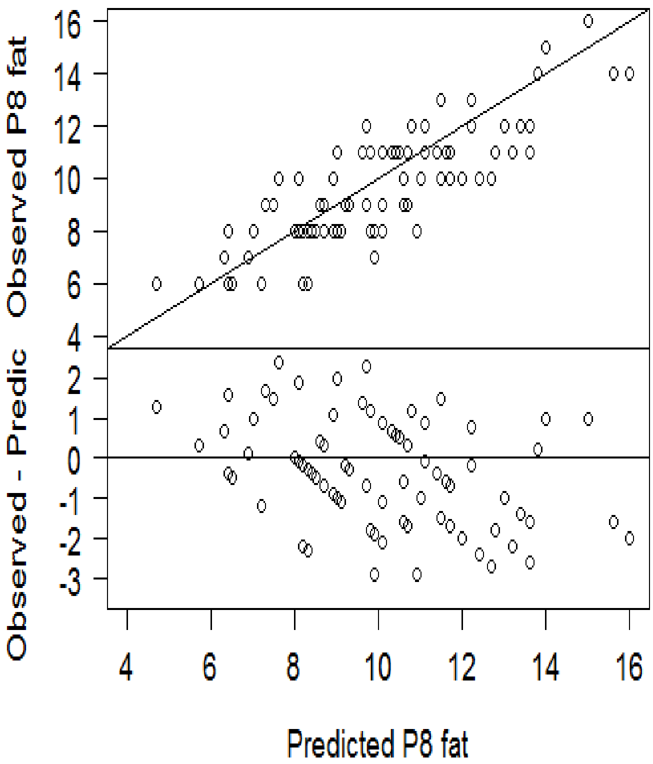


Figure 25. Relationship of P8 fat depth when using carcase rump fat EBV to assist predictions of P8 fat depth of (a) observed *versus* predicted and (b) residual (observed – predicted) *versus* predicted P8 fat depth in a cohort of steers from the NSW DPI muscling herd.

3.3.1 Incorporation of Growth Trait EBVs:

The evaluation of the incorporation of EBVs into the BeefSpecs modelling system was extended to include growth EBVs. An additional steer cohort from within the NSW DPI muscling herd (born in 2007) was also used to test the inclusion of growth EBVs in BeefSpecs. In the 2006 and 2007 cohorts, the correlations between frame score and average daily gain (ADG), both used as inputs by the BeefSpecs model, and the growth EBVs are displayed in Table 9.

Table 9. Correlations between observed average daily gain/frame score and estimated breeding values (EBV) for growth traits in the 2006 and 2007 born steer cohorts from the NSW DPI muscling herd.

	Average Daily Gain (kg/d)		Frame Score	
	2006 cohort	2007 cohort	2006 cohort	2007 cohort
200d weight EBV	0.274	0.437	0.434	0.448
400d weight EBV	0.495	0.417	0.432	0.440
600d weight EBV	0.545	0.391	0.504	0.465
Carcase weight EBV	0.543	0.392	0.409	0.501
Mature Weight EBV	0.542	0.201	0.424	0.404

The correlations between growth EBVs and either ADG or frame score suggest that the EBVs influence both traits. The relationship between the 600 day weight breeding value and observed average daily gain are depicted in Figure 31. While the observed correlations between the growth EBVs and frame score in Table 8 are similar in magnitude to those between ADG and the growth EBVs, further evaluation of using EBVs to inform frame score inputs was not undertaken. This decision was taken due to frame score being a BeefSpecs input that can be directly measured while ADG is an input that requires some degree of experience/education to estimate. Consequently the inclusion of EBVs to increase the accuracy of the ADG input is anticipated to increase the accuracy of BeefSpecs predictions.

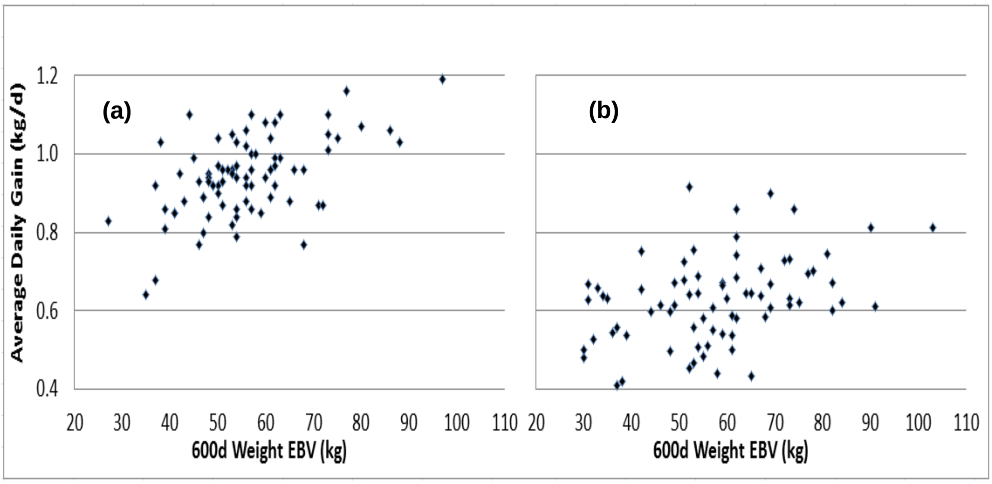


Figure 26 Relationship of 600 day (d) weight EBV between observed average daily gain (ADG) until slaughter *versus* 600 day weight EBVs of two steer cohorts (a) 2006 Cohort and (b) 2007 Cohort from the NSW DPI muscling herd (born 2006 and 2007).

The relationships shown in Figure 26 suggest that the growth EBVs influence ADG and could be included in BeefSpecs. Testing the incorporation of growth EBVs into BeefSpecs was undertaken using a four step process. The initial step (Base) was the base scenario with no EBVs (identical to the base scenario used in rib and rump fat EBV evaluation presented above) and observed ADG used. The second step (Ave. ADG) which again used no EBVs but replaced observed ADG with the average ADG of the cohort. The third step (Full EBV) involved the development of linear regressions of EBVs on ADG for the 2006 cohort (as presented in Figure 26 for 600 day weight EBVs). The regressions of ADG on the 600 day weight and carcase weight EBVs were (Equations 16 and 17):

$$ADG = 0.695 + (0.004 * 600D\ EBV) \quad (R^2 = 0.29, SE = 0.09) \quad (16)$$

$$ADG = 0.828 + (0.004 * Carcase\ Weight\ EBV) \quad (R^2 = 0.29, SE = 0.09) \quad (17)$$

The final step in testing growth EBV inclusion (Adjust EBV) involved developing linear regressions between the EBVs and the difference between observed ADG and cohort average ADG (ADG – Ave. ADG: ADG_{DIFF}). The ADG_{DIFF} predicted by the EBVs is added to the cohort average ADG to provide the ADG input for BeefSpecs. The regressions of ADG_{Diff} on the 600 day weight and carcase weight EBVs were (Equations 18 and 19):

$$ADG_{Diff} = 0.248 - (0.004 * 600D\ EBV) \quad (R^2 = 0.29, SE = 0.085) \quad (18)$$

$$ADG_{Diff} = 0.115 – (0.004 * Carcase\ Weight\ EBV) \quad (R^2 = 0.29, SE = 0.086) \quad (19)$$

The predictive accuracy of including the 600 day weight and carcase weight EBVs was again tested using the evaluation protocol that was used during the development of BeefSpecs (outlined in McPhee et al. (2008) and Walmsley et al. (2010)). The mean bias in carcase P8 prediction in both the base scenario and using the average herd ADG was close to zero (0.06 for base and 0.12 for average ADG in the 2006 cohort; Tables 10 and 12, and 3.25 for base and 3.28 for average ADG in the 2007 cohort; Tables 11 and 13). Using ADG derived from either the 600 day weight or carcase weight EBVs reduced the mean bias and Root Mean Square Error of Prediction (RMSEP) for the carcase P8 fat prediction in the 2007 cohort, but no reductions were observed in the 2006 cohort. Using the ADG estimated from EBVs resulted in the regression slope between observed and predicted having a greater deviation from unity and a higher proportion of the Mean Square Error of Prediction (MSEP) being due to slope error (Tables 10 and 11) compared to the base scenario. This repartitioning of error from the random to the slope component suggests the inclusion of EBVs is creating systematic bias in BeefSpecs predictions. This is demonstrated by comparison of Figures 32 to 37. Comparison of the two methods for including EBVs (Full ADG or Adjust ADG) revealed the Full EBV method generally produced a smaller mean bias and RMSEP than the adjusted EBV method.

Table 10. Assessment of differences between observed (n=80; P8 fat = 9.68 mm) and predicted P8 fat depths for the 600 day weight in the 2006 born cohort of the NSW DPI muscling herd.

Scenario	Base	Ave ADG	Full EBV	Adjust EBV
Predicted P8 fat, mm	9.61	9.56	9.28	10.31
Mean Bias, mm	0.06	0.12	0.39	0.63
Slope of observed on predicted, b	0.78	0.81	0.73	0.71
Correlation between observed and predicted P8 fat, r	0.65	0.67	0.62	0.65
RMSEP[1], mm	1.72	1.67	1.84	1.88
Bias, %	0.13	0.48	4.53	11.23
Slope, %	5.77	4.23	7.31	9.63
Random, %	94.10	95.28	88.16	79.13

[1]RMSEP = root mean square prediction error, Bias = MSEP decomposed into error due to overall bias of prediction; Slope = MSEP decomposed into error due to deviation of the regression slope from unity, Random = MSEP decomposed into error due to the random variation.

Table 11. Assessment of differences between observed (n = 78; P8 fat = 11.00 mm) and predicted P8 fat depths for the 600 day weight in the 2007 born cohort of the NSW DPI muscling herd.

Scenario	Base	Ave ADG	Full EBV	Adjust EBV
Predicted P8 fat, mm	7.75	7.72	12.55	7.92
Mean Bias, mm	3.25	3.28	1.55	3.08
Slope of observed on predicted, b	0.76	1.01	0.43	0.32
Correlation between observed and predicted P8 fat, r	0.35	0.44	0.27	0.20
RMSEP[1], mm	4.70	4.61	4.02	4.94
Bias, %	47.72	50.52	14.83	38.99
Slope, %	0.71	0.00	10.45	9.76
Random, %	51.58	49.48	74.71	51.24

[1]RMSEP = root mean square prediction error, Bias = MSEP decomposed into error due to overall bias of prediction; Slope = MSEP decomposed into error due to deviation of the regression slope from unity, Random = MSEP decomposed into error due to the random variation.

Table 12. Assessment of differences between observed (n=80; P8 fat = 9.68 mm) and predicted P8 fat depths for the carcase weight EBV in the 2006 born cohort of the NSW DPI muscling herd.

Scenario	Base	Ave ADG	Full EBV	Adjust EBV
Predicted P8 fat, mm	9.61	9.56	9.58	9.59
Mean Bias, mm	0.06	0.12	0.10	0.08
Slope of observed on predicted, b	0.78	0.81	0.69	0.73
Correlation between observed and predicted P8 fat, r	0.65	0.67	0.59	0.66
RMSEP[1], mm	1.72	1.67	1.86	1.74
Bias, %	0.13	0.48	0.29	0.22
Slope, %	5.77	4.23	9.49	9.72
Random, %	94.10	95.28	90.24	90.06

[1]RMSEP = root mean square prediction error, Bias = MSEP decomposed into error due to overall bias of prediction; Slope = MSEP decomposed into error due to deviation of the regression slope from unity, Random = MSEP decomposed into error due to the random

Table 13. Assessment of differences between observed (n=78; P8 fat = 11.00 mm) and predicted P8 fat depths for the carcase weight EBV in the 2007 born cohort of the NSW DPI muscling herd.

Scenario	Base	Average ADG	Full EBV	Adjust EBV
Predicted P8 fat, mm	7.75	7.72	13.08	7.98
Mean Bias, mm	3.25	3.28	2.08	3.02
Slope of observed on predicted, b	0.76	1.01	0.49	0.43
Correlation between observed and predicted P8 fat, r	0.35	0.44	0.33	0.27
RMSEP[1], Mm	4.70	4.61	4.18	4.78
Bias, %	47.72	50.52	24.91	40.00
Slope, %	0.71	0.00	8.47	6.92
Random, %	51.58	49.48	66.62	53.08

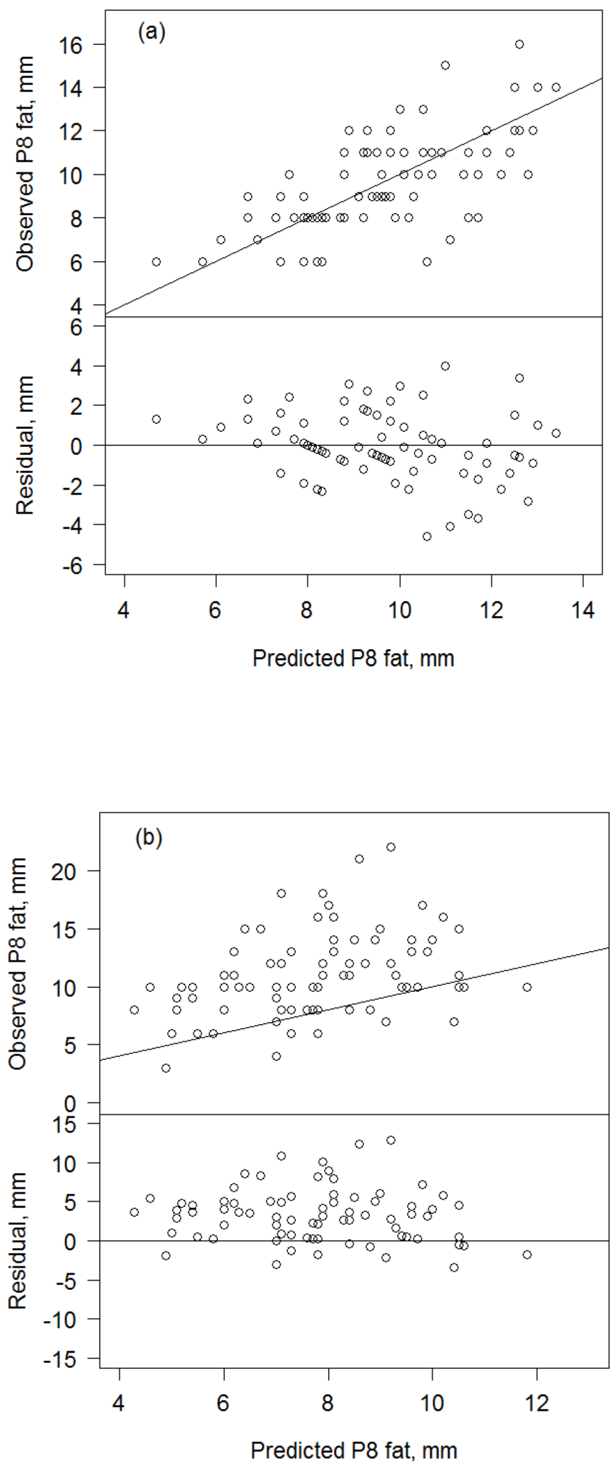
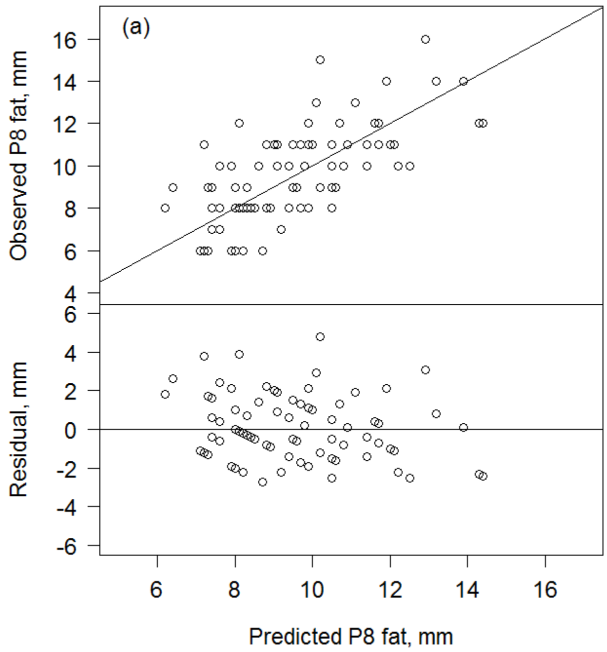


Figure 27. Relationship of P8 fat (mm) when not using EBVs to predict P8 fat depth between observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.



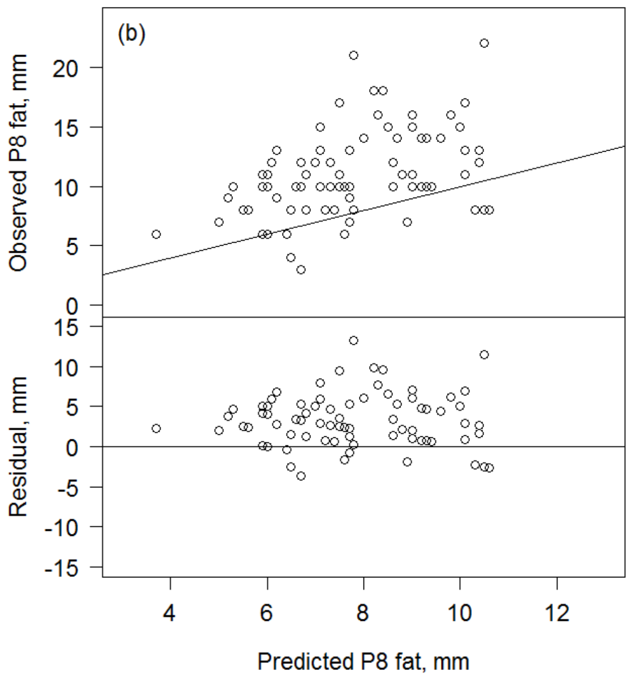


Figure 28. Relationship of P8 fat depth when the average ADG of the herd assists predictions of P8 fat depth of observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.

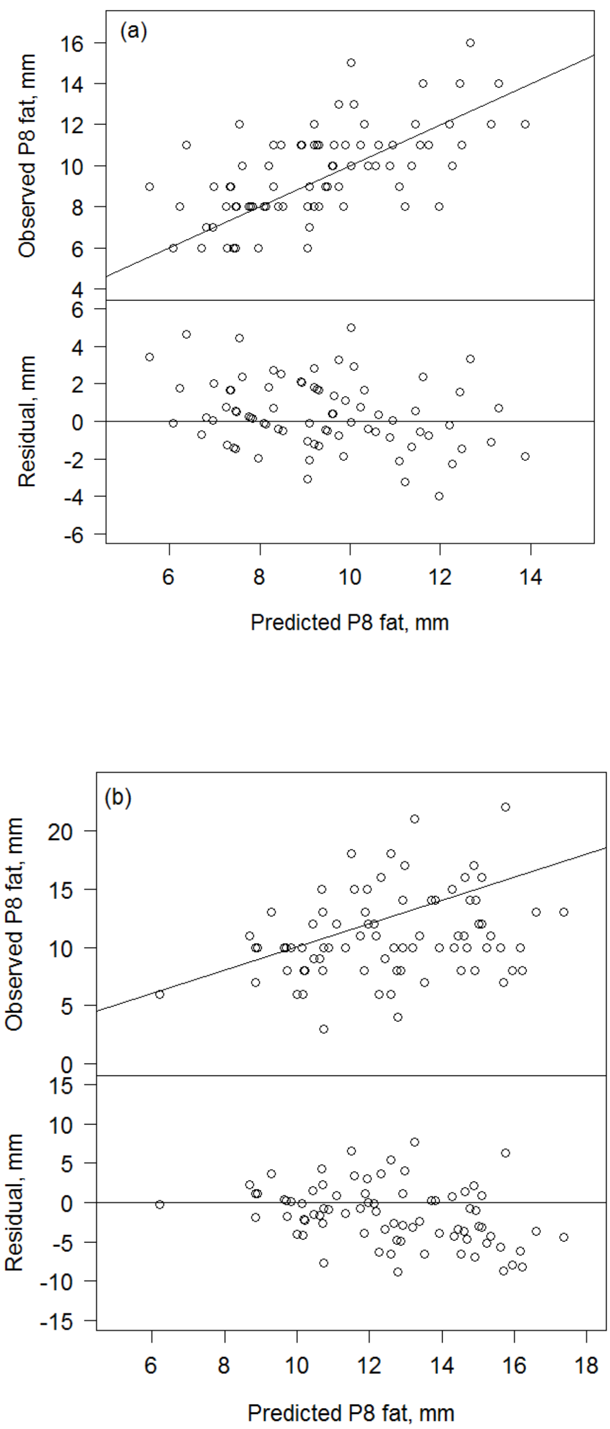


Figure 29. Relationship of P8 fat when using the full 600 day weight EBV to assist predictions of P8 fat depth of observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.

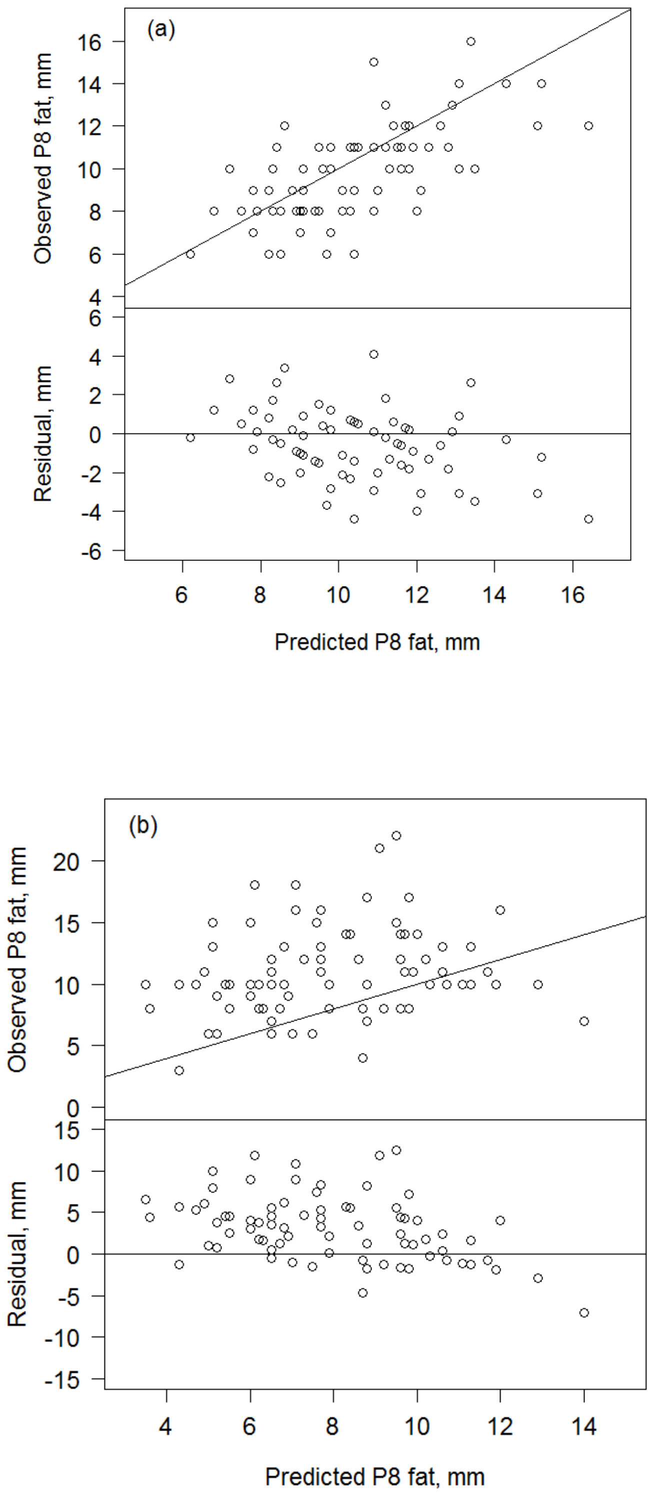


Figure 30 Relationship of P8 fat when using the adjusted 600 day weight EBV to assist predictions of P8 fat depth of observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.

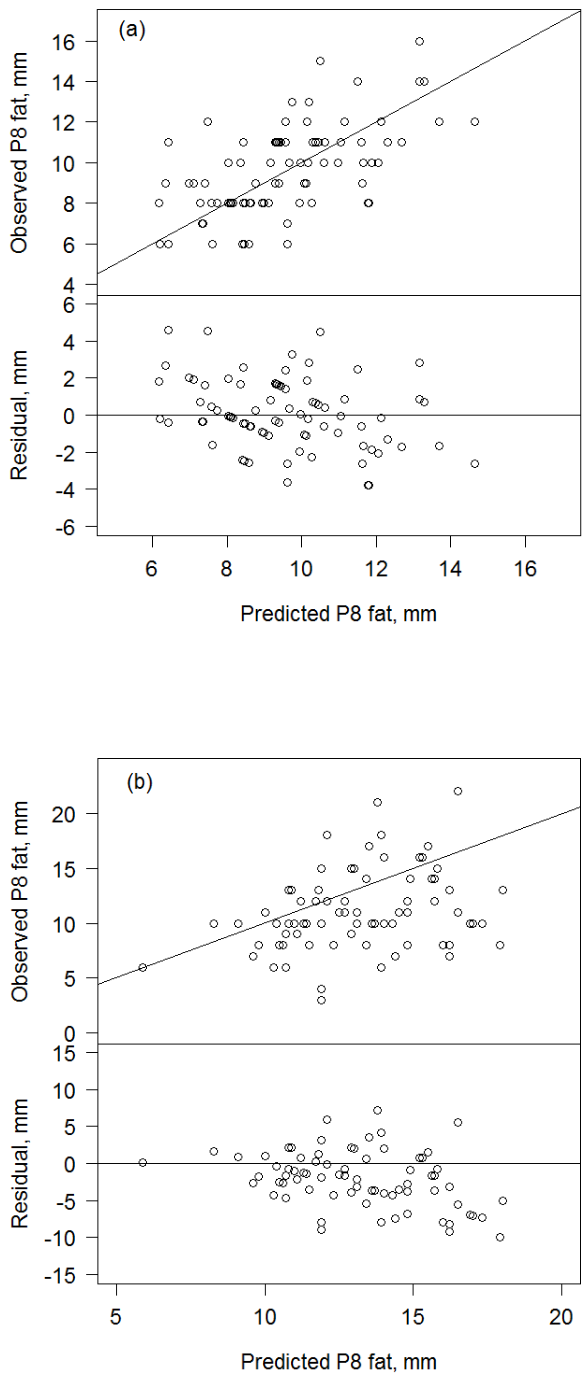
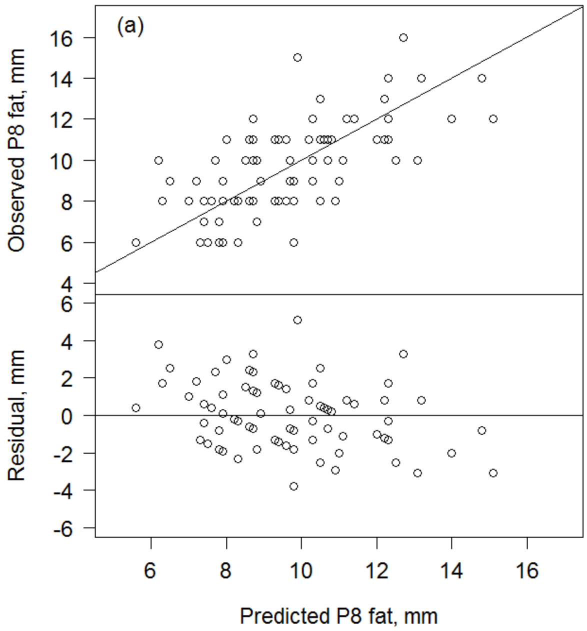


Figure 31. Relationship of P8 fat when using the full carcase weight EBV to assist predictions of P8 fat depth of observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.



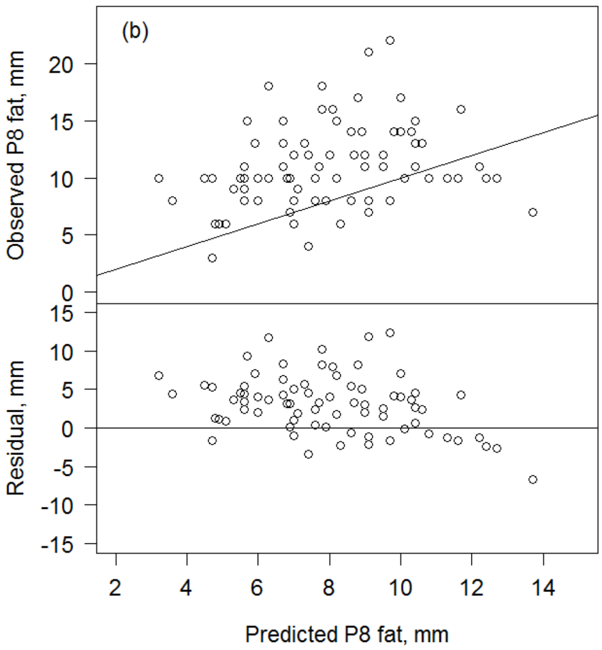


Figure 32. Relationship of P8 fat when using the adjusted carcase weight EBV to assist predictions of P8 fat depth of observed *versus* predicted and residual (observed – predicted) *versus* predicted P8 fat depth for (a) 2006 and (b) 2007 cohort of steers from the NSW DPI muscling herd.

3.3.2 Incorporation of IMF EBVs:

The inclusion of IMF EBVs in the BeefSpecs calculator has not been investigated due to the unavailability of data necessary for this exercise. Agreement has been reached with Angus Australia for them to provide the necessary data from cohort 3 of the Australian Angus SBMP to conduct this research.

3.4 Conclusions

These results suggest the inclusion of EBVs in phenotypic prediction models such as BeefSpecs still provides value in terms of increasing predictive accuracy. However, some issues still remained as areas of concern during this process. Constraining the THETA and POBKF values during the estimation process using DE to prevent values beyond biological reality being obtained produced predictive accuracies which were lower than those achieved when not using EBVs. Further investigation is warranted into how carcase fat EBVs influences the fat partitioning parameters within the MARC model. These investigations may need to focus on alternative fat traits (e.g., total body fat) for consideration which could warrant consideration of how genetic evaluations are used in pig modelling systems to describe differences in pig populations (Doeschl-Wilson et al. 2007).

This exercise has been entirely dependent on the development of a dataset that contained animals with EBVs and phenotypic information of sufficient quality to allow BeefSpecs evaluation. This was achieved by incorporating the NSW DPI muscling herd into Angus Group BreedPlan. However, additional datasets are still required and they are extremely hard to obtain to allow outputs from this exercise to be extensively tested. Datasets of this nature would allow analysis of how EBVs influence predictive accuracy when little or no information is available to inform the inputs into BeefSpecs that are not measurable (e.g., anticipated future ADG).

Another important consideration which needs to be re-iterated for the inclusion of EBVs into the BeefSpecs calculator and other related phenotypic modelling systems is the mode of delivery of current industry EBVs. In the Australian beef industry EBVs are delivered on a breed specific basis hence phenotypic prediction tools also need to follow a similar pattern. This limits the capacity for such modelling systems to predict performance in cross breeding production systems. The EBVs used in this exercise are Angus EBVs derived from the NSW DPI muscling herd. The underpinning MARC model currently functions across breeds by specification of breed type (British, European, *Bos indicus*) which has specific impacts on model parameters and is highly conducive for use in cross breeding production systems. Delivery of EBVs across breeds would complement this mechanism and reduce the difficulty of including EBVs in phenotypic prediction tools. Consequently, to gain full advantage of the development of phenotypic prediction tools and to allow them to operate with the highest efficiency and to gain the highest impact across the beef industry, genetic information will need to be delivered in a uniform manner across breeds in the future.

4 Test new additions to BeefSpecs using BIN data and other available data sources

Testing new additions to BeefSpecs with additional data [dataset 2 from MLA projects (B.BSC.0339 and B.SBP.0108), data from the Beef CRC and data from the Angus Australia] occurred extensively throughout sections 1 and 3 of this report.

5 Develop a BeefSpecs optimisation tool for use in pasture-fed systems (based on the current feedlot tool)

5.1 Introduction

The development of the BeefSpecs pasture optimisation system is underpinned by the BeefSpecs feedlot optimisation system which was developed during the Beef CRC. The input screen for the BeefSpecs pasture optimisation system is shown in Figure 33. The BeefSpecs feedlot optimisation system is based on the stochastic carcase price discounts grid described by Mayer *et al.* (2013). This stochastic grid was developed from a carcase pricing schedule for a feedlot market. A more up-to-date (03/08/2015) pasture-fed pricing schedule was selected as the basis for development of the stochastic pasture carcase price discount grid in preference to the pricing schedule described by (McPhee and Walmsley, 2014). The capacity to readily change the carcase pricing schedule has now also been incorporated into the pasture optimisation system (Figure 34) to increase the functionality of the tool. Output screens of the pasture otimisation tool of the economic and production comparisons are shown in figures 35 and 36, respectively.

5.2 Discussion

Mayer *et al.* (2013) described how the overall between-animal variation in target populations is used as the stochastic information during formation of the stochastic price discounts grid. Mayer *et al.* (2013) used four independent feedlot datasets to derive their standard deviation estimates of 23 kg and 5.1 mm for carcase weight and P8 fat depth. Pasture data used to examine between animal variation in growth and fattening rates for *Bos taurus* steers was taken from the CRC for Cattle and Beef Quality (Dicker *et al.* 2001 and Upton *et al.* 2001). The steers were from four breeds (Angus, Hereford, Murray Grey and Shorthorn) in 1995, 1996 and 1997, and three breeds (Angus, Hereford and Shorthorn) in 1998. These animals were part of growth path studies which involved finishing in both feedlot and pasture systems. The entire dataset contained 1055 animals of which 505 were pasture finished with the remaining animals feedlot finished. Further details can be obtained from McPhee *et al.* (2012). Analysis of the pasture finished animals including adjustment for differences in initial liveweight and fatness revealed there were slight differences in the variation in growth and fattening rates between feedlot and pasture finished systems. The standard deviations estimated from this data for carcase weight and P8 fat depth were 25.4 kg and 3.59 mm, respectively.

The default production costs used by the pasture optimisation system have been updated to better reflect the costs of producing pasture-fed animals. These costs were derived from the beef production gross margins published by NSW DPI (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/175533/Summary.pdf). The largest change in the costs structures has been reducing the feed cost per tonne from $250.00 to $50.00 based on the assumption it costs $0.005 per MJ ME to produce pasture containing 10 MJ ME/kg. The purchase price of animals has been increased to $3.00 per kg liveweight to reflect September 2015 cattle prices. The medicine costs per head per day used in the feedlot optimisation system are similar to those described in the European Union cattle gross margin published by NSW DPI and thus remain unchanged. The other costs remain unchanged but are readily altered.

The BeefSpecs feedlot optimisation tool was used to investigate datasets collected in April and October 2009 from the intakes of a commercial feedlot. The results from this analysis found fine-tuning the optimisation such as using more pens, allowing unequal numbers in pens, and formal optimisation offered little improvement in profit gain (1%). This suggested that the heuristic rules applied in the feedlot optimisation system accounted for most of the profit gain possible without extensive computational effort. However, such an exercise has not been possible with the pasture optimisation system due to the unavailability of an appropriate dataset.

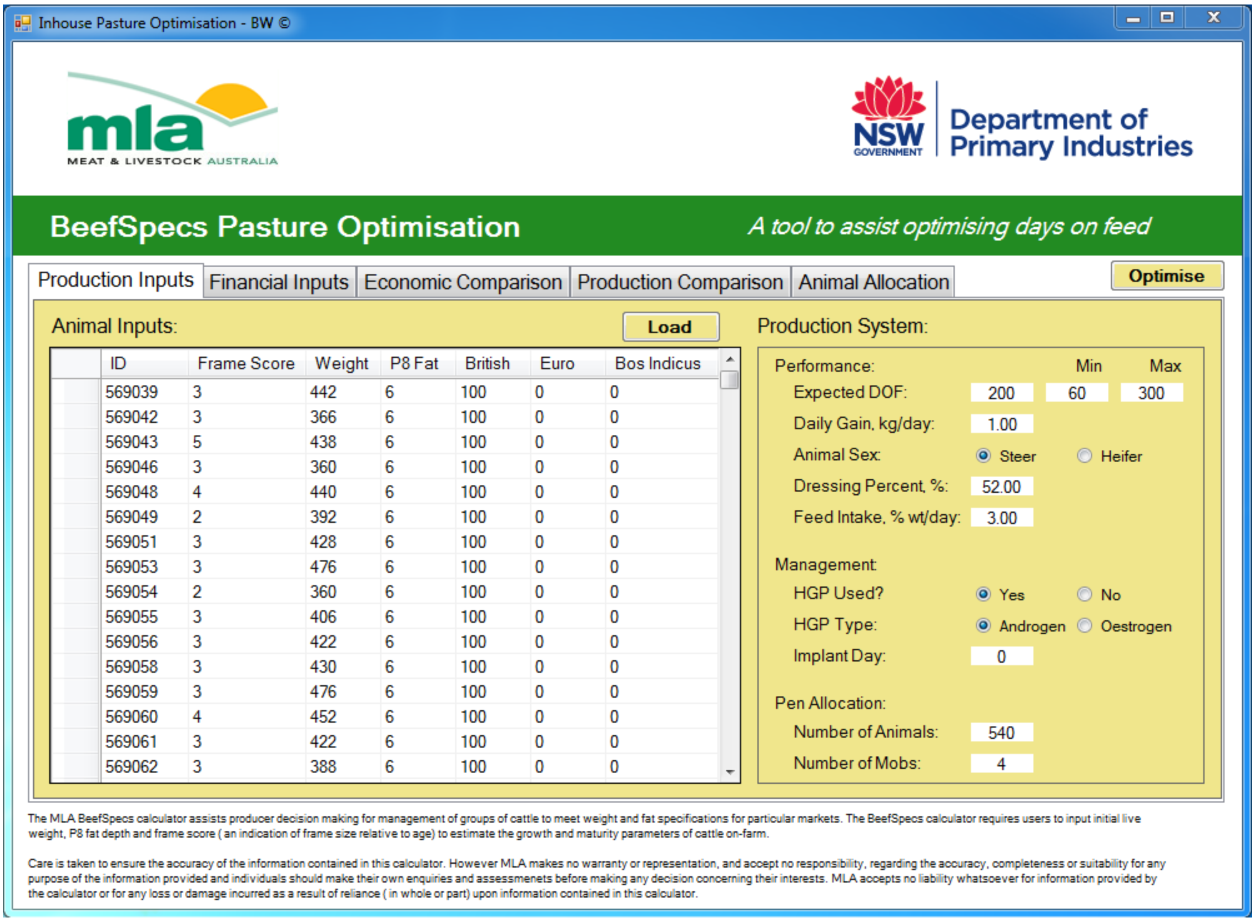


Figure 33. A demonstration of the production inputs tab of the BeefSpecs pasture optimisation tool that includes individual animal inputs and production system inputs.

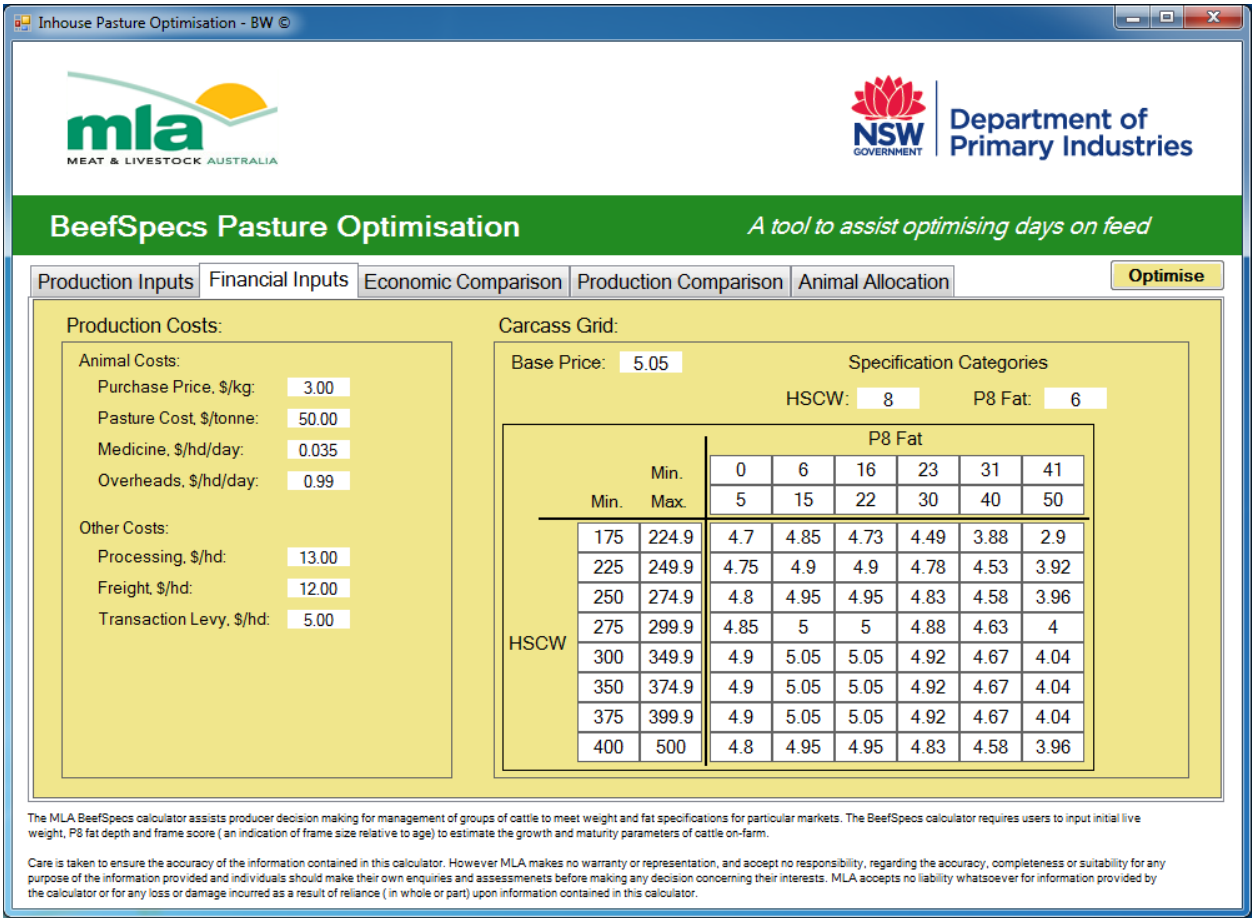


Figure 34. A demonstration of the financial inputs tab of the BeefSpecs pasture optimisation tool that includes production cost inputs and the target carcase grid which is used to develop the stochastic discounts grid.

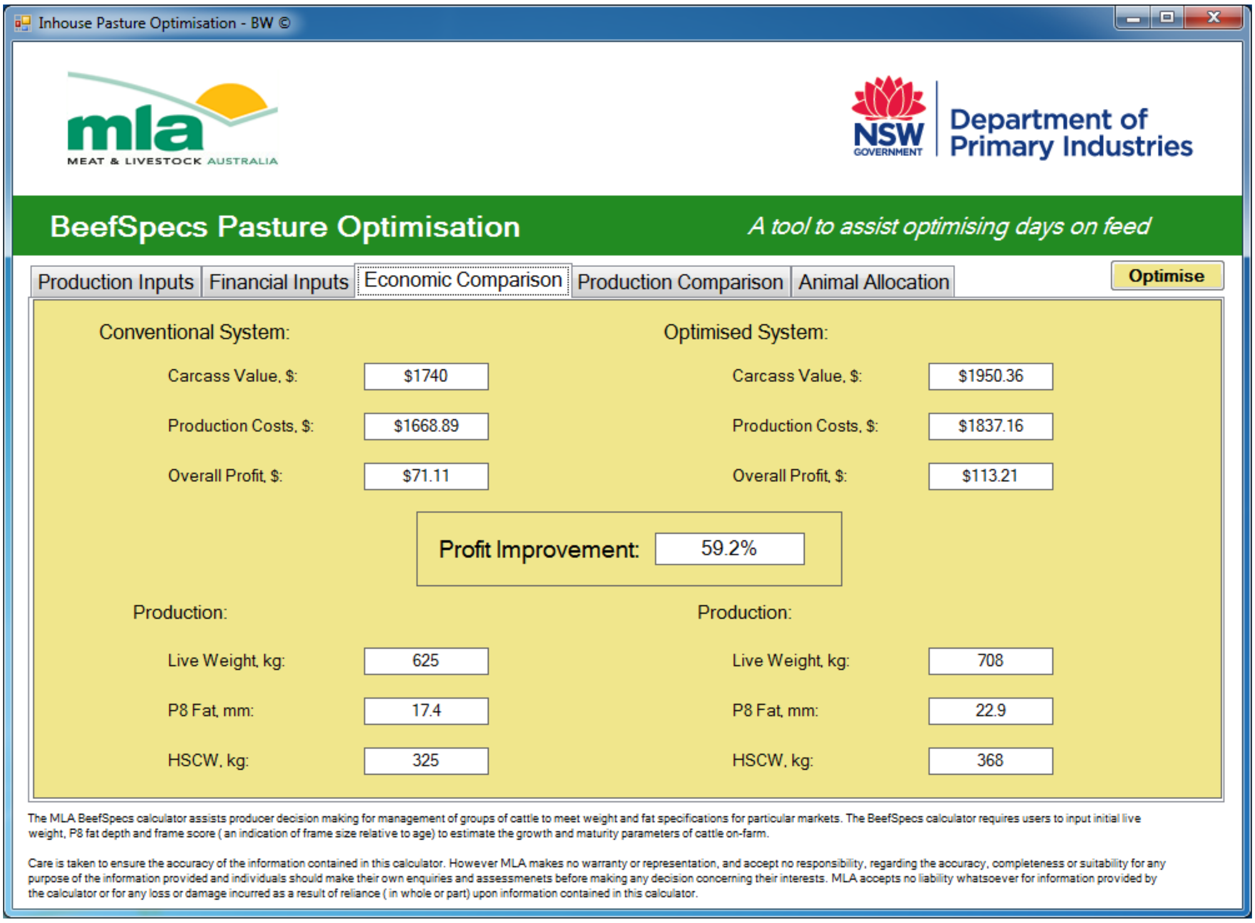


Figure 35. A demonstration of the economic comparison tab; conventional *versus* optimised system and the overall improvement in profitability that can be achieved when using the BeefSpecs pasture optimisation tool.

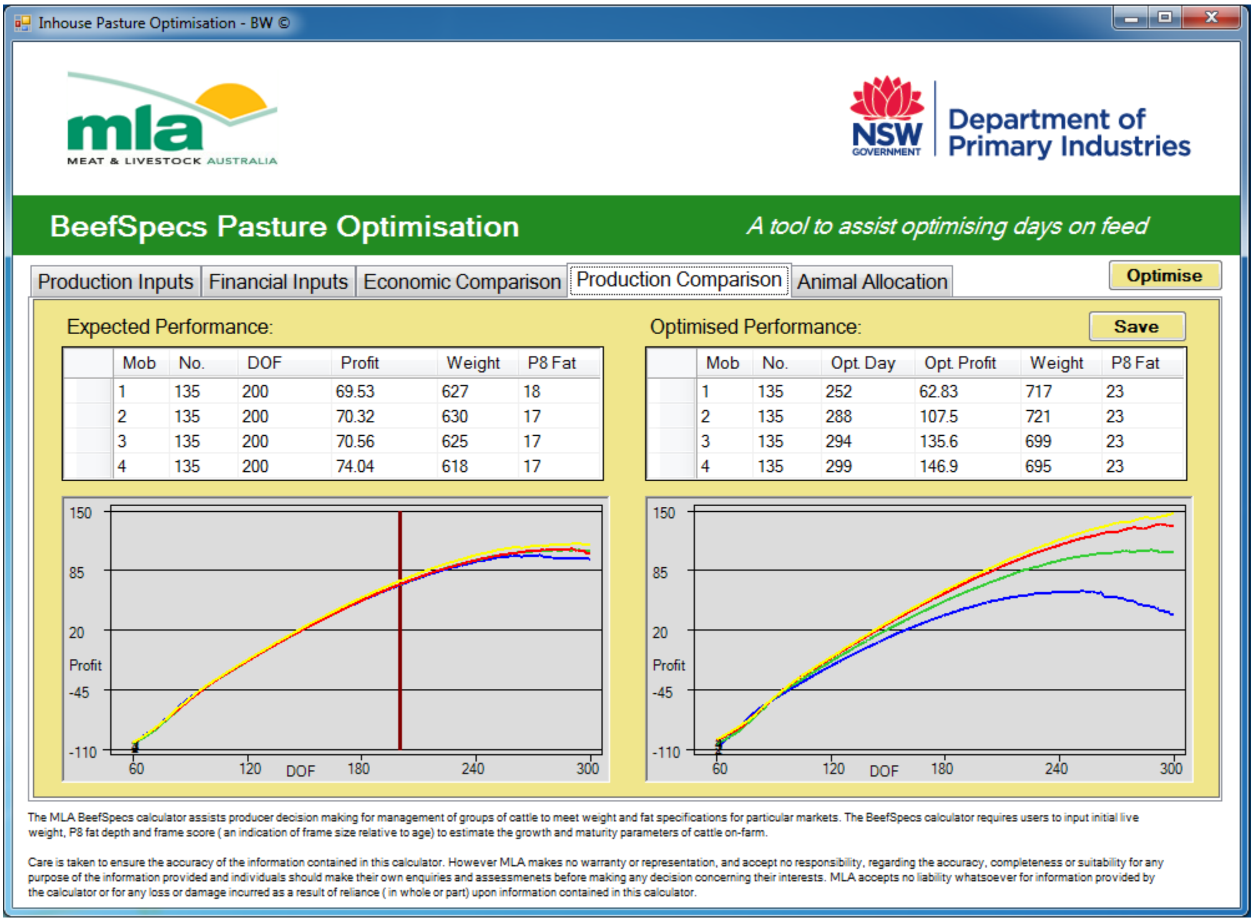


Figure 36. A demonstration of the production comparison tab with a graphical display of the expected *versus* optimised performance that can be achieved when using the BeefSpecs pasture optimisation tool.

5.3 Conclusion

The BeefSpecs feedlot optimisation system uses the assumption that all feedlot pens within one optimisation run have the capacity to hold the same quantity of animals. This assumption simplifies the optimisation but may be unrealistic in pasture-fed production systems where paddock size and/or carrying capacities are seldom uniform. Initial steps were taken to examine the value of incorporating tactical logistical constraints in the optimization, but have not been pursued further and were considered to provide little value to the optimisation in its current form due primarily to computational time constraints. Future developments in technology may facilitate the further development of methods to consider logistical constraints and as such should not be completely disregarded.

6. Develop linkages between visual imaging systems, BeefSpecs, and the livestock data link (LDL) database

The work undertaken to achieve this objective is preliminary. The objective was to provide direction on the steps required to accomplish the linkages between a visual imaging system integrated with BeefSpecs and the linkage that could then be developed with the LDL. The linking of objective measurements from 3D images on live animals into BeefSpecs, to assist producers and managers make strategic management decisions, is a *very* critical and important step. A number of planning meetings were held that have led to the following outcomes.

6.1 Linking BeefSpecs with visual imaging systems.

Integrating a 3D visual imaging system with BeefSpecs in real time has been under discussion with the University of Technology Sydney. This concept is driven by the need and opportunity to link on-farm decisions concerning live animals that affect production along the whole supply chain as well as the final carcass traits with objective on-farm measurements. Obtaining objective measurements early in the life of an animal will facilitate value based trading systems. BeefSpecs has already emerged as a vital part of a system integrating performance, marketing and carcass feedback data by virtue of its prediction capabilities, which will be greatly improved and enhanced by the development of a technology that can make fast and accurate objective measurements on live animals. An integrated system will provide the mechanism to improve efficiency and profit throughout the beef supply chain.

Steps to achieve this goal include:

- Collecting data to extend the 3D image outcomes on *Bos indicus* genotypes and European cattle;
- Classification on *Bos indicus* genotypes and European cattle
- Determine the sampling strategy required to cover the complete gambit of genotype ratios of cattle;
- The development of a portable lightweight free standing calibration apparatus.
- Evaluation on the length of coat;
- Research into gait and taking 3D images of unconstrained cattle needs to be conducted; and
- Development of equipment that can be implemented into a range of on-farm races.

A funding proposal has been drafted to address these steps to achieve the goal of developing a fully integrated system to improve efficiency and profitability within the beef supply chain.

6.2 Development of a BeefSpecs generic grid to link with LDL

A prediction system based on a generic grid has been developed (Figure 37) to provide an economic assessment of meeting market specifications. Estimates of HSCW and P8 fat from the BeefSpecs Drafting Tool are reported in Columns C and D of Figure 37. The discounts applied for out of specification carcases for both HSCW and P8 fat are then determined from the discounts (c/kg) reported in columns U to W where associated discounts are averaged over the current grids of 4 processors (columns L to S and rows 2 to 5 for HSCW specifications and columns L to N and rows 7 to 9 for P8 fat specifications). The base figure for carcases meeting specifications in this example is highlighted ($5.80). The discounts associated with HSCW are reported in column H and the discounts only associated with P8 fat are reported in Column J. The input of the base figure generates the discounts based off the generic grid. Economic returns of carcases are reported in column F and the average price and total value of the consignment are reported. To develop the discounts the user enters the base price (carcase price with NO DISCOUNTS for weight and fat) (Figure 37).

Id	Group	HSCW	P8 Fat	$/kg	Total	Base	Discount	Price
3	2	330	15	5.80	1914.00	5.80	0.00	5.80
8	2	281	15	5.74	1612.94	5.74	0.00	5.74
10	2	284	15	5.74	1630.16	5.74	0.00	5.74
30	2	305	14	5.80	1769.00	5.80	0.00	5.80
36	2	292	24	5.64	1646.88	5.74	0.10	5.64
A1	5	328	12	5.80	1902.40	5.80	0.00	5.80
B2	5	291	13	5.74	1670.34	5.74	0.00	5.74
6	5	318	17	5.80	1844.40	5.80	0.00	5.80
7	5	312	17	5.80	1809.60	5.80	0.00	5.80
11	5	301	18	5.80	1745.80	5.80	0.00	5.80
12	5	326	16	5.80	1890.80	5.80	0.00	5.80
14	5	311	13	5.80	1803.80	5.80	0.00	5.80
15	5	320	15	5.80	1856.00	5.80	0.00	5.80
21	5	334	15	5.80	1937.20	5.80	0.00	5.80
26	5	323	13	5.80	1873.40	5.80	0.00	5.80
27	5	313	15	5.80	1815.40	5.80	0.00	5.80
29	5	297	3	5.39	1600.83	5.74	0.35	5.39
31	5	296	15	5.74	1699.04	5.74	0.00	5.74
33	5	290	12	5.74	1664.60	5.74	0.00	5.74
34	5	293	4	5.39	1579.27	5.74	0.35	5.39

HSCW Specifications							
Min Wt	200	220	240	260	280	300	350
Max Wt	220	240	260	280	300	350	500
Price ($/kg)	5.55	5.60	5.65	5.70	5.74	5.80	5.35

P8 Fat Specifications (mm)	
Minimum	5
Maximmum	22

Average Price of consignment	$5.74
Total value of consignment	$35,265.86

Base price: 0-2 tooth MSA steer		
($/kg)		$5.80
Discounts (c/kg)		
Wt	350-500	45
	300-350	0
	280-300	6
	260-280	10
	240-260	15
	220-240	20
	200-220	25
Fat	0-4mm	35
	5-22mm	0
	23-32mm	10
Dent	0-2 teeth	0
	3-4 teeth	15
HGP	Yes	6
Butt shape	A-C	0
	D	24
Heifers		5

Figure 37. Screen shot of Beefspecs Drafting Tool economic returns calculator.

6.3 Conclusions

Linking BeefSpecs with visual imaging systems

Progress towards linking BeefSpecs with a visual imaging system is progressing. Obtaining data from a feedlot to develop machine learning algorithms is paramount to the success of developing a real time system. In addition to collecting data research into the gait, animal movement and length of coat needs to be conducted. The development of software also needs to be undertaken to speed up the machine learning techniques so that induction of cattle into a feedlot is not slowed down and the collection of on-farm data does not slow down existing operations.

Development of a BeefSpecs generic grid to link with LDL

The physical and financial impacts of an integrated system have not yet been validated but several critical steps have been put in place. The comparison between the economic returns, based on live animals, from the BeefSpecs drafting tool as compared to the feedback via LDL could provide a mechanism to start a conversation between producer and processor to strengthen the linkages that exist and therefore provide a benefit to both producer and processor. However the LDL is still in the early stages of development and hence linking BeefSpecs with LDL is premature.

7 Review existing training material and produce new BeefSpecs training material

The following points highlight the new BeefSpecs training material developed in the light of a review of existing traning material:

- Beefspecs (Calculator & Drafting Tool) tools were presented to Charlotte Fox and More Beef from Pastures (MBFP) state coordinators on 12th February 2015.
  - ✓ Positive feedback from state coordinators was received. BeefSpecs will be delivered within a MBFP framework.

- ✓ Feedback indicated that an economic returns calculator (Figure 37) would be a valuable asset to the BeefSpecs tools. Additional feedback from Victorian Department of Agriculture suggested that further discussions with the LDL team need to be conducted before this is released.
- ✓ Coordinators copy of a draft manual has been issued

- 'Tips and tools' for the Beefspecs Drafting Tool – hard copy and video
  - ✓ A hard copy of the 'Tips and tools' for the BeefSpecs Drafting Tool (a support document for users) is completed. (Appendix 2)
  - ✓ The youtube video is available at: (https://www.youtube.com/watch?v=tEithQ9ynlc).

- The Beefspecs Manual (draft copy; Appendix 3) has been distributed to Peter Schuster & State MBFP coordinators 17th February 2015.
- Two Prime Facts have been developed that can be distributed at workshops.
- Four pilot workshops reported in Table 4 are in place to develop industry feedback on the use of the BeefSpecs drafting tool and the management changes that are required to assist producers meet market specifications.

Table 14. Location, coordinator, collaborating processor, number of attendees, course structure and progress of pilot workshops

Location	Coordinator	Collaborating Processor	Number of participants	Course Structure	Progress
Nambucca Valley, NSW	Todd Andrews (NSWDPI) / Brendan O'Brien (North Coast LLS)	Wingham Beef Exports	18	Two field days to monitor steer progress; processor visit to view carcases, carcase feedback field day	Completed
Nambucca Valley, NSW	Todd Andrews (NSWDPI) / Brendan O'Brien (North Coast LLS)	Wingham Beef Exports	32	Two field days to monitor steer progress; processor visit to view carcases, carcase feedback field day	Completed
Eura	Patricia O'Keeffe (NSWDPI) / Maree Crawford (VicDPI	JBS	15	Using supplements to finish steers year round	1 producer meeting held
Hastings Valley, NSW	Todd Andrews (NSWDPI) / Albert Mullen (Central Rivers LLS)	Wingham Beef Exports	-	Two field days to monitor steer progress; processor visit to view carcases, carcase feedback field day	To be determined

8 General discussion

This project has enhanced the BeefSpecs tools to assist pasture fed beef producers improve compliance rates and 'meet market specifications' before slaughter. The new enhancements include a new input for muscle score and the prediction of denuded lean meat yield (%), MSA marbling score and MSA index of live animals. The development of the BeefSpecs drafting tool initiated during the former Beef CRC has now been developed for the web and is available on the NSW DPI web site (http://beefspecs.agriculture.nsw.gov.au/drafting/). A prototype pasture-fed BeefSpecs optimisation tool to optimise beef herds has been developed that can be customized to enable large pastoral companies to optimise their production systems and increase profitability. Growth trait EBVs were evaluated and confirmed that the inclusion of EBVs provides value in terms of increasing predictive accuracy. A BeefSpecs prototype economic calculator based off a generic grid has been developed and predicts total value of consignment. Workshop material has been developed and four pilot workshops are in the pipe line with a focus on the management changes that are required to assist producers meet market specifications.

The following points highlight what worked:

- The research was achieved by running a serial slaughter using low and high muscling cattle that provided the variation to develop the new BeefSpecs models. Data collected from research conducted in MLA projects (B.BSC.0339 and B.SBP.0108) and the Beef CRC also assisted in either challenging models or developing models within this project.
- Including muscle score as a new input into BeefSpecs has led to the development of a lean mean yield.
- The objective of developing a BeefSpecs Pasture optimisation model was again achievable because it built on the BeefSpecs Feedlot optimisation model developed in collaboration with MLA and the Beef CRC.
- NSW DPI Development Officer assisted in developing material (e.g., youtube videos and manuals) to assist producers quickly and easily learn how to use the tools developed.

9 Achieved objectives

Objective	Fully achieved	Partially achieved	Not achieved	Comment
1. Incorporate Retail Beef Yield (RBY), MSA marbling grade and MSA ossification predictions in the BeefSpecs calculator	Yes			Lean meat yield incorporated as discussed above.
2. BeefSpecs predictions linked quantitatively to the MSA index	Yes			
3. Develop a BeefSpecs optimisation tool for use in pasture-based systems (based on the current feedlot tool)		Yes		*Data requirements* Appropriate dataset from a large pastoral company is required to fully test this system out. *Future developments* Future developments in technology may facilitate the development of methods to consider logistical constraints.
4. Test new additions to BeefSpecs using BIN data and other available data sources		Yes		*Chemical IMF (%)* Additional work needs to be conducted with chemical IMF (%) to strengthen the new relationships developed. *IMF EBVs* The inclusion of IMF EBVs in the BeefSpecs calculator will be conducted using the BIN data (cohort 3 of SBMP) from the Angus society that is available after December 2015.
5. Develop linkages between visual imaging systems, BeefSpecs, and the livestock data link (LDL) database		Yes		*Visual imaging systems* Ongoing work is required for linking the visual imaging system to tools such as BeefSpecs. A new funding proposal has been put forward to complete research and develop at least 2 units to be made available for industry to test the units before they are

				commercially available. *LDL* Ongoing work is required here. Initially conversations need to be held between leaders of the LDL and the BeefSpecs team to evaluate the feedback that can be achieved from BeefSpecs predictions on live animals and the feedback that is generated from the LDL.
6. Further develop methods for including genetic information in the form of EBVs integrated into BeefSpecs predictions	Yes			
7. Review existing training materials and produce new BeefSpecs training material	Yes			

10 Conclusion and recommendations

Future work should focus on the following key areas of research.

1. Develop a fast, effective and cheap real time method to predict P8 fat and muscle score from live animals.
    a. The highest priority is the development of an effective and cheap real time system to objectively measure P8 fat and muscle score. A project proposal has been developed to conduct further research on the issues of gait and movement through the race; an extension of the 3D cameras to include *Bos indicus*, *Bos indicus* crosses and European cattle; further software development to speed up the processing of the machine learning techniques employed; development of portable on-farm equipment; and software to automate the process in real time. The application for a feedlot
2. A compositional study on *Bos indicus*, *Bos indicus* crosses and European cattle.
    a. A serial slaughter study on *Bos indicus*, *Bos indicus* crosses and European cattle would provide a valuable dataset on total fat and lean components for these genotypes. The data would be valuable for both the industry and for further enhancements as required to the BeefSpecs equations.
3. A focus meeting with key MLA staff and both the feedlot and large pastoral companies to discuss how the BeefSpecs Feedlot and Pasture-fed optimisation tools could be used.
    a. A meeting with key MLA staff and industry (both feedlot and large pastoral companies) would strengthen the adoption rate of these

optimisation tools that can play a significant role in assisting feedlots and large pastoral companies improve market compliance rates. These tools customized to specific operations have the potential to significantly improve the profitability of these industries.

4. Collection of data to expand/strengthen the intramuscular fat (%) and MSA marbling score, and EBV relationships within BeefSpecs.
    a. Data from the Angus BIN program has been identified to assist in improving the IMF (%) relationship and hence the MSA marbling score value.
    b. The study on developing methods for including genetic information in the form of EBVs integrated into BeefSpecs builds on the preliminary evaluation (Walmsley *et al.* 2013). Growth trait EBVs and IMF EBVs have been evaluated in this project. Further evaluation is warranted into how carcase fat EBVs influence fat partitioning parameters. Studies conducted within the pig industry may assist in developing an alternative method of partitioning fat parameters.
5. A workshop with the LDL team to discuss the evaluation of feedback from the 5 pilot workshops to pave a way forward for developing a conversation between producers and processors.
    a. A conversation between producers and processors on “meeting market specifications” is critical for both sectors. Both the LDL and the BeefSpecs tools can play a role in providing feedback to producers. The outcomes of 5 pilot workshops on the BeefSpecs drafting tool in a workshop environment with the LDL team my pave a way forward at how linkages can be drawn between LDL feedback data (i.e., slaughter data) *versus* predictions of market specification traits while animals are alive.

11 Acknowledgements

Helen Smith, Alistair Donaldson, Bill Johns, Reg Woodgate, Todd Andrews (NSW DPI), and numerous students and temporary staff that have assisted with various slaughters. Thanks also goes to Brad Skinner and Alen Alempijevic from UTS that have collected camera images of cattle to enhance the collaborative work that NSW DPI and UTS are doing with MLA on the MLA project No: B.SBP.0121 “Value based trading system: image analysis of sheep and beef carcases- proof of concept”. Matt Wolcott for live animal scanning of steers and heifers in the early stages of the project and subsequently Roger Evans. Linda Cafe assisted in the early stages with muscle scoring and the management of the high and low muscling cattle from Glen Innes. Peter Newman and Peter Kamphorst from Glen Innes Research station and their efforts are greatly appreciated and in particular the decisions they needed to make under difficult and challenging environmental conditions are acknowledged. In particular thanks goes to Jason Siddell (LLS, formerly NSW DPI) for his assistance in the objective measurement of muscle score.

Brad Walmsley, Hutton Oddy, and Boyd Gudex (NSW DPI) for significant roles in developing models to be implemented into BeefSpecs and David Mayer (QDPI) for biometrical assistance.

12 References

Bibby J, Toutenburg H (1977) ‘Prediction and improved estimation in linear models.’ (John Wiley & Sons and Akademie-Verlag Berlin: German Democratic Republic)

Cafe LM, McKiernan WA and Robinson DL (2014) Heritability of muscle score and genetic and phenotypic relationships with weight, fatness and eye muscle area in beef cattle. *An*imal Production Science **54**(9) 1443-1448

Dicker RW, Ayres JF, McPhee MJ, Robinson DL, Turner AD, Wolcott ML, Kamphorst PG, Harden S and Oddy VH (2001) Post-weaning growth of cattle in northern New South Wales. 2. Growth pathways of steers. *Australian Journal of Experimental Agriculture* **41**, 971-979.

Doeschl-Wilson, AB, Knap, PW, Kinghorn, BP and van der Steen, HAM (2007) Using mechanistic animal growth models to estimate genetic parameters of biological traits. *Animal* **1**: 489-499.

Haecker TL. (1920) Investigations in beef production. The University of Minnesota, University Farm, St. Paul.

Kinghorn BP, Shepherd RK (1999) Mate selection for the tactical implementation of breeding programs. In 'Proceedings of the Association for the Advancement of Animal Breeding and Genetics'. Mandurah, Western Australia pp. 130-133.

Kinghorn, BP (2012) The use of genomics in the management of livestock. *Animal Production Science* **52**: 78-91.

Mayer DG, Walmsley BJ, McPhee MJ, Oddy VH, Wilkins JF, Kinghorn BP, Dobos RC, McKiernan WA (2013) Integrating stochasticity into the objective function avoids Monte Carlo computation in the optimisation of beef feedlots. *Computers and Electronics in Agriculture* **91**, 30-34.

McKiernan WA and Robards GE (1997) Growth performance of steers sired by high and low muscle scored bulls. In 'Proceedings of the Association for the Advancement of Animal Breeding and Genetics'. 12: 77

McKiernan WA, Gaden B, and Sunstrom B (2007) PrimeFact 340 NSW Agriculture

McPhee, MJ, Oltjen, JW, Fadel, JG, Perry, D and Sainz, RD (2008) Development and evaluation of empirical equations to interconvert between twelfth-rib fat and kidney, pelvic, and heart fat respective fat weights and to predict initial conditions of fat deposition models for beef cattle. *Journal of Animal Science* **86**: 1984-1995.

McPhee MJ, Harden S, Robinson DL, Dicker RW and Oddy VH (2012) Effects of backgrounding and finishing growth rates on P8 fat and intramuscular fat in *Bos taurus* steers. *Animal Production Science* **52**, 354-364.

McPhee MJ and Walmsley BJ (2014) Assessment of compliance in grass-fed cattle and evaluation of increasing accuracy of BeefSpecs inputs. Final Report No. B.SBP.0108, Meat and Livestock Australia, North Sydney.

Moulton CR, Trowbridge PF and Haigh LD (1922) Studies in animal nutrition. I. Changes in form and weight on different planes of nutrition. University of Missouri, College of Agriculture, Agricultural Experimental Station, Research Bulletin 55, Columbia, Missouri.

Price, K and Storn, R (1997) Differential Evolution - A simple evolution strategy for fast optimisation. *Dr Dobb's Journal* **264**: 18-24.

Tedeschi, L. (2006). Assessment of the adequacy of mathematical models. *Agricultural Systems* **89** : 225 – 247.

Upton W, Burrow HM, Dundon A, Robinson DL and Farrell EB (2001) CRC Breeding program design, measurements and database: Methods that underpin CRC research results. *Australian Journal of Experimental Agriculture* **41**, 943-952.

Walmsley, BJ, Wolcott, ML and McPhee, MJ (2010) Modelling the relationship between scanned rump and 12th-rib fat in young temperate and tropical bovines: Model development and evaluation. *Journal of Animal Science* **88**: 1848-1859.

Walmsley, BJ, Kinghorn, BP, Oddy, VH and McPhee, MJ (2013) A preliminary evaluation of a method for incorporating genetic information into phenotypic prediction models. Proceedings of the Association for the Advancement of Animal Breeding and Genetics **20**: 527 – 530.

Walmsley BJ, McPhee MJ and Oddy VH (2014) Development of the BeefSpecs model to assist decision making to increase compliance rates with beef carcase specifications. *Animal Production Science special issue of the 8th International Workshop on Modelling Nutrient Digestion & Utilization in Farm Animals.* **54:** 2003-2010

Watson, R, Polkinghorne, R and Thompson J (2008) Development of the Meat Standards Australia (MSA) prediction model for beef palatability. *Australian Journal of Experimental Agriculture* **48:** 1368-1379.

13 Appendix 1. On-farm data, carcase traits, preliminary statistics and summary of dataset1

Tables 1 to 16 of on-farm and carcase traits of the serial slaughter study and figures 1 to 16 of the preliminary statistical analysis. Tables 17 and 18 of dataset 1

On-farm data

Table 1 : Summary of age in days at each recording date

Sex		Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	37	25	12
	Max	268	384	468	552	647
	Min	210	326	410	494	594
	Mean	244.7	360.7	446.0	528.4	626.3
	Std Dev.	13.9	13.9	13.8	15.9	16.3
Steer	n	78	78	58	38	19
	Max	267	383	466	550	648
	Min	206	322	406	490	588
	Average	245.7	361.7	444.2	528.2	622.8
	Std Dev.	13.9	13.9	14.1	14.9	16.7
Both Sexes	n	127	127	95	63	31
	Max	268	384	468	552	648
	Min	206	322	406	490	588
	Mean	245.3	361.3	444.9	528.3	624.2
	Std Dev.	13.9	13.9	13.9	15.1	16.4

Table 2: Summary of liveweights (kg) for birth, weaning and subsequent recording dates

Sex		Birth Weight	Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	49	37	25	12
	Max	48	328	344	410	470	640
	Min	29	164	188.5	241	309	450
	Mean	37.0	248.8	266.1	332.7	398.4	552.5
	SD	4.5	36.4	31.1	33.6	41.6	60.8
Steer	n	78	78	78	58	38	19
	Max	49	351	394	440	538	740
	Min	30	193	255	325	410	544
	Mean	40.7	280.3	325.2	387.2	475.4	633.1
	SD	4.5	33.8	29.1	29.1	30.7	49.1
Both Sexes	n	127	127	127	95	63	31
	Max	49	351	394	440	538	740
	Min	29	164	188.5	241	309	450
	Mean	39.3	268.2	302.4	366.0	444.8	601.9
	SD	4.9	38.0	41.5	40.7	51.7	66.3

Table 3: Summary of ultrasound scanning of P8 fat (mm) at weaning and subsequent recording dates

Sex		Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	37	25	12
	Max	13	7	10	16	20
	Min	2	1	3	6	13
	Mean	5.3	3.5	5.7	10.0	16.3
	SD	2.0	1.2	1.6	2.5	2.4
Steer	n	78	78	58	38	19
	Max	9	7	7	11	17
	Min	1	1	2	4	10
	Mean	4.4	3.2	4.0	6.9	13.4
	SD	1.7	1.1	1.2	1.8	2.3
Both Sexes	n	127	127	95	63	31
	Max	13	7	10	16	20
	Min	1	1	2	4	10
	Mean	4.7	3.3	4.7	8.1	14.5
	SD	1.8	1.1	1.6	2.6	2.7

Table 4: Summary of ultrasound scanning of rib rat (mm) at weaning and subsequent recording dates

Sex		Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	37	25	12
	Max	8	6	6	9	14
	Min	1	1	2	4	10
	Mean	3.8	3.1	4.1	6.4	11.3
	SD	1.4	1.1	1.0	1.0	1.4
Steer	n	78	78	58	38	19
	Max	7	6	6	8	14
	Min	1	1	2	3	7
	Mean	3.2	2.7	3.4	5.4	10.2
	SD	1.3	0.9	0.9	1.3	2.0
Both Sexes	n	127	127	95	63	31
	Max	8	6	6	9	14
	Min	1	1	2	3	7
	Mean	3.4	2.9	3.7	5.8	10.6
	SD	1.4	1.0	1.0	1.3	1.8

Table 5: Summary of ultrasound scanning of intramuscular fat (%) at recording dates

Sex		11/11/13	10/2/14	19/5/14
Heifer	n	37	25	12
	Max	6.2	7	7.7
	Min	2.6	4.7	5.8
	Mean	4.8	5.9	7.1
	SD	0.8	0.7	0.6
Steer	n	58	38	19
	Max	5.6	6.3	7.8
	Min	2.1	3.8	5.5
	Mean	4.2	5.1	6.6
	SD	0.8	0.6	0.6
Both Sexes	n	95	63	31
	Max	6.2	63	7.8
	Min	2.1	7	5.5
	Mean	4.5	3.8	6.8
	SD	0.9	5.4	0.7

Table 6: Summary of ultrasound scanning of eye muscle area (cm^2) at weaning and subsequent recording dates

Sex		Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	37	25	12
	Max	56	57	67	76	84
	Min	29	33	46	57	67
	Mean	40.8	44.0	56.1	62.0	76.4
	SD	6.7	4.7	5.4	4.4	4.7
Steer	n	78	78	58	38	19
	Max	68	64	69	78	92
	Min	32	41	49	62	73
	Mean	47.7	50.6	59.6	67.0	83.7
	SD	7.9	4.2	4.3	3.6	5.8
Both Sexes	n	127	127	95	63	31
	Max	68	64	69	78	92
	Min	29	33	46	57	67
	Mean	45.1	48.0	58.2	65.0	80.9
	SD	8.2	5.4	5.0	4.6	6.4

Table 7. Summary of numerical muscle scores (1 to 15 scale; A+ = 15, C = 8, E- = 1) at weaning and subsequent recording dates

Sex		Wean (2/5/13)	26/8/13	11/11/13	10/2/14	19/5/14
Heifer	n	49	49	37	25	12
	Max	12	11	11	10	10
	Min	2	2	1	3	4
	Mean	7.0	7.4	7.1	7.2	7.0
	SD	2.3	1.8	2.3	1.9	1.8
Steer	n	78	78	58	38	19
	Max	13	13	13	13	13
	Min	3	3	2	2	4
	Mean	8.3	8.5	8.1	7.8	8.1
	SD	3.1	2.6	3.2	2.2	2.2
Both Sexes	n	127	127	95	63	31
	Max	13	13	13	13	13
	Min	2	2	1	2	4
	Mean	7.8	8.1	7.7	7.6	7.7
	SD	2.9	2.4	2.9	2.1	2.1

Carcase traits

Table 8. Summary of ossification scores for each of the 4 slaughters

		Kill 1 (28/08/13)	Kill 2 (20/11/13)	Kill 3 (12/02/14)	Kill 4 (21/05/14)
Heifer	n	12	12	13	12
	Max	150	150	180	230
	Min	100	120	150	150
	Mean	123.3	131.7	155.4	179.2
	SD	14.4	9.4	8.8	23.1
Steer	n	20	20	19	19
	Max	110	140	150	150
	Min	100	100	120	110
	Mean	103.0	114.5	137.9	135.3
	SD	4.7	12.3	9.8	9.0
Both Sexes	n	32	32	32	31
	Max	150	150	180	230
	Min	100	100	120	110
	Mean	110.6	120.9	145.0	152.3
	SD	13.7	14.0	12.7	26.8

Table 9. Summary of hot carcase weight (kg) for each of the 4 slaughters

		Kill 1 (28/08/13)	Kill 2 (20/11/13)	Kill 3 (12/02/14)	Kill 4 (21/05/14)
Heifer	n	12	12	13	12
	Max	186	215	256	361
	Min	119	155	163	253
	Mean	140.9	176.7	212.7	312.7
	SD	22.1	17.0	25.7	32.9
Steer	n	20	20	19	19
	Max	206	228	273	404
	Min	138	170	208	306
	Mean	169.6	199.8	243.9	358.3
	SD	17.7	15.9	17.4	26.3
Both Sexes	n	32	32	32	31
	Max	206	228	273	404
	Min	119	155	163	253
	Mean	158.8	191.1	231.3	340.6
	SD	23.7	19.7	26.0	36.4

Table 10. Summary of carcass rib fat (mm) for each of the 4 slaughters

		Kill 1 (28/8/13)	Kill 2 (20/11/13)	Kill 3 (12/12/13)	Kill 4 (21/3/14)
Heifer	n	12	12	13	12
	Max	3	5	7	12
	Min	1	1	2	9
	Mean	1.3	3.0	4.9	10.8
	SD	0.8	1.2	1.6	1.1
Steer	n	20	20	19	19
	Max	3	4	7	13
	Min	1	1	1	5
	Mean	1.6	2.5	3.6	9.1
	SD	0.7	1.0	1.6	2.3
Both Sexes	n	32	32	32	31
	Max	3	5	7	13
	Min	1	1	1	5
	Mean	1.5	2.7	4.2	9.7
	SD	0.7	1.1	1.7	2.1

Table 11. Summary of carcass P8 fat (mm) for each of the 4 slaughters

		Kill 1 (28/08/13)	Kill 2 (20/11/13)	Kill 3 (12/02/14)	Kill 4 (21/05/14)
Heifer	n	12	12	13	12
	Max	5	7	15	27
	Min	1	1	3	15
	Mean	2.2	3.2	10.7	20.2
	SD	1.4	2.0	3.3	4.3
Steer	n	20	20	19	19
	Max	3	6	10	26
	Min	1	1	3	10
	Mean	1.7	4.5	5.9	15.2
	SD	0.8	2.1	2.5	4.3
Both Sexes	n	32	32	32	31
	Max	5	7	15	27
	Min	1	1	3	10
	Mean	1.8	3.2	7.9	17.13
	SD	1.1	2.0	3.7	4.9

Table 12. Summary of eye muscle area (cm^2) for each of the 4 slaughters

		Kill 1 (28/08/13)	Kill 2 (20/11/13)	Kill 3 (12/02/14)	Kill 4 (21/05/14)
Heifer	n	12	12	13	12
	Max	68	69	94	99
	Min	38	44	58	74
	Mean	47.3	54.3	64.5	80.4
	SD	8.3	7.3	9.4	6.6
Steer	n	20	20	19	19
	Max	77	69	78	110
	Min	45	43	56	72
	Mean	54.9	58.2	65.4	85.3
	SD	9.6	5.9	6.4	8.7
Both Sexes	n	32	32	32	31
	Max	77	69	94	110
	Min	38	43	56	72
	Mean	52.0	56.7	65.0	83.4
	SD	9.7	6.6	7.6	8.2

Table 13. Summary of USDA marble scores for each of the 4 slaughters

		Kill 1 (28/08/13)	Kill 2 (20/11/13)	Kill 3 (12/02/14)	Kill 4 (21/05/14)
Heifer	N	12	12	13	12
	Max	350	360	410	510
	Min	130	260	200	330
	Mean	200.8	308.3	286.9	400.8
	SD	69.3	31	73.5	54.0
Steer	N	20	20	19	19
	Max	220	360	360	480
	Min	120	190	190	290
	Mean	154.5	278.0	284.7	355.8
	SD	34.4	46.0	54.3	46.3
Both Sexes	N	32	32	32	31
	Max	350	360	410	510
	Min	120	190	190	290
	Mean	171.9	289.4	285.6	373.2
	SD	54.3	43.1	61.7	53.4

Table 14. Dataset 1: Summary statistics of liveweight (LW, kg), P8 fat (mm), hot standard carcase weight (HSCW) and ossification (OSS) of heifers (n=50) for each of the recorded dates

Date	Trait	min	Max	mean	SD
23/01/2013	LW	198	359	273	41.6
	P8 fat	3	14	7	2.2
16/04/2013	LW	209	346	276	39.4
	P8 fat	3	9	6	1.3
25/07/2013	LW	316	491	416	47.9
	P8 fat	7	20	12	3.1
4/09/2013	LW	354	552	450	50.5
	P8 fat	5	26	13	4.2
15/09/2013	HSCW	193	303	242	28.7
	OSS	130	160	141	6.6

Table 15. Dataset 2: Summary statistics of liveweight (LW, kg), P8 fat (mm), hot standard carcase weight (HSCW) and ossification (OSS) of steers (n=81)

Date		min	max	mean	SD
16/04/2008	LW	131	359	289	41.3
	P8 fat	2	9	4	1.6
Slaughter	HSCW	202.8	355	271	25.3
	P8 fat	4	18	12	3.4
	OSS	110	150	136	10.3

Table 16. Dataset 3: Summary statistics of liveweight (LW, kg), P8 fat (mm), hot standard carcase weight (HSCW) and ossification (OSS) of steers (n=24)

Day		min	max	mean	SD
0	LW	237	353	293	31.5
	P8 fat	3	9	5	1.3
195	LW	374	568	466	54.3
	P8 fat	7	13	9	1.5
286	LW	424	622	536	59.1
	P8 fat	9	20	13	2.8
332	LW	438	652	566	52.6
	P8 fat	7	25	14	4.4
332	HSCW	239	363	317	33.2
	OSS	130	160	146	6.5

Table 17. Live animal traits (last recording prior to slaughter) of the 2011 NSW DPI muscling herd (dataset 1)

		N	**Min**	**Max**	**Avg**	**SD**
Age	GRAIN	37	612	690	659.5	16.3
(days)	GRASS	40	519	592	560.6	16.8
	Grand Total	**77**	**519**	**690**	**608.1**	**52.4**
Weight	GRAIN	37	526	736	614.4	50.7
(kg)	GRASS	40	391	546	458.7	30.8
	Grand Total	**77**	**391**	**736**	**533.5**	**88.5**
P8 fat	GRAIN	37	7	22	15.4	3.7
(mm)	GRASS	40	3	16	7.6	2.6
	Grand Total	**77**	**3**	**22**	**11.3**	**5.0**
rib fat	GRAIN	37	6	18	10.4	2.7
(mm)	GRASS	40	3	10	5.4	1.7
	Grand Total	**77**	**3**	**18**	**7.8**	**3.4**
IMF	GRAIN	37	4.5	7.0	5.8	0.7
(%)	GRASS	37	2.3	5.5	4.1	0.6
	Grand Total	**74**	**2.3**	**7.0**	**4.9**	**1.1**
EMA	GRAIN	37	63	94	78.2	8.3
(cm3)	GRASS	40	44	78	58.2	6.8
	Grand Total	**77**	**44**	**94**	**67.8**	**12.6**
Muscle	GRAIN	37	4	12	8.2	2.5
(score)	GRASS	40	3	14	8.0	2.9
	Grand Total	**77**	**3**	**14**	**8.1**	**2.7**

Table 18. Carcase traits of dataset 1

		n	Min	Max	Avg	SD
Age (days)	GRAIN	37	615	693	662.5	16.3
	GRASS	40	544	617	585.6	16.8
	Grand Total	**77**	**544**	**693**	**622.6**	**42.0**
Carcase Wgt (kg)	GRAIN	37	312	438	363.4	31.0
	GRASS	40	223	313	258.4	19.9
	Grand Total	**77**	**223**	**438**	**308.8**	**58.7**
P8 fat (mm)	GRAIN	37	7	26	15.8	4.7
	GRASS	40	3	15	8.2	3.7
	Grand Total	**77**	**3**	**26**	**11.8**	**5.7**
rib fat (mm)	GRAIN	37	6	15	9.9	2.5
	GRASS	40	1	9	4.9	1.7
	Grand Total	**77**	**1**	**15**	**7.3**	**3.3**
MSAMB (score)	GRAIN	37	280	580	393.8	69.7
	GRASS	40	190	430	328.0	54.6
	Grand Total	**77**	**190**	**580**	**359.6**	**70.2**
EMA (cm3)	GRAIN	37	69	94	80.5	6.7
	GRASS	40	51	84	66.7	7.5
	Grand Total	**77**	**51**	**94**	**73.3**	**9.9**

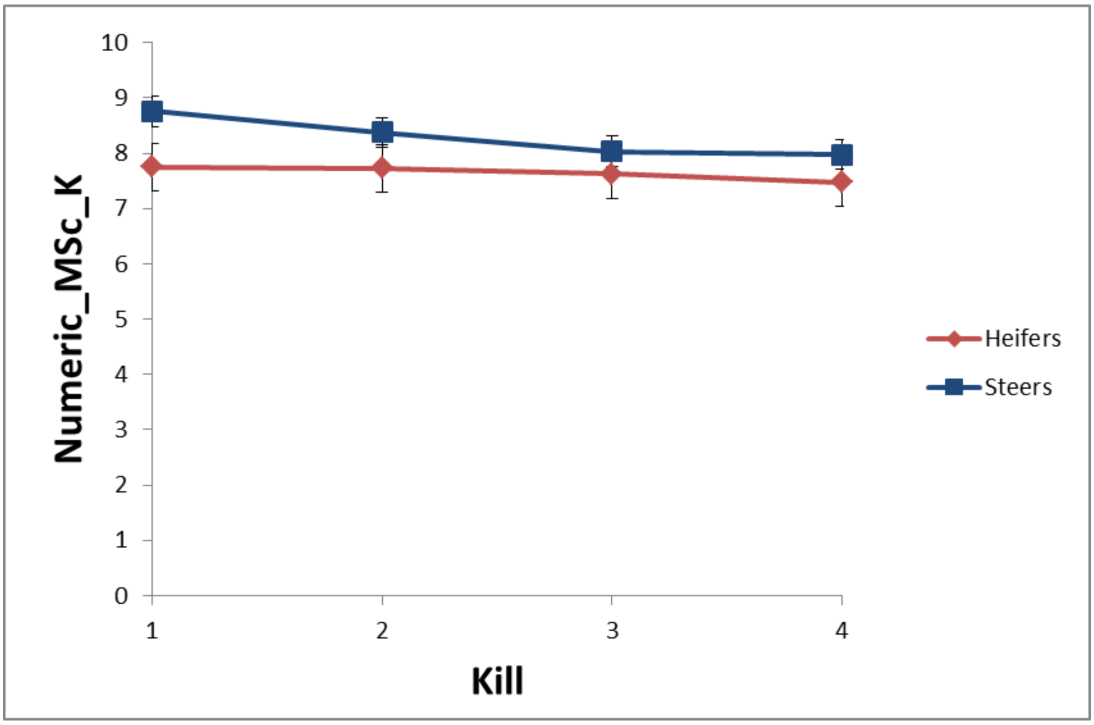


Figure 1. Relationship of numerical muscle score and sex across kills 1 to 4

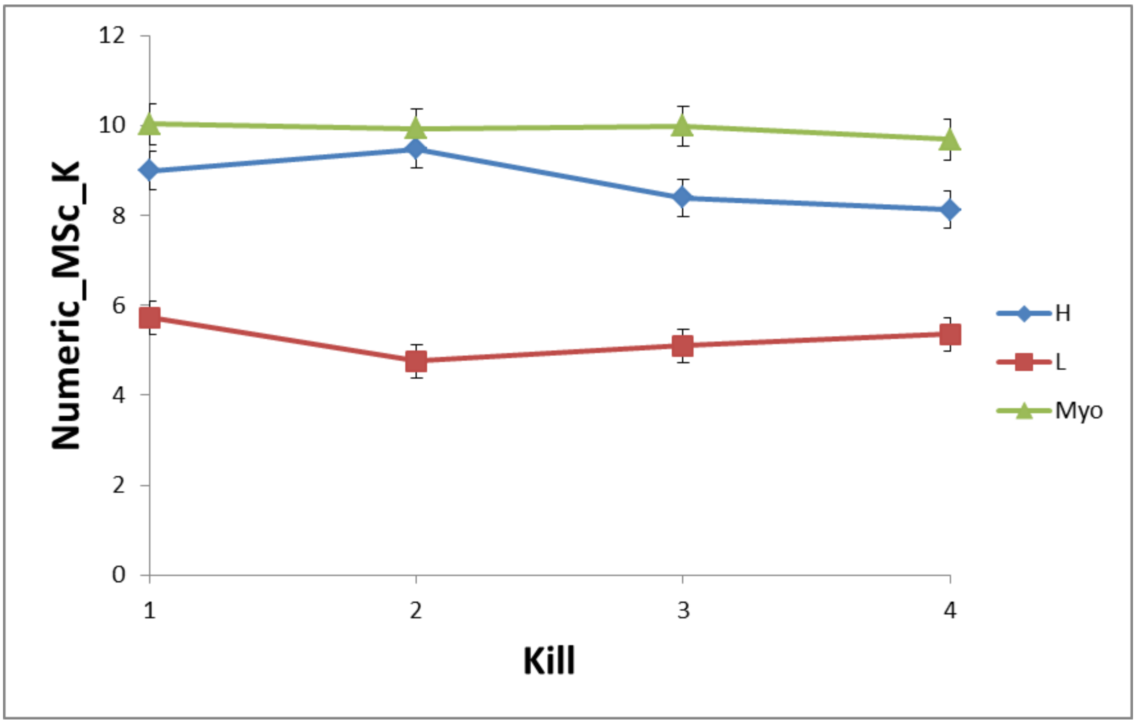


Figure 2. Relationship of numerical muscle score and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across slaughters 1 to 4

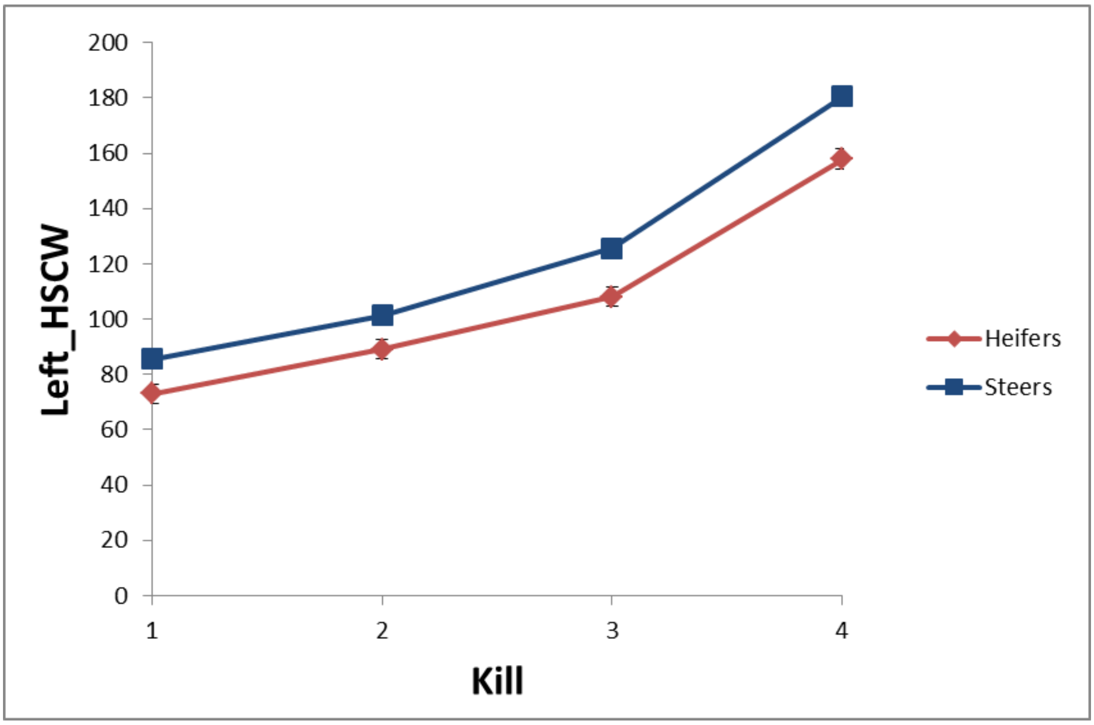


Figure 3. Relationship of left hot standard carcase weight (HSCW, kg) and sex across kills 1 to 4

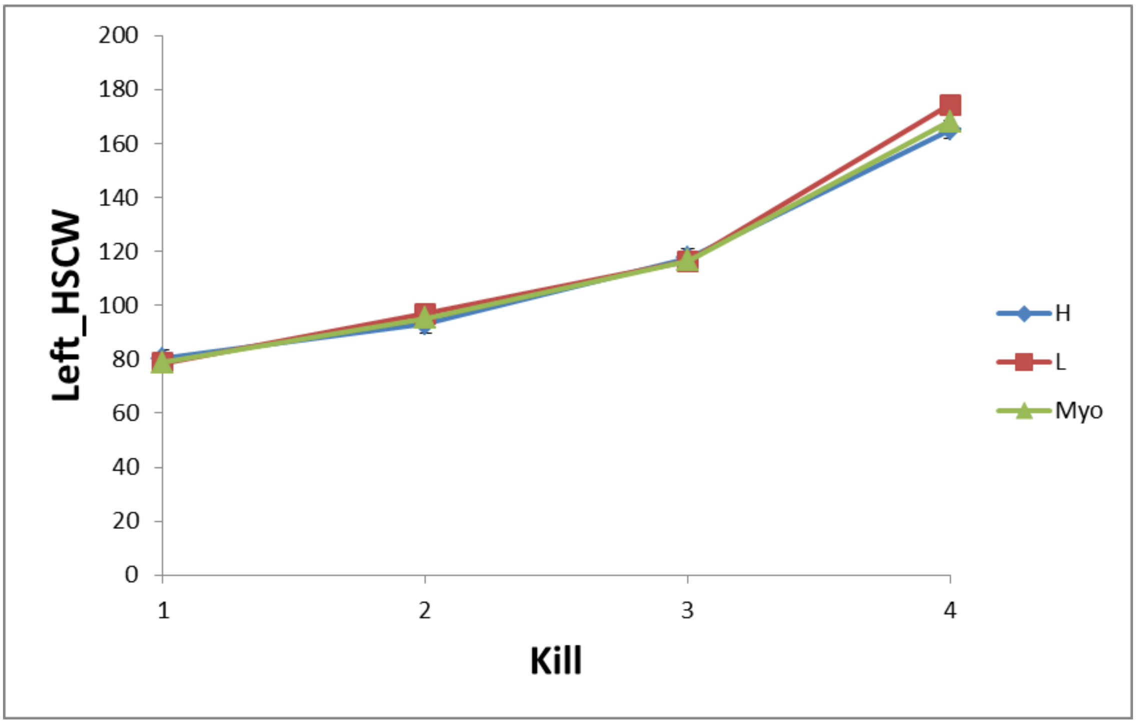


Figure 4. Relationship of left hot standard carcase weight (HSCW, kg) and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

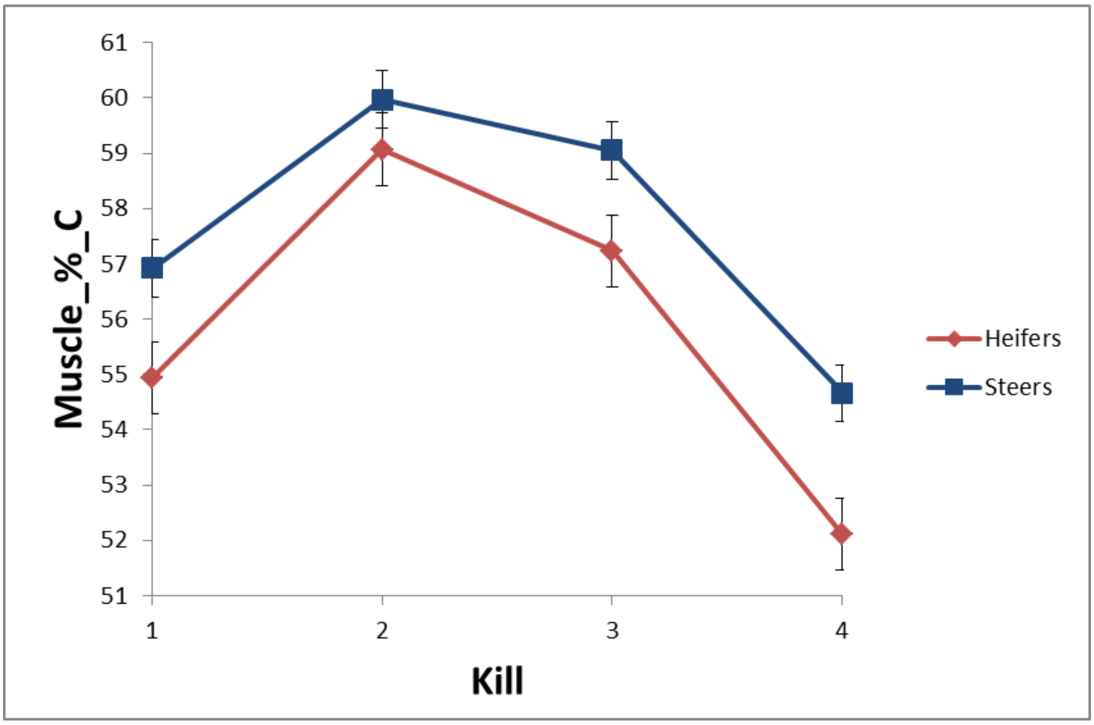


Figure 5. Relationship of muscle (%) and sex across kills 1 to 4

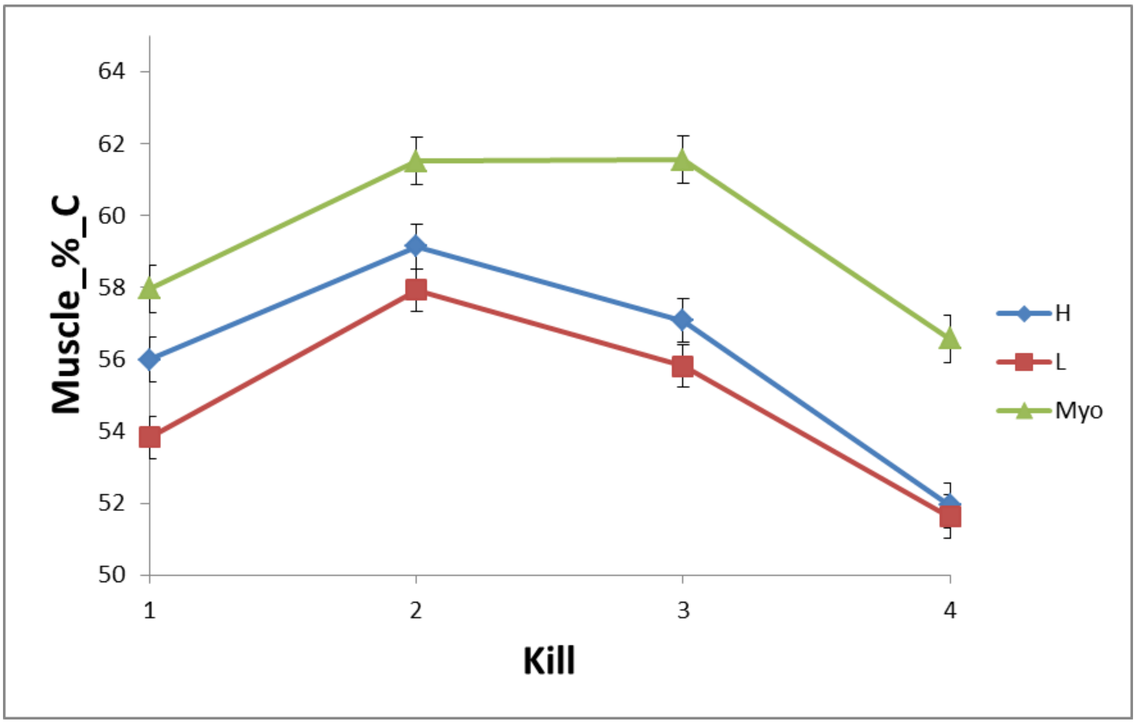


Figure 6. Relationship of muscle (%) and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

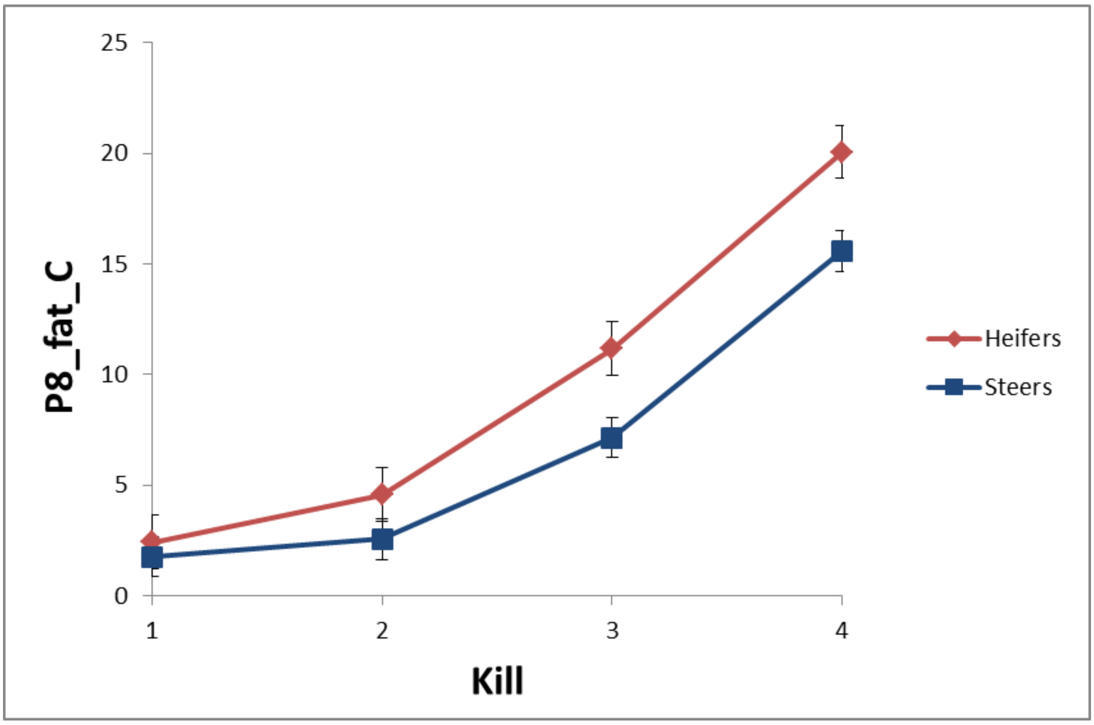


Figure 7. Relationship of P8 fat (mm) and sex across kills 1 to 4

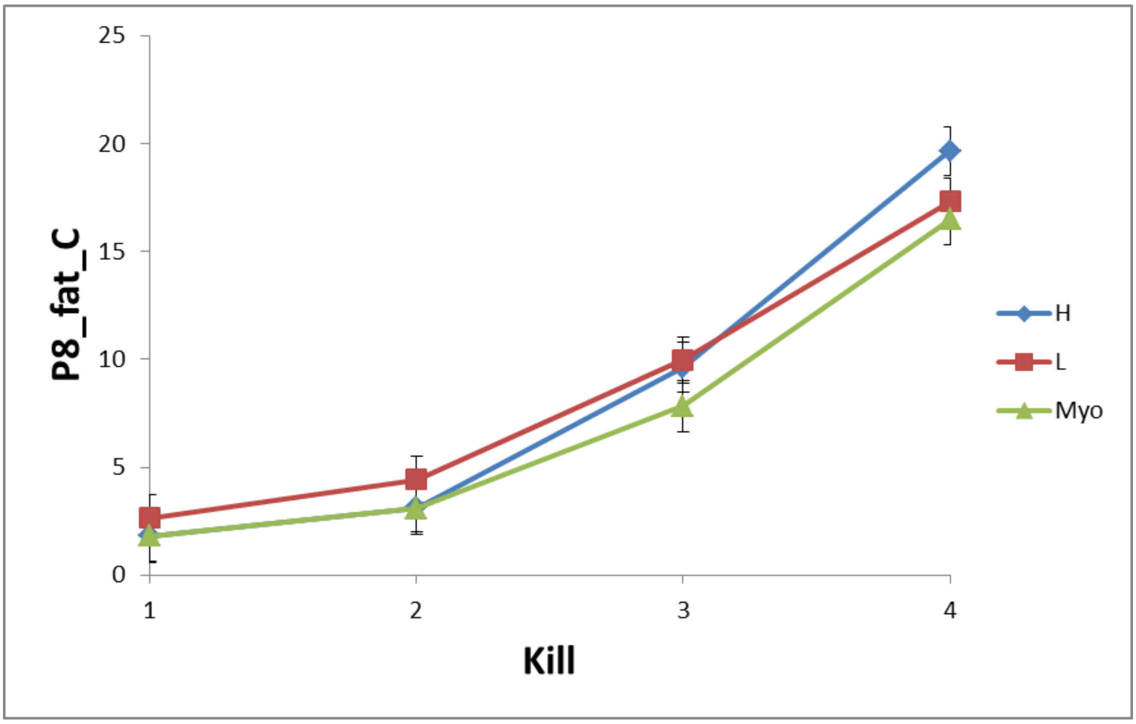


Figure 8. Relationship of P8 fat (mm) and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

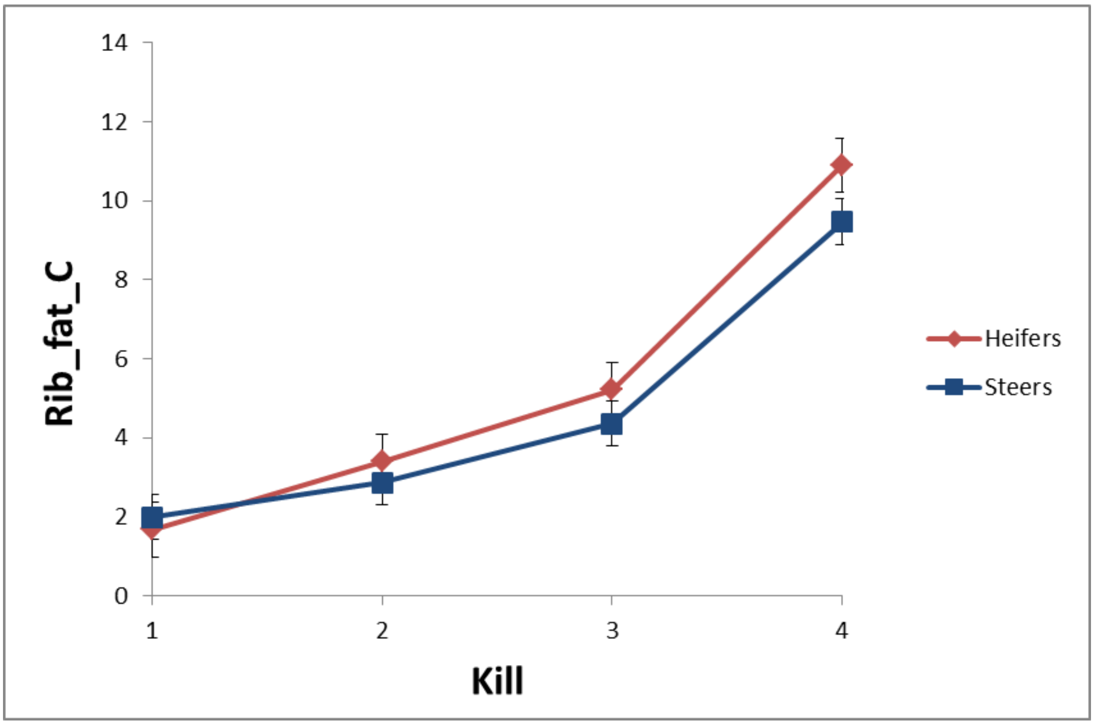


Figure 9. Relationship of rib fat (mm) and sex across kills 1 to 4

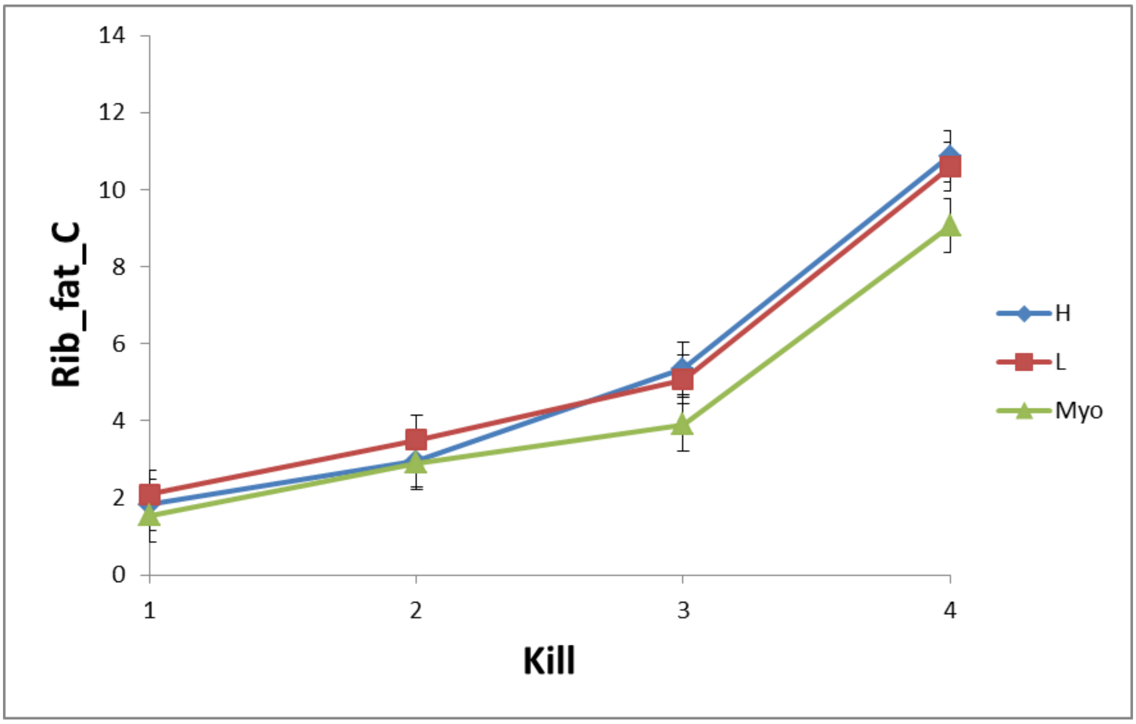


Figure 10. Relationship of Rib fat (mm) and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

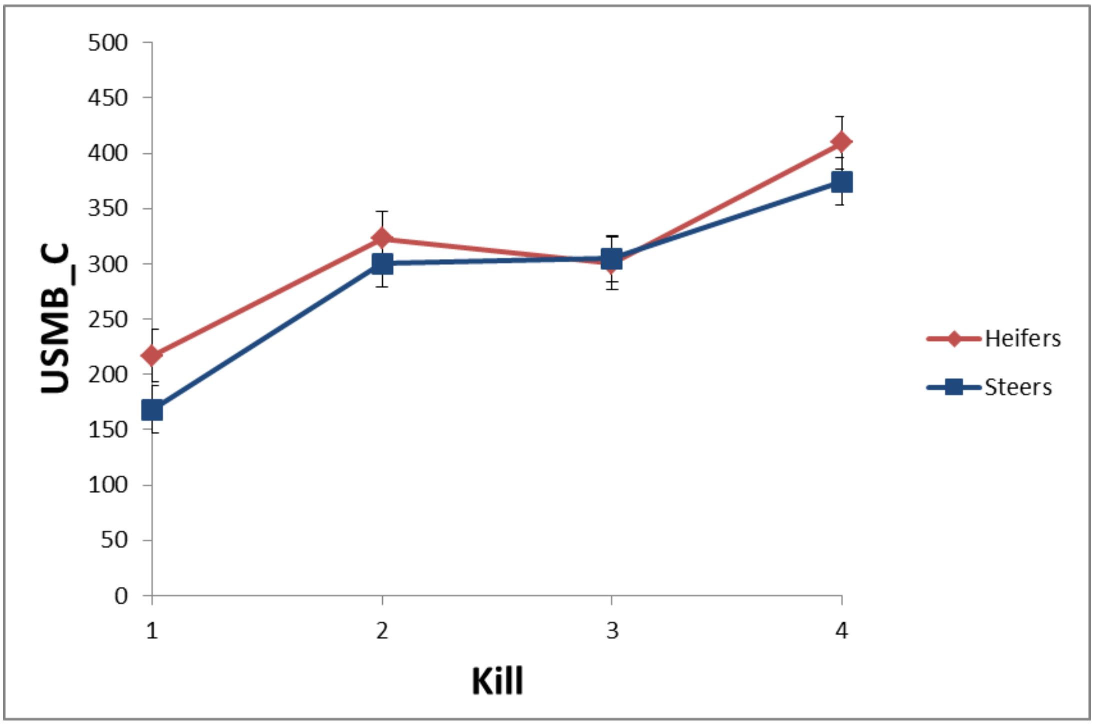


Figure 11. Relationship of USDA marble score and sex across kills 1 to 4

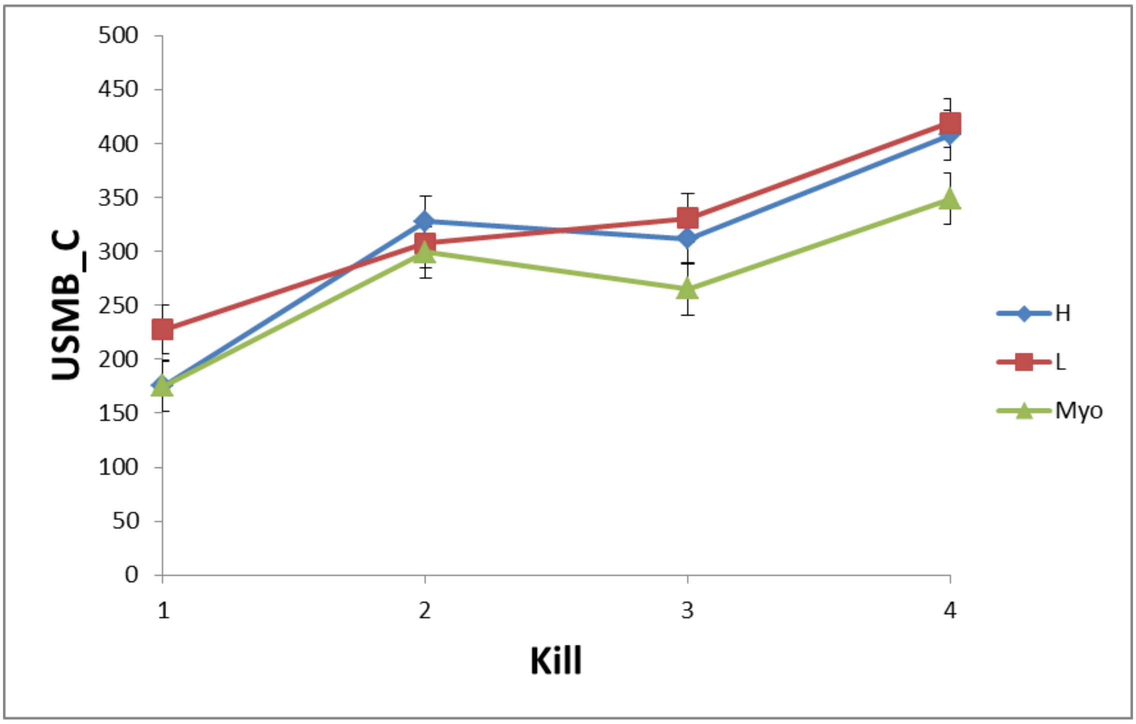


Figure 12. Relationship of marbling score and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

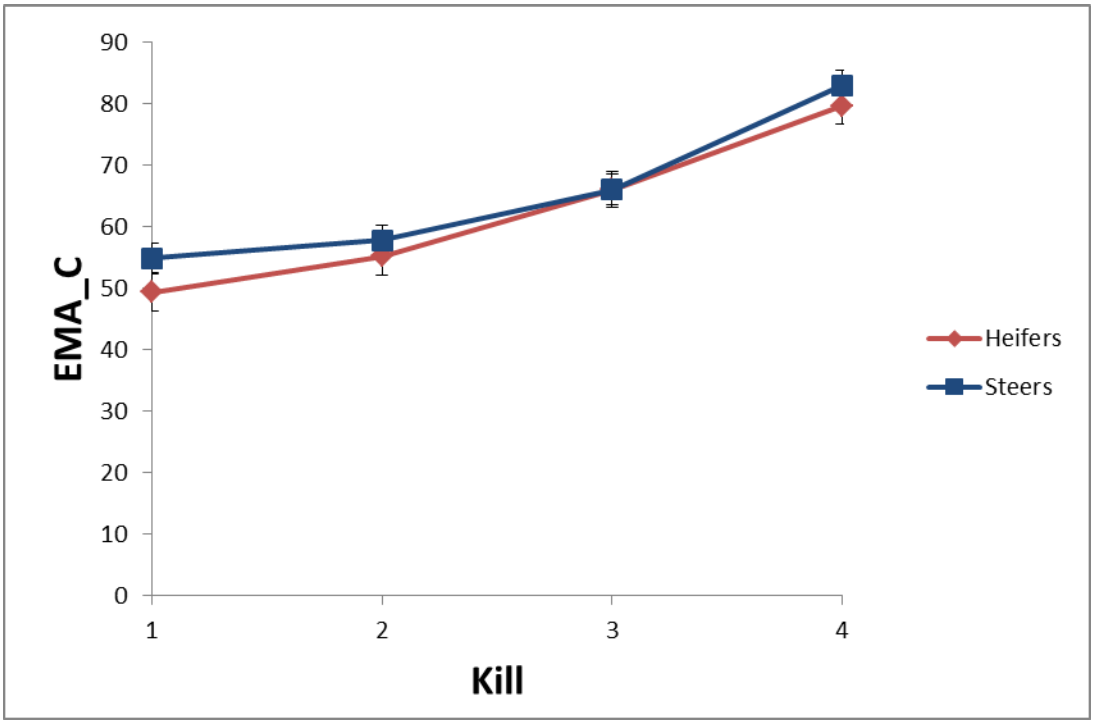


Figure 13. Relationship of eye muscle area (EMA, cm^2) and sex across kills 1 to 4

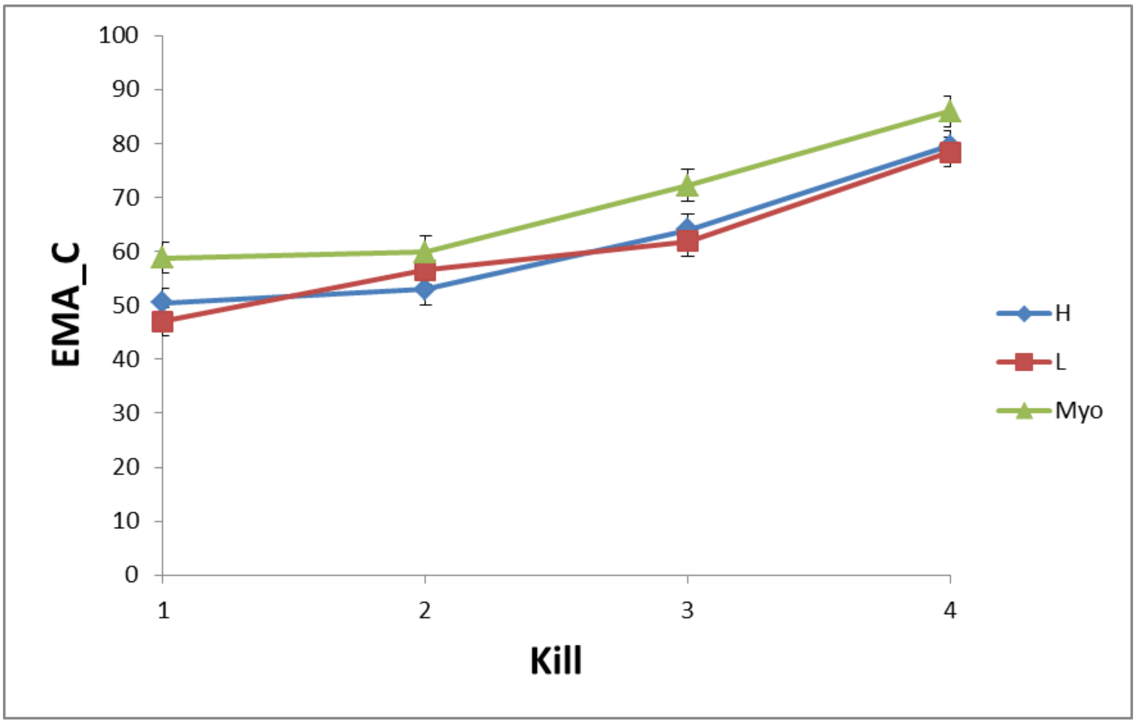


Figure 14. Relationship of eye muscle area (EMA, cm^2) and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

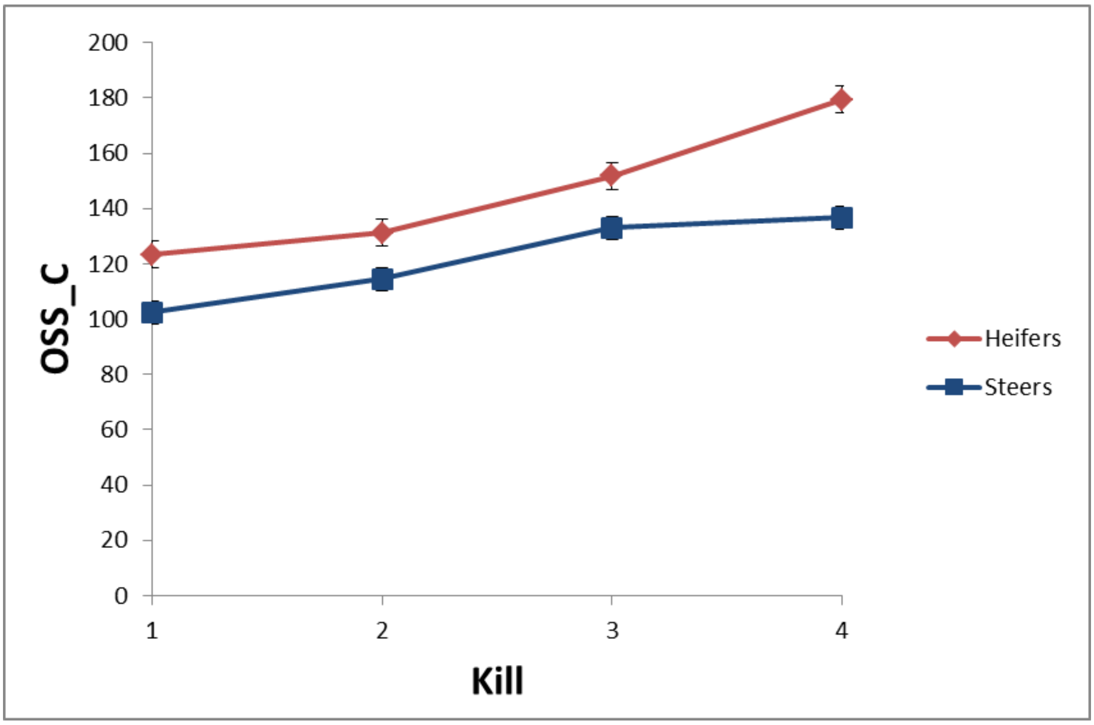


Figure 15. Relationship of ossificaion and sex across kills 1 to 4

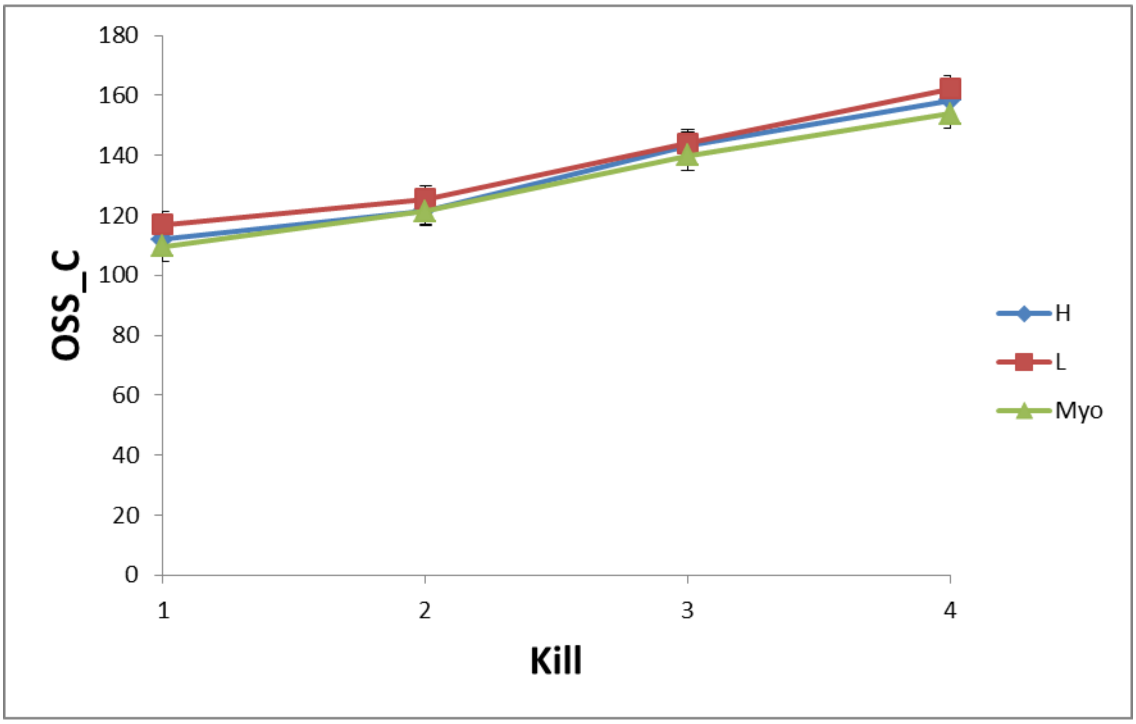


Figure 16. Relationship of ossification and muscle-lines [high (H), low (L), and myostatin (Myo) (see herd details in M&M)] across kills 1 to 4

14 Appendix 2. BeefSpecs Drafting Tool

BEEFSPECS DRAFTING TOOL

The BeefSpecs suite of Tools aims to help producers understand the implications of a range of factors on individual carcase development and subsequent compliance of cattle mobs to market specifications. Knowing the market requirements is an essential part of this process and Beefspecs tools help by predicting the carcase specifications of live animals and enabling users to quantify likely returns.

Information on the way that the Beefspecs Calculator works and how it predicts carcase specifications can be found at http://beefspecs.agriculture.nsw.gov.au/. The associated Tips and Tools give information about the main beef markets, how their specifications differ and how to comply.

The Beefspecs Drafting Tool is complementary to the Calculator and utilises the predicted carcase information for individual animals to sort them into groups. This allows the user to identify the number of animals likely to meet market specifications. For those animals whose carcases fall outside the premium area of the grid, it allows the user to try different management strategies to increase compliance rates or, alternatively, to identify a market with different specifications and estimate the subsequent compliance rate.

The Beefspecs Drafting Tool could be used by Feedlots, beef producers and agricultural consultants to maximise compliance and marketing profit.

Using the BeefSpecs Drafting Tool

The Drafting tool requires the user to enter existing animal data and expected performance information in the Production Inputs screen, pictured below, under a number of sub-headings.

Figure 1. The on-screen display of the 'Production Inputs' tab in the BeefSpecs Drafting tool is used to load data and input information about Performance, Management, and Carcase Specifications (green circles highlight the sections that require inputs and the steps required to draft cattle)

Step 1: Load data

Click on this icon (Figure 1) to Load an Example Dataset in the “Quick Start” option, or to Download a Template under “Upload data”. A downloaded template can be used to input your own data in the correct format, which can then be saved and loaded by choosing “Select data file”.

The data template is an Excel spreadsheet that has the column headings and requires the following information:

- ID (animal identification; no units)
- Frame (Frame score)
- liveweight (kg)
- P8 fat (mm)
- British, Euro and *B. indicus* (estimated breed content- note that the BeefSpecs calculator visual depiction of a beast may be helpful here)

After loading data, a spreadsheet containing individual animal records will be displayed (Figure 1). Click on the column headings in the table to sort the entire dataset, in ascending or descending order. Click the column heading again to restore the data to its original order. The arrows at the bottom of the table scroll through, or proceed directly to either end of, the dataset.

Additional information is then required for the tool to predict animal performance and carcase specifications:

Performance

- growth rate (estimated Mean daily weight gain, kg/hd/day)
- days on feed (number of days on feed, based on a pasture feed budget or a feeding target in a feedlot)
- sex
- dressing percentage (estimated by the user based on fat and muscle score, sex)

Management

- Feed type (grass or grain- note that a diet must consist of at least 70% grain in order to be classified as a grain diet)
- HGP status (Ticking this box to indicate that the stock have been HGP treated will prompt the program to require either an androgen or oestrogen based HGP)

Carcase Specifications

Access these figures from the grid of one or more potential processors or feedlots. Note that there may be other specifications, such as dentition, meat colour etc, not accounted for here.

- Minimum and maximum HSCW (hot standard carcase weight, kg)
- Minimum and maximum carcase P8 fat(mm)

Hold the cursor over the input boxes in the Performance, Management and Carcase Specification sections to access brief explanations of the required input. Additional information on performance and management inputs are available in the Tips and Tools of the BeefSpecs calculator.

Step 2: Draft

Once all the data has been entered, click the “Step 2 Draft” button to go to the Performance screen.

Performance tab screen

The liveweight, HSCW and estimated P8 fat for each of the animals are reported in the predicted initial performance table (Figure 2). Animals are drafted into Groups, based on their HSCW and P8 fat, respective to the specifications entered.

There are 9 possible carcase groups (Table 1) based on the carcase specification inputs of P8 fat and HSCW (Figure 1). Group 1 contains animals whose carcases are predicted to be below minimum fat and weight specs, Group 2 will be within the required fat range but below the minimum weight specified, and so on up to Group 9 (Table 1). Group 5 is the only group that contains carcases that comply with both the specified HSCW and P8 fat.

Table 1. Group numbers allocated to each carcase indicate whether they are predicted to be below, within or above the specified maximum (max) and minimum (min) Hot Standard Carcase Weight (HSCW) and P8 fat. Green colouring indicates Group 5; those carcases within the specified range for both HSCW and P8 fat.

	Group 3	**Group 6**	**Group 9**
Max P8 fat			
	Group 2	**Group 5**	**Group 8**
Min P8 fat			
	Group 1	**Group 4**	**Group 7**
	Min HSCW	Max HSCW	

Group	Description
1	Below specified HSCW & P8 fat
2	Below specified HSCW but within P8 fat range
3	Below specified HSCW but above specified P8 fat
4	Within specified HSCW but below specified P8 fat
5	Within specified HSCW & P8 fat
6	Below specified HSCW but above specified P8 fat
7	Above specified HSCW but below specified P8 fat
8	Above specified HSCW but within specified P8 fat
9	Above specified HSCW & P8 fat

The compliance grid of the carcases is also shown on the right hand side of the ‘Performance’ tab. Carcases that are compliant are represented by blue dots while non-compliant carcases are represented by orange dots. Each dot is surrounded by a white ‘cloud’ that represents the potential error associated with that dot as a result of differences that may occur between the actual and predicted Mean growth rate and/or dressing %. Placing the cursor over any dot will report the HSCW and P8 fat of that animal and placing the cursor over the white ‘cloud’ will report the Mean HSCW and Mean P8 fat for that group of carcases.

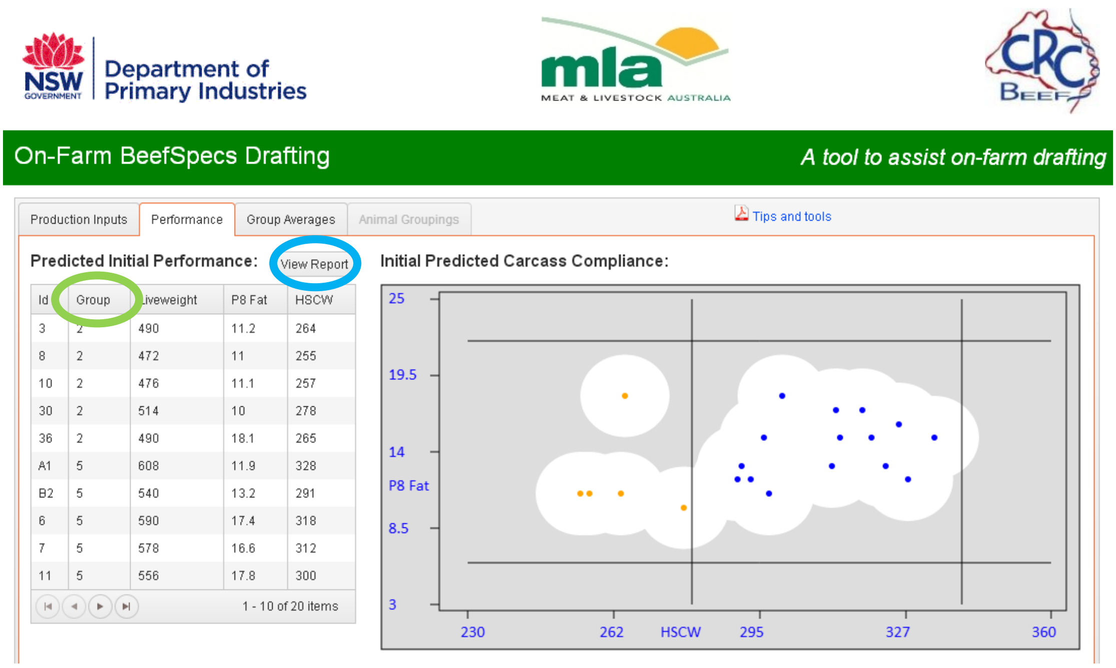
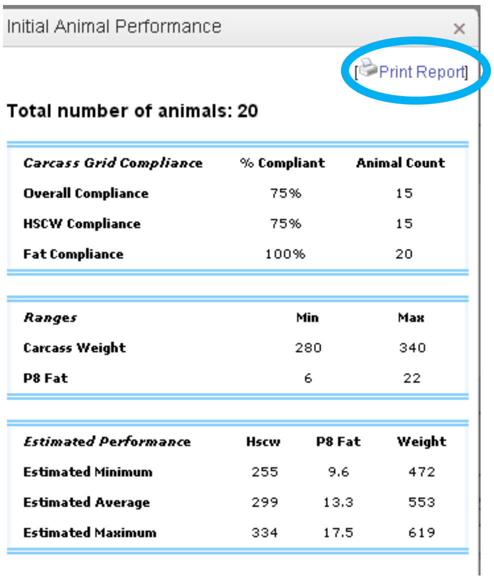


Figure 2. The 'Performance' tab in the BeefSpecs Drafting tool shows the initial performance of carcases as a table and also as a compliance grid. In the table, each carcase has been assigned to a Group (circled in green) based on the specified HSCW and P8 fat. In the graph of P8 fat (mm) versus HSCW (kg), non-compliant carcases are shown as brown dots while compliant carcases (group 5) are shown as blue dots, where horizontal and vertical lines indicate specified P8 fat and HSCW respectively. The white cloud represents the variation around predicted performance. Click on the blue circle to generate compliance summaries

View Report

Within the Performance tab, click the "View Report" button (Figure 2) to generate a carcase compliance summaries for both HSCW and P8 fat. The minimum, Mean and maximum figures for HSCW, P8 fat, and liveweight are also listed (Figure 3).


Initial Animal Performance

[Print Report]

Total number of animals: 20

Carcass Grid Compliance	% Compliant	Animal Count
Overall Compliance	75%	15
HSCW Compliance	75%	15
Fat Compliance	100%	20

Ranges	Min	Max
Carcass Weight	280	340
P8 Fat	6	22

Estimated Performance	Hscw	P8 Fat	Weight
Estimated Minimum	255	9.6	472
Estimated Average	299	13.3	553
Estimated Maximum	334	17.5	619

Figure 3. A summarised report of carcase performance. Click on 'Print Report' (circled in blue) to print.

Group Means tab screen

Carcase group data are shown here (Figure 4). Means for liveweight (kg), P8 fat (mm) and HSCW (kg) for each group are reported. The HSCW, P8 fat and overall compliance rates (%) for the base scenario are summarised in the bottom left corner of the screen (Figure 4).

Click on the arrows, or type in new figures, to adjust the Daily Gain, number of Days on Feed, Feed Type, HGP use or timing of HGP use within each Group (note: Group 5 is already within the specified HSCW and P8 fat ranges) and then select the **"Step 3: Re-Run"** button**.** The compliance rates reported for any Refined Management scenario can then be compared with the Base Scenario. Continue to change management scenarios until a satisfactory compliance is achieved.

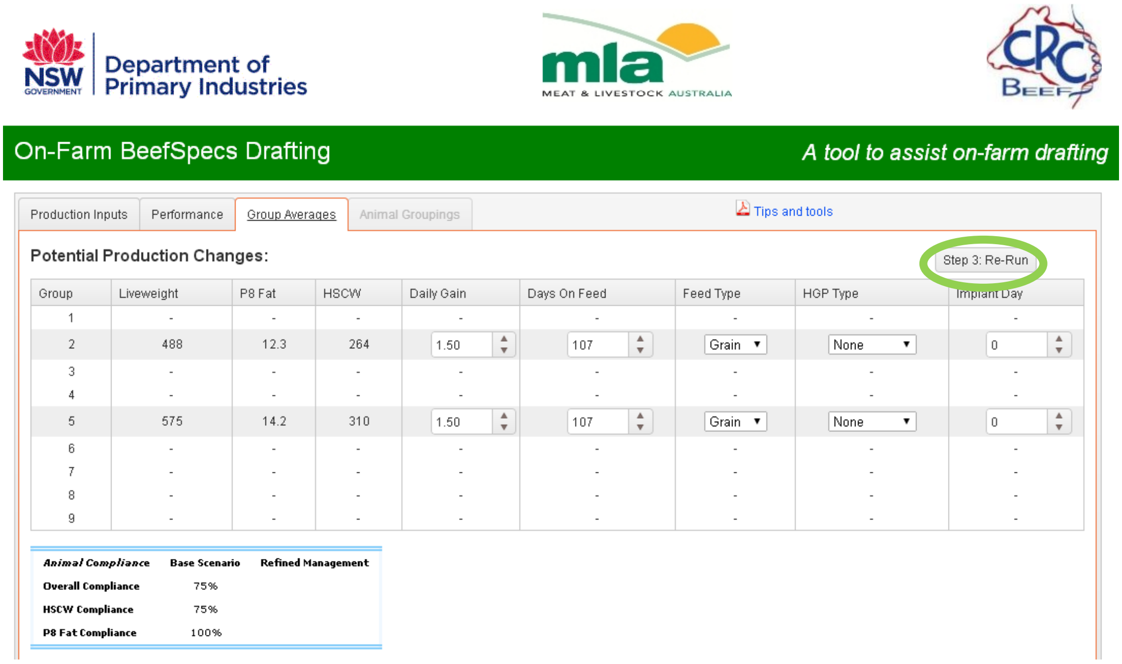


Figure 4. The on-screen display of the 'Group Means' tab reports group liveweight (kg), P8 fat (mm) and HSCW (kg) Means for each group. It also lists the compliance rate (%) for the base scenario for overall, HSCW, and P8 fat and provides input cells for 5 potential production changes [daily gain (kg/hd/day), days on feed, feed type, HGP type, and or implant day]. The "Step 3: Re-Run" button circled in green is used to recalculate compliance after production changes are entered.

An example of Refined Management

In the Example Dataset, there are five carcases that do not comply and these are all in Group 2, i.e. acceptable for P8 fat (Figure 3) but not minimum HSCW. The following steps are an example of potential production changes:

1. Increase the Days on Feed tab to 140 (numbers can be entered or the speed dial arrows can be used to get the desired value).
2. Select the "**Step 3: Re-Run**" button (Figure 4).
3. View results of the re-run. In this example the 'Base Scenario' HSCW compliance was 75% but after increasing the 'Days On Feed' for those animals in Group 2, the 'Refined Management' increases compliance to 100% (Figure 5).

Figure 5. After increasing Days On Feed to 140 for animals in Group 2, and clicking "Step 3: Re-Run", the compliance has improved from75% in the Base Scenario to 100% in the Refined Management scenario.

Animal Groupings tab screen

The Animal Groupings tab (Figure 6) reports the final liveweight (kg), P8 fat (mm), and HSCW (kg) in a table and the final carcase grid in a graphical format, indicating compliance or non-compliance of the drafted cattle into various groups.

The Final Predicted Carcase Compliance graph shows where the carcases fit the specified grid. Those carcases that are predicted not to meet the specifications in the 'Base Scenario' are still identified with brown dots. Predicted carcase data are listed in the 'Animal by Group' table. If there are numerous carcases that do not meet minimum carcase P8 fat requirements then consider the feedlot market where animals are sold on a liveweight basis with minimal fat requirements. Note that liveweight specifications are required for feedlot entry.

Click the 'View Report' button (Figure 6) to view a summary sheet that lists the Mean performance for each of the Groups of animals represented in the Carcase Compliance Graph (Figure 6). Download the Drafting List (Figure 7) for individual carcase data in a spreadsheet.

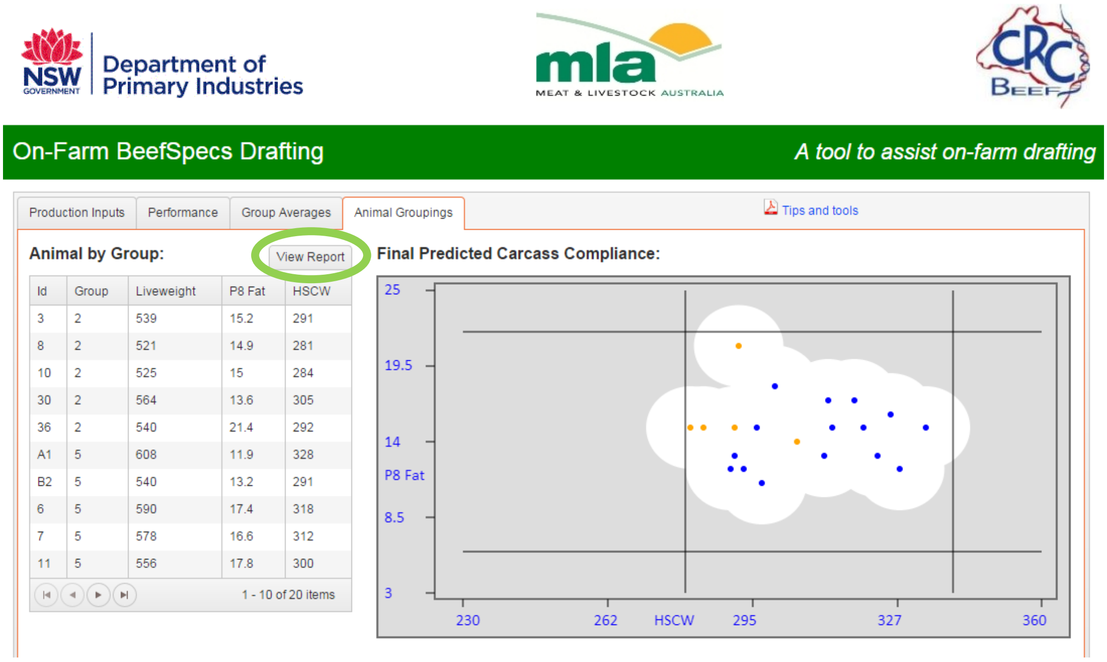


Figure 6. The 'Animal Groupings' tab reports final predicted performance as a table and carcase compliance grid. In the table, the original group of animals is displayed but liveweight, P8 fat and HSCW have been updated according to changes made. In the graph of P8 fat (mm) versus HSCW (kg), carcases that were originally non-compliant are still shown as brown dots but their specifications have been updated. Carcases that were originally compliant (group 5) cattle are still shown as blue dots.

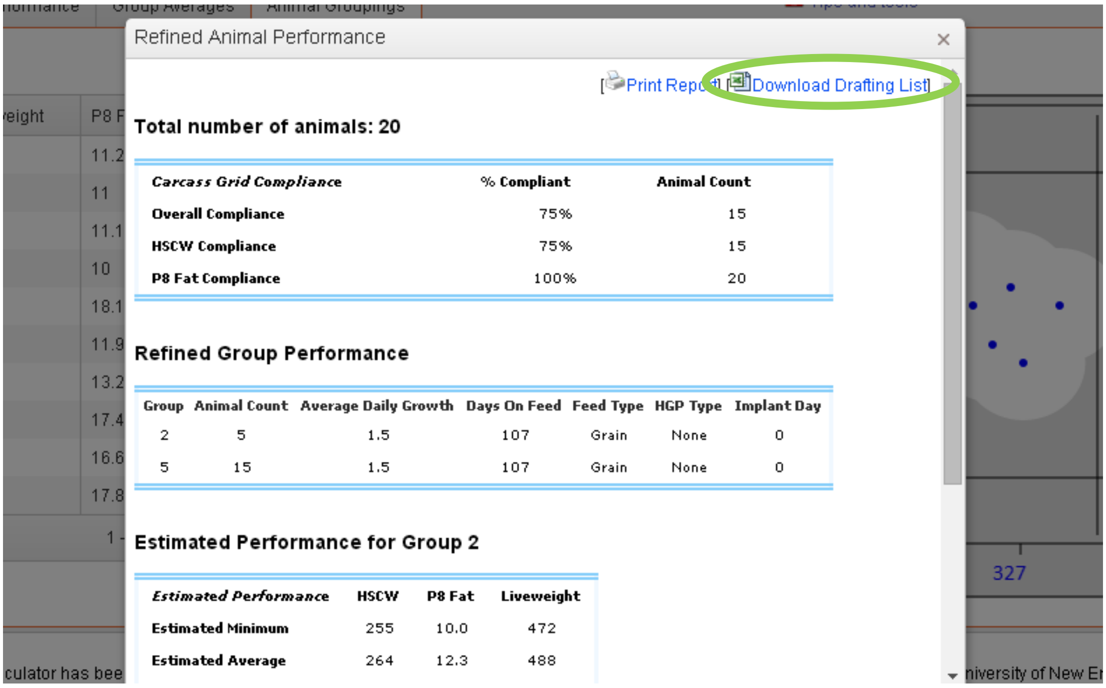


Figure 7. Report of the final refined animal carcase grid compliance (%) including animal numbers, production information on groups and the estimated performance for each group; green circle denotes a drafting list that could be downloaded.

15 Appendix 3. BeefSpecs Workshop

BeefSpecs Workshop Supplementary Notes

BeefSpecs Introduction

Australian beef producers compete with beef from other countries and meat from other species for market share. Supplying beef cuts and carcases that meet specifications of domestic and international customers is crucial in ensuring Australia remains competitive in the international marketplace. Achieving the right combination of weight and fat cover for end users, whilst also complying with age and other restrictions, is a challenge for producers.

Producers can adjust breed composition, animal nutrition and management practices in order to meet this challenge. The BeefSpecs Calculator has been developed to assist beef producers in making production decisions that allow them to manage cattle to better meet specifications for domestic and international markets.

The BeefSpecs Calculator uses readily collected on-farm measures (frame score, fatness, weight) to drive predictions of carcase traits that can be related directly to target market specifications. To obtain accurate and usable information from BeefSpecs, users need to provide the tool with information about the market, animal and pasture characteristics of their production systems.

The following module summaries for BeefSpecs provides basic information on the topics covered, and the data required to maximise benefit from the BeefSpecs fat calculator to understand the key components driving beef production enterprise profitability. Links to further sources of information are also provided.

Market specifications

The domestic and international beef markets that Australian producers supply have a variety of specifications which need to be met to avoid discounts. The specifications that are most obvious to beef producers include weight (live or carcase), fat depth (usually P8), sex, breed and age (dentition). Other important specifications include QA accreditation (e.g. MSA or EU), lifetime traceability, muscle / butt shape, HGP status, pH, meat and fat colour and fat distribution. The specifications for different markets are defined by a combination of requirements. In order to satisfy as many specifications as possible, producers need to manage their breeding and nutrition programs while continually improving their live animal assessment skills to ensure the highest proportion of cattle meet market specifications.

Specific markets

Specifications of some general markets are presented below. Actual specifications within each market vary depending on backgrounder/feedlot/processor. Producers should familiarise themselves with the specific requirements of the purchasers of their livestock. In most cases, processors accept animals or carcases outside prescribed specifications but will discount according to a prescribed price ‘grid’.

Store weaners: There are no sex or breed restrictions or weight or fat specifications, though heavier calves are generally more profitable. Store weaners sold through saleyards of the same condition and weight but one higher muscle score (e.g. B versus C) have been found to attract price premiums of $0.16 to $0.30 per kg liveweight.

Veal: Calves are slaughtered before reaching a maximum carcase weight of 150 kg, generally without being weaned. There is no sex or breed restrictions or minimum fat requirements. Buyers favour calves that are showing “bloom” or in other terms have been grown very quickly with no setback prior to sale. Distinct premiums are payed for high yielding, well muscled vealers.

Local butcher: Milk-fed, grass or grain finished, 0-2 tooth steers or heifers with 150 – 220kg carcase weights are suitable for this market. There may be *Bos indicus* content restrictions and animals with early to moderate maturity patterns are generally suitable. A number of different breeds (e.g. dairy infused cows) and management strategies (e.g. creep feeding) can be used to ensure cattle have 3-8 mm P8 fat at slaughter.

Supermarket: Heifers and steers with 0 (preferred) to 2 permanent teeth and weighing 370-500 kg liveweight are required for this market. Animals can be grass finished or grain fed for up to 70 days and slaughtered with carcase weights of 200-280 kg with 5-16 mm P8 fat. *Bos indicus* content restrictions can vary.

Short fed steer: Generally British, British x European or up to 50% *Bos indicus* steers are preferred weighing 400 - 500kg liveweight with up to 4 permanent teeth, and 3 to 12mm P8 fat (fat score 2-3). Some feedlots and markets take both steers and heifers as well as pure bred *Bos indicus* cattle. Steers are grain fed for 120-150 days and slaughtered at carcase weights of 280 - 400kg destined for Asian supermarkets (Japan and Korea). There is a trend towards heavier carcases and thus heavier feedlot entry weights (380-520 kg liveweight).

Jap Ox: Grass finished steers with carcase weights 300-420kg and 7- 22mm P8 fat are slaughtered for lower value Asian markets. There are no breed or age restrictions for this market although steers with more than 6 permanent teeth can be discounted.

Jap feeder steer (B2-B3): Angus, Shorthorn and their British breed cross steers weighing 380-520 kg are suited to this market. The preference is for lifetime traceability or vendor bred cattle with a maximum of 12 mm P8 fat (fat score 3). Steers are grain fed for 150 – 350 days and slaughtered at carcase weights of 350 – 450kg. To ensure that animals do not get over fat at the end of the long feeding program, moderate and later maturing animals are generally more suitable. A highly marbled carcase is the primary objective.

European Union: This market requires grass or grain finished steers or heifers with carcase weights 260 - 419kg, with up to 4 teeth and 7-22mm P8 fat. Stock must never have been treated with hormonal growth promotants (HGPs). Properties must be EU market accredited to supply cattle. There are no breed restrictions, although mid to later maturing animals (e.g. European breeds and their crosses) enable high carcase weights to be achieved without excess fat penalties, particularly for heifers.

Live Cattle Assessment

Live cattle assessment is a skill that is developed over time through training and practise. It can be performed on an individual animal or a mob or mob segment basis. Live cattle assessment includes assessment of:

- Frame Score
- Fat - P8 rump site (mm)
- Live muscle score (5 or 15 point scale)
- Live weight /Empty weight (kg)
- Dressing percentage (%) and Carcase weight (kg HSCW)
- Dentition

Composition of live animal to product

Liveweight: can be described in several ways. Two descriptions are: Full liveweight (liveweight when taken directly from the paddock) or Empty/shrunk liveweight (liveweight after animals have been removed from feed and water i.e. curfewed). Empty/shrunk liveweight is generally (91-94% of full liveweight).

Hot Standard Carcase Weight (HSCW): this is the weight of the carcase after the head, hooves, hide, offal, blood, gut fill, bruise and standard AUSMEAT trim have been removed.

Saleable meat (primal and 85CL trimmings): this is the saleable product (meat) left after the carcase has been broken down to remove bone and excess fat leaving primal cuts and 85CL.

Frame score

Height of an animal at a given age can be used as a measure of its maturity type, or growth potential. Frame score is assessed in a range from 1 to 11:

- Frame score 1-3 - Early maturing - small frame
- Frame score 4-6 - Moderate maturing—average frame
- Frame score 7-8 - Late maturing—large frame
- Frame score 9-11 - Very late maturing—extreme frame

The recommended point for height measurement is a point directly over the hips from a level surface (Figure 1). It is measured in centimetres.

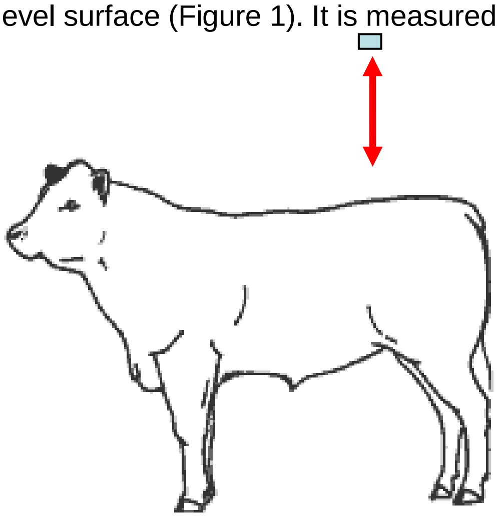


Figure 1 Measurement point for frame score (over point of hip)

Charts to convert hip height and age into frame score are embedded in the BeefSpecs calculator and are also available from: http://www.dpi.nsw.gov.au/agriculture/livestock/beef/appraisal/publications/frame-scoring.

Fat assessment

A standardised national approach is used to describe cattle fatness. This description is used by market reports to describe both store and fat stock. Fat Scoring is assessed in a range between 1 and 6 and is related to millimetres of fat at the P8 site (rump). These relationships are demonstrated in Table 1.

Table 1: Fat scores for beef cattle (Source: NLRS)

Fat Score	P8 fat depth (mm)	12/13th rib fat depth (est. mm)
1	0 - 2	0 - 1
2	3 - 6	2 - 3
3	7 - 12	4 - 7
4	13 - 22	8 - 12
5	23 - 32	13 - 18
6	Above 32	18+

Fat score can be assessed either visually, manually or objectively.

Visual Assessment

Key assessment positions are the tail head, pin bones, twist, flank, cod or udder, underline, brisket, ribs and muscle seam in the hide quarter.
As cattle fatten:

- the ribs become less visible.
- the tail head softens and rounds of fat increase beside the tail.
- the muscle seams of the hindquarter become covered with fat and are less evident when cattle walk.
- the brisket, flank, cod and twist fill out and give the beast a square appearance in these areas that contrasts with the roundness of muscles.

Manual Assessment

To manually assess cattle for fatness it is important only locations where fat overlays bone are felt so fat tissue can't be confused with muscle tissue. Manually palpating different positions on the body and feeling for tissue softness will indicate the level of cattle fatness. Positions that best show the level of fatness are the pin bone, hip/hook bone, long ribs, short ribs (this position is only of use when animals are fat score 1 and poorly muscled) and the back line.

Manual fat assessment is possibly best described using a position on the body as one example. Consider palpating the hip/hook bone and feeling for tissue softness to estimate fatness at the P8 site. If there is no 'give' or softness felt then the animal will have less than 4 mm of fat at the P8 site. If some softness is felt then 4-7 mm fat will be at the P8 site or if the tissue is easily depressed fat depth will be 7mm more. It is critical to regularly calibrate manual fatness assessments with abattoir kill data.

Objective Assessment

Objective fat assessment of live animals can only be performed by ultrasound scanning at the ribs (usually 12/13th) or P8 site. When ultrasound scanning it is important care is taken to ensure the correct location is identified and measured. The P8 site is located by drawing a line from the pin bone forward towards the hip/hook bone then drawing a line perpendicular to the high sacral vertebra (3rd sacral vertebra). The intersection of these lines is the P8 site. Rib fatness is assessed on the *longissimus dorsi* muscle (eye muscle) between the 12 and 13th ribs. This position is found by locating the last long rib (13th rib) and moving ¾ of the width across the *longissimus dorsi* away from the spine. A range of ultrasound scanning devices can be used to determine subcutaneous fat depth at these positions on the live animal.

More information on fat assessment can be obtained from:
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/95863/visual-and-manual-assessment-of-fatness-in-cattle.pdf

Muscle Assessment
Muscling is scored on the scale A (very heavy) to E (light). This scoring system can be increased to a 15 point scale by including pluses and minuses around each score (e.g. A+, A, A- to E+, E, E-). Muscle score describes the shape of cattle independent of fatness. Muscling is the degree of thickness or convexity of an animal relative to its frame size, after adjustments have been made for subcutaneous fat (see fat assessment above). Animals that are fat (i.e. have 18mm or more at the P8 site) but lack muscle may look wide and thick so allowance must be made for high levels of subcutaneous fat.

More information on muscle assessment can be obtained from:
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/103938/muscle-scoring-beef-cattle.pdf

Dressing Percentage Guide
Dressing percentage is carcase weight as a percentage of liveweight calculated as (carcase wt / liveweight) x 100. It is not yield. Carcase weight can be calculated as liveweight x dressing percentage. There are a number of factors that affect dressing percentage. These include the following:- (Note: The factors in bold have a major influence):

- **Fatness**
- **Time off feed**
- **Muscularity**
- **Breed**
- **Carcase dressing procedures**
- **Type of feed**
- Weight
- Pregnancy status
- Transit loss
- Bruising
- Sex
- Age
- Class of country
- Weather

Information on the impacts these factors have on dressing percentage can be obtained from:
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/103992/dressing-percentages-for-cattle.pdf
http://www.dpi.nsw.gov.au/agriculture/livestock/beef/appraisal/publications/shape-muscle-score

Dentition
Dentition of cattle is used to classify animals into AUSMEAT categories and can be assessed by looking at the number of permanent incisors. Charts describing the AUSMEAT categories used to describe animals based on dentition can be obtained from:
http://www.ausmeat.com.au/media/1753/beef%20categories%20brochure.pdf

Cattle Growth and Development

1. Three phases of growth

Animals progress through three growth stages where priority is given to development of bone, then muscle and finally fat. The point in time at which the growth of these tissues increases or decreases will largely depend on the age, weight, breed, maturity type, sex and nutritional history of the animal. As demonstrated in Figure 1, a calf will grow along a trajectory showing acceleration around puberty and slowing down as maturity is approached. Stage 1 of growth is the initial stage after birth (calf phase) when the early development of bone occurs before progressively slowing until maturity. Stage 2 of growth (growout phase) is the period when muscle develops at a rapid rate relative to bone and fat. Stage 3 (finishing phase) occurs when muscle growth slows, making a greater amount of energy available for fattening to occur.

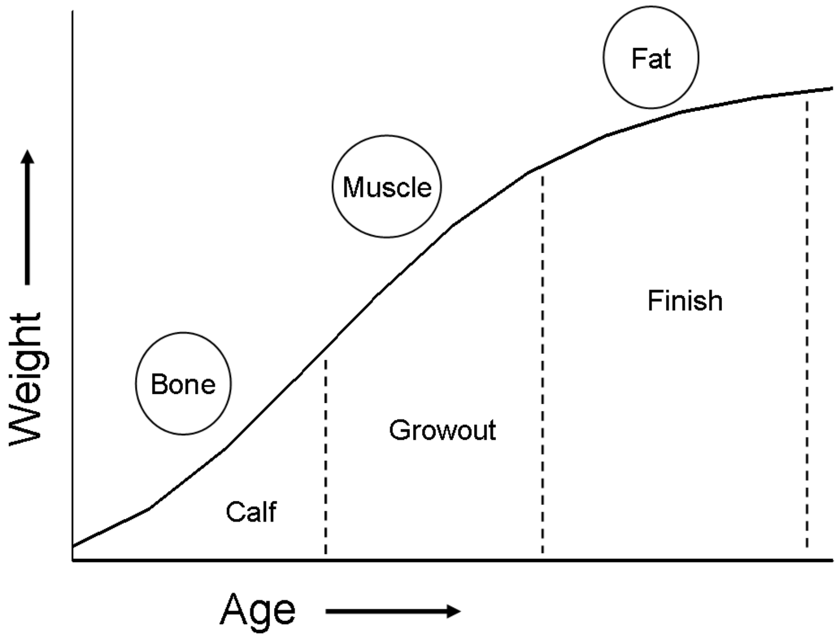


Figure 1: The three phases of growth as an animal develops from calf to maturity.

2. Maturity type and frame score

The maturity type or frame score (FS) of an animal affects the capacity of beef producers to meet target market specifications. Cattle are classified as either early maturing (FS 1, 2, 3), moderate maturing (FS 4, 5, 6) late maturing (FS 7, 8) or very late maturing (FS 9, 10, 11). Frame score estimates the relative size of cattle and is assessed on a 1 to 9 point scale within BeefSpecs (FS 10 and 11 are considered extreme), with ‘1’ being the lowest mature weight animals and ‘9’ being higher mature weight animals. Most British breeds fall into the 1–7 frame score range and most European breeds fall in the 4–9 frame score range.

3. Effect of frame size on fatness

An animal’s mature frame size plays an important role in determining fat cover at a target liveweight. Cattle grow the quickest until they reach physiological maturity (the stage of growth when fattening begins). Smaller framed cattle reach that point at an earlier age and at lighter weights than do medium and large-framed cattle. Consequently, smaller framed cattle begin to fatten at younger ages, where as medium and larger framed cattle take longer to reach the fattening phase of growth.

Larger framed animals will also be heavier than moderate framed animals at the same age. This means moderate framed cattle will be fatter than larger framed animals at the same age. As a general rule as frame score increases fatness decreases at the same liveweight (Figure 2).

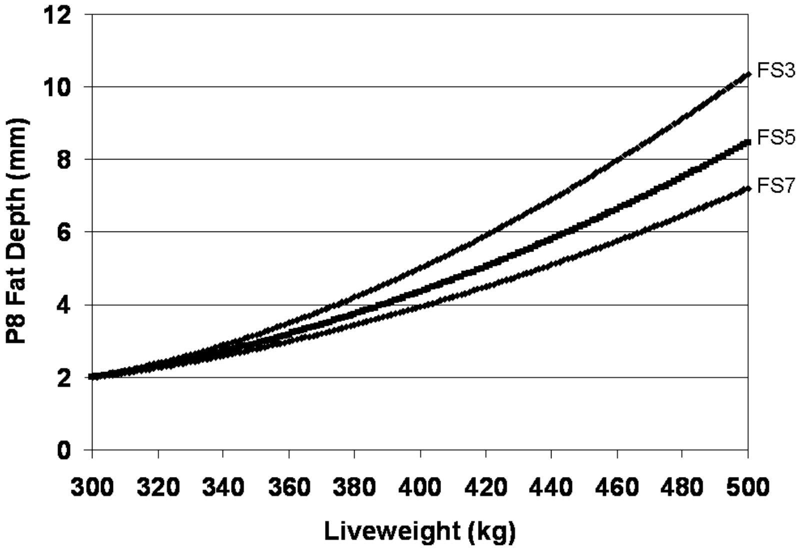


Figure 2: Deposition of P8 fat by frame score 3, 5 and 7 animals while growing at the same rate and starting at the same weight and fatness.

4. Effect of sex on fatness

As an animal matures its sex will play an important role in determining it's liveweight (kg) and fatness (measured at P8 site in mm). In general:

- Heifers will be lighter than steers at the same age.
- Heifers will be fatter than steers at the same age.

The effect that sex has on fatness increases with age and so the greatest difference in liveweight and fatness between heifers and steers will be in the finishing phase. Consider, for example, a mixed mob of British bred weaner heifers and steers of frame score 5, with an average liveweight of 300kg and an average P8 fat depth across both sexes of 2mm. BeefSpecs predicts the final P8 fat measurement of the heifer portion of the mob to be 15.2 mm compared to 9 mm for the steer portion if these cattle were grown at 1.0 kg/day on a grain diet for 200 days.

5. Effect of growth rate on fatness

Knowing the actual and potential growth rate of cattle is one of the most important factors in predicting the ability of cattle to meet market specifications within a given timeframe. Faster growing animals with a similar frame score will deposit more fat over a feeding period. Also, the faster the growth rate the heavier the animal will be after a feeding period.

The initial liveweight of an animal prior to the commencement of the feeding period will also influence the rate/amount of fat deposited at a given Average Daily Gain (ADG). For example, a 500kg steer growing at 1.0kg/day will deposit 3.3 mm rib fat per month compared to a 300kg steer which will deposit 1.7 mm per month. The difference of 1.6 mm per month is due to the different growth stage of each animal (finishing vs. growing out).

6. Effect of Hormonal Growth Promotants (HGPs) on fatness

Hormonal Growth Promotants (HGPs) increase the expected rate of growth by approximately 10%. HGPs have the potential to reduce marble score and tenderness while also increasing carcase ossification score. Implanted cattle may be leaner than non-HGP implanted cattle at the same weight. However, this largely depends on the type of HGP implant used. If an androgenic implant is used an increase in growth rate but a reduction in fatness will occur, while if an oestrogenic implant is used there will be an increase in growth rate but **no** reduction in fatness. Therefore, a 300kg heifer treated with an androgenic implant growing at 1.0kg/day will deposit 1.3 mm rib fat per month compared to a non-implanted heifer that will deposit 1.4 mm per month when gaining at 1kg/day. If using HGP implants - increase ADG by **10%** over non-implanted cattle when entering growth rates into BeefSpecs. So in the above example, the same treated heifer gaining 1.1 kg/day will deposit 1.6 mm per month.

7. Effect of feed type on fatness

Grass fed cattle will be leaner than grainfed cattle at the same liveweight. A grain diet is a concentrate-based diet with greater than 70% grain content. A grass diet is a roughage-based diet with greater than or equal to 30% pasture/roughage content i.e. a diet with less than 70% grain. For grain fed animals BeefSpecs will automatically assume a dressing percentage **2%** higher than animals on a grass based diet i.e. 52% for grass versus 54% for grain. The lower fibre density of a grain diet can result in lower rumen activity, but a higher proportion of carcase weight (dress %).

Cattle Nutrition

Drivers of animal production

In the short term, producers have limited or no capacity to alter traits such as sex, frame score, breed type or starting weight and fatness and their implications on meeting market specifications. However growth rate, feed type, HGP use and length of the feeding period can be refined to optimise outcomes. The impacts HGPs have on growth and body composition have been described above. Growth rate, feed type and feeding period length have interacting impacts on animal performance.

The BeefSpecs calculator uses estimated growth rate across a defined feeding period to predict P8 fat depth. Consequently, BeefSpecs relies on producers having the capacity to estimate cattle growth rates, based primarily on past experience or Grazfeed output for example. Producers are able to manipulate growth rate and feeding period length inputs to BeefSpecs to explore the animal performance consequences (e.g. P8 fat depth) of making management changes. BeefSpecs also allows producers to explore the consequences of changing animals from a grass based diet to a grain based diet.

Using BeefSpecs to make management changes

BeefSpecs uses daily weight gain as the mechanism by which the effects of feed quality (digestibility, energy and protein) and availability (kg/ha of pasture or kg of grain fed daily) on animal performance are predicted. Accordingly, growth rate can be used to prescribe (in association with other information and producer experience) the level of animal nutrition required to achieve a desired level of production and satisfy market specifications. The interaction between nutrition and the growth rate entered into BeefSpecs is best described in the following examples.

1) Based on a given feeding period and likely weight gain scenarios, BeefSpecs predicts that animals will have insufficient fat cover for the target market. Options to

consider include identifying alternative markets, such as targeting feedlot entry weights instead of the fat/processor market. Alternatively, increasing weight gain would result in increased fat deposition. This might be achieved by reducing stocking rate (thereby increasing feed availability), providing a high energy supplement (such as grain or a forage crop) or giving an HGP.

2) BeefSpecs predicts that after a given feeding period and likely weight gain, animals will have fat cover in excess of the target market specifications. Again, an option includes identifying a different market. Alternatively, the producer could consider adjusting the length of the feeding period. If the animals were able to achieve the required liveweights (and therefore carcase weights) producers could shorten the length of the feeding period (e.g. shorten from 150 days to 100 days) and sell animals at an earlier date. However, if animals were unable to reach the required liveweights producers would then need to examine their feed base to make necessary changes. These changes could be reducing feed availability with higher stocking rates or reducing feed quality, both of which would result in a slowing of growth and fattening rates.

3) BeefSpecs predicts animals will meet market specifications at the end of the feeding period, allowing the producer to follow their production plan. However, continual monitoring of animal performance (i.e. weight gain and fatness) and pasture thresholds is still important as it reinforces marketing options and the allocation of resources to best meet their production goals.

As well as recording animal performance, monitoring pasture quality and quantity is also extremely important in being able to meet animal production targets. Fodder budgets can be an important component in any planning process as they allow producers to quantify any extra feeds required or to use alternative means (e.g. feedlotting) to reach short term or long term production targets.

Acknowledgements: The following staff from NSW Department of Primary Industries collaborated in writing this information note as part, and on behalf on the Beef Co-operative Research Centre:- Todd Andrews, Michael Beer, Brett Littler, Hutton Oddy, Trevor Rose, Jason Siddell and Brad Walmsley.

16 Appendix 4. BeefSpecs Drafting Tool

BeefSpecs drafting tool

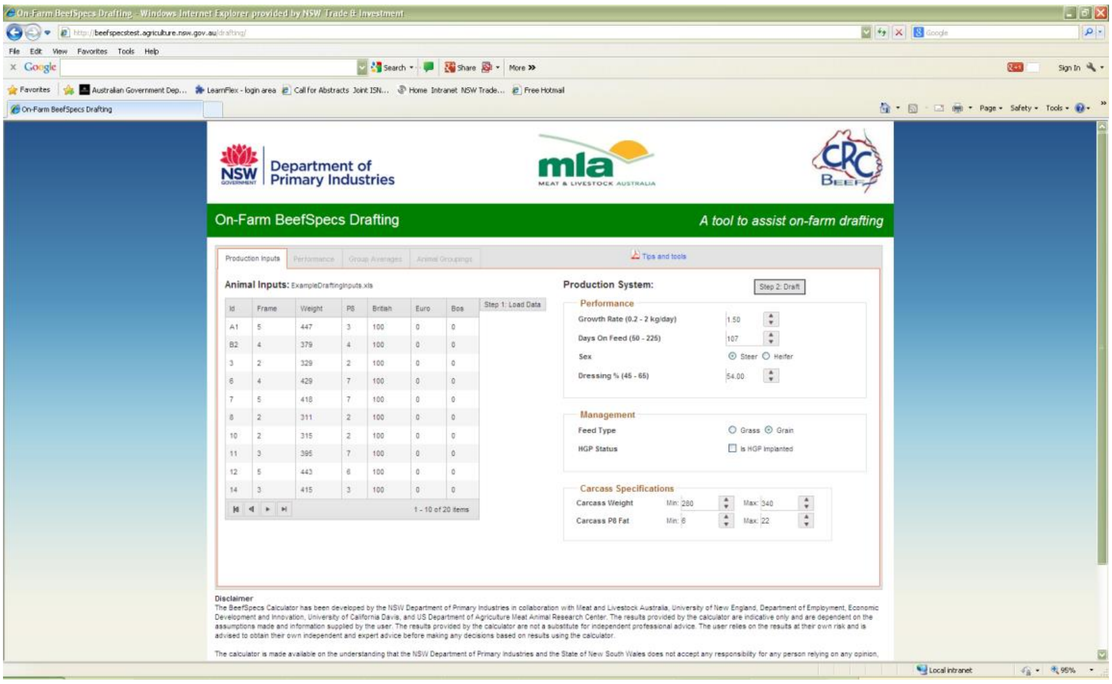


Figure 1. Production inputs screen

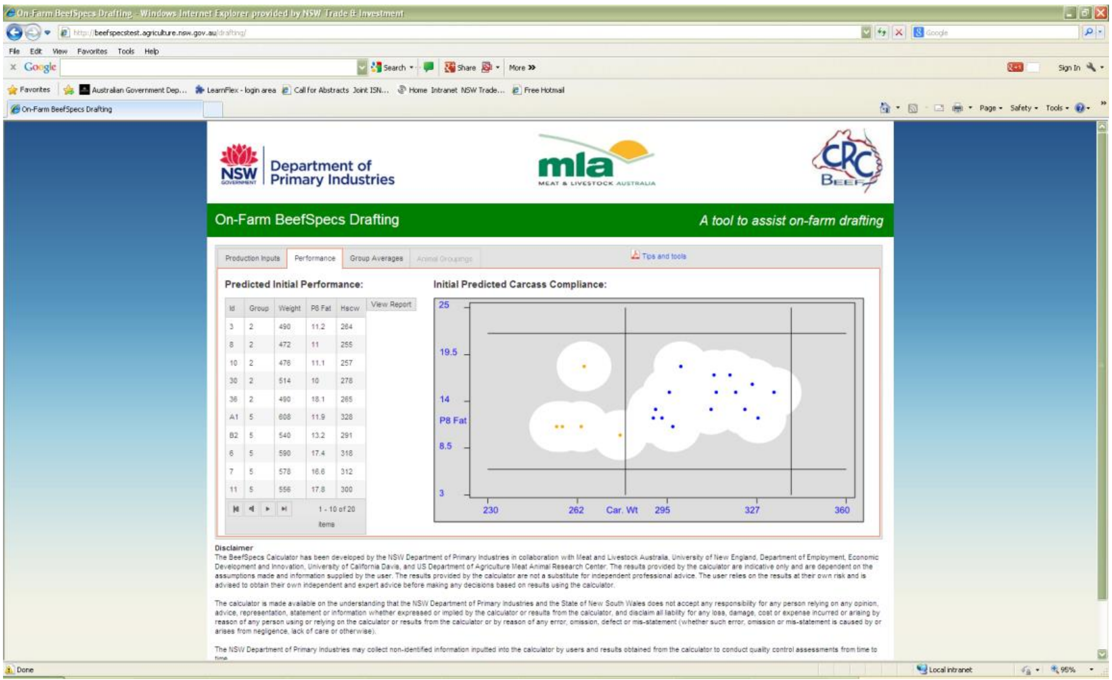


Figure 2. Outcome of drafting

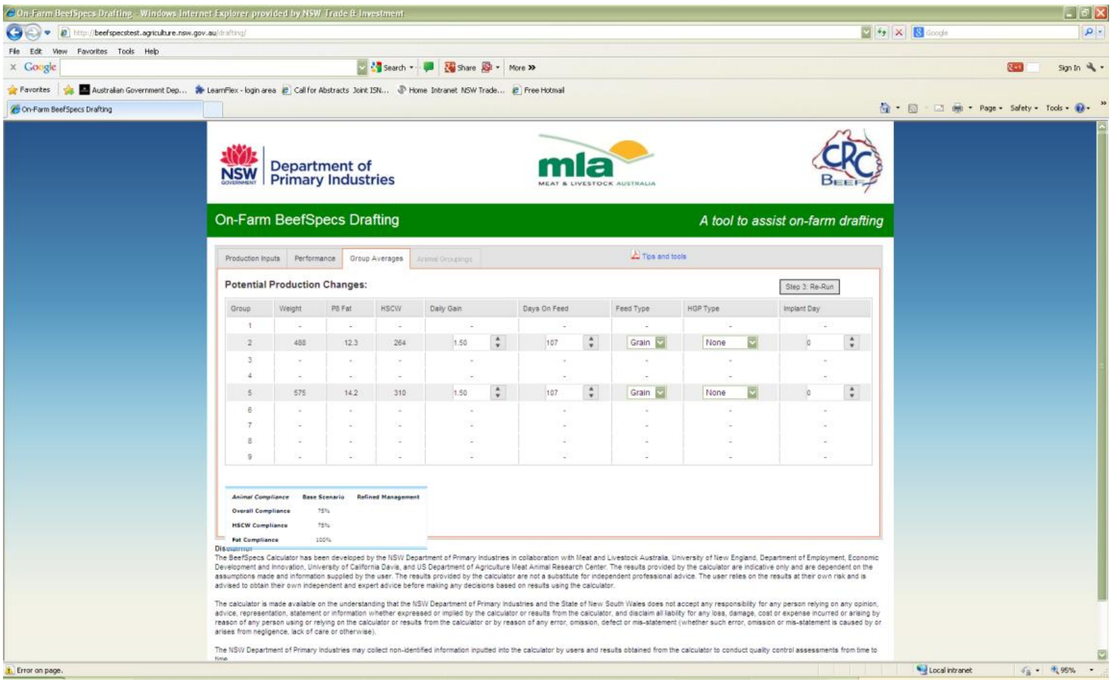


Figure 3. Group averages of potential production changes.