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PREDICTION OF BEEF CARCASS COMPOSITION FROM NON-CARCASS PARTS

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ABSTRACT

Six Kedah-Kelantan bulls and five Draughtmaster steers were used to develop a method of estimating the weights of the four carcass tissues - muscle, bone, fat and connective tissue.

From an investigation of a number of non-carcass parts it was found that three measurements could be used to estimate all four carcass components. The measurements were (a) short-cut tongue; (b) right shanks weight; (c) chilled side weight.

Simple and multiple regression equations were developed to estimate the weights of muscle, bone and connective tissue in the chilled side. The most useful equations employed were short-cut tongue weight and chilled side weight to estimate total side muscle weight, and the right shanks weight to estimate both total side bone weight and total side connective tissue weight.

Fat weight was estimated by an indirect method using chilled side weight and the estimates of the weights of the other three carcass components. This technique was more accurate than the fat thickness measurement at the 10th rib.

Advantages of using the non-carcass parts technique are as follows All four major carcass components are predicted; no commercial loss of offals or by products occur; measurements can be taken without disrupting the abbatoir process. The additional information enables an objective assessment of carcass components.

CONTENTS

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Malaysia is self-sufficient in poultry, eggs and pork but only about 65% self-sufficient in beef. It is a declared objective of the government that the country be self-sufficient in beef by 1990 (Noordin 1982).

It has now been established that increase in liveweight of an animal does not translate to increase in muscle weight (Barton 1967). In beef animals the amount of muscle in a carcass is the most important criteria although a certain proportion of fat is necessary for consumer taste. It is therefore imperative that cattle be slaughtered at optimum weights when the proportions of the carcass tissues are at ideal proportions (Berg and Butterfield 1968). This would save the industry considerable cost as there is no wastage due to excess fat and the farmer is able to produce cattle with the consumers' preferences taken into account.

Numerous attempts have been made to estimate carcass composition for example, total dissection technique, backfat measurement, ultrasonic probes, specific gravity and etc. Techniques used must be inexpensive, rapid, relatively simple to carry out, non-destructive and should contain no harmful residues. Johnson (1979) introduced a new approach by using non-carcass parts to predict beef carcass composition on the slaughter floor. Prediction is based on the fact that weight distribution among carcass tissues extends to those tissues of the non-carcass parts.

In the following study some non-carcass parts which are easily available from the slaughter floor were used to predict the respective total carcass components.

LITERATURE REVIEW

Beef cattle are raised for the edible products they produce. The amount and quality of the edible portion of a beef carcass is influenced by its composition. The three major components of a carcass are muscle, bone and fat. Muscle is the most important tissue of the beef carcass.

Considerable research involving many diverse techniques has been and is being done in attempts to develop reliable measures of carcass composition. Methods being tried are direct or indirect, destructive or non-destructive, costly or cheap, time consuming or fast, sophisticated or simple, but all have essentially the same goals - those of estimating with reasonable accuracy the composition of the carcass. The various parameters that have been used especiall in combinations have included weights of entire muscles, loin eye area, the rib cut, carcass length and carcass weight, dissection of sample joints, backfat thickness, specific gravity, ultrasonic scanning and potassium 40 counting.

Measurements Of The Rib-Cut

Rib sample joints have been used as predictors of total carcass composition by various authors. For example wholesale rib joint was used by Callow (1962). This technique based on physical separation of the 9-10-11th rib-cut into muscle, fat and bone, has had widespread use for prediction purposes in cattle experiments. Selection of the 10th rib for investigation by Kempster and Jones (1977) was based on the fact that it was cheaper than wholesale joint and the removal of which would detract less from the value of the remainder of the carcass.

Back Fat Thickness

Backfat thickness measured over the longissimus dorsi muscle has proven to be a useful predictor of total or percentage fat and directly of muscle in a carcass. For practical purposes perhaps, breed and sex differences in the relationship of backfat to total carcass fat can be ignored, but more research is needed in this area (Berg and Butterfield 1976). Fat thickness is currently determined by use of an electrical conductivity probe which has been developed over the last six years. However, the accuracy and reliability of this probe appear to require further investigation. Accurate fat thickness measurement is further complicated by the damage frequently done to the sub-cutaneous fat layers by mechanized hide-pulling, especially over the area of the caudal ribs (Berg and Butterfield 1976).

Johnson and Vidyadaran (1981) used measurements of fat thickness at the 12th rib and at the sacral crest to estimate side fat weight and percentage. Sacral crest has an advantage in that it is conveniently located and is an alternative to the 12th rib and the fat layer is not damaged by use of hide pullers.

Loin Eye Area

Area of the rib-eye muscle measured at the various sites at which carcass are quartered has been used as an estimate of carcass muscling. It unfortunately accounts for only a small variation in total or percentage muscle. However as it does account for some of the variation in carcass muscling and because simple and direct measures of muscling have not been devised, it continues to be advocated with other simple measures of estimating carcass composition (Ledger and Hutchison 1962).

Area of rib-eye muscle as an indicator of total muscle, may be independent of breed to a greater extent than weight or length of carcass. However, general skeletal structure (long or short) may influence rib-eye area though the weight of the longissimus dorsi may remain proportionate to total muscle.

Weights Of Entire Muscles

Weights of individual selected muscles should be reasonably predictive of total muscle. Weight independent of breed because of the relative constancy of muscle proportions. Johnson (1979) found that muscle biceps femoris and longissimus dorsi both gave a correlation co-efficient of 0.99.

But in the commercial situation this is not practical since it involves removal of the muscle thereby affecting the carcass and disrupting the routine procedure.

Carcass Weight

Side weight either hot or chilled is highly correlated to total side muscle and bone weight. It can easily be weighed in a slaughter line and doesn't disrupt the slaughter procedure. In a study done by Patmasingam and Ahmad Shokri (1982) of grazed draughtmaster cattle, it was found that slaughter weight gave the best correlations ($r=0.87, P< 0.01$) and the prediction equation gave values that had zero or a small average percentage deviation from the observed values. But Berg and Butterfield (1976) reported that carcass weight within a group of animals of a particular breed and sex, fed the same way, is reasonably predictive of composition. However its usefulness breaks down when attempting to predict composition in animals of different breeds and nutritional history.

Linear Measurements

Various linear measurements on the carcass including length, width and depth have been advocated as useful predictors of carcass composition. Length seems to have no predictive value, while width measurements designed to estimate plumpness and muscling usually are influenced more by fat than by muscle. Depth measurements seem to have no predictive value. Ratios of length, depth and width measurements although they may describe shape, have little predictive value for composition (Berg and Butterfield 1976).

Other Predictive Methods

Subjective estimates of carcass composition are the basis for much of the grading of carcasses and of trading in carcasses in many countries. Subjective estimates are difficult to quantify and have not stood up to objective assesment. Conformation has in the past been the main basis for subjective assesment of carcasses. It has been shown to be more influenced by fat than by muscle (Berg and Butterfield 1976).

Measuring the specific gravity of a side by weighing in water appears to be the most accurate method of measuring carcass composition. It could be easily worked into the routine of a packing plant and is relatively simple, non-destructive method. However its use has not caught on in the industry.

Predicting carcass composition of live animals is a further step removed and more difficult than predictions made from the carcass. Routine live animal measurements are of little value for predicting carcass composition. The most promising techniques for live animal assesment are ultrasonic scanning and potassium 40 counting. Ultrasonic scanning is low cost, non-destructive, non-harmful and portable. Potassium 40 requires expensive equipment but is also non-destructive, non-harmful and reasonably accurate. Some techniques being used are not accurately predicting composition and interpretations are quite misleading. More research is required to improve the accuracy and applicability of these and other live animal evaluation methods (Berg and Butterfield 1976).

MATERIALS AND METHOD

Animals

Six Kedah-Kelantan bulls aged about 18 months and five Draughtmaster steers aged about 15 months were used in this study. The five Draughtmaster's were selected at random from a total of forty-six steers. The six Kedah-Kelantan's were randomly selected from twenty-four bulls.

Nutrition And Treatment

Kedah-Kelantan bulls were grazed on setaria splendida with mineral and vitamin supplement. Initial liveweight of all animals was about 150 kg. Total duration of experiment was thirty weeks.

Draughtmaster steers were fed on palm kernel cake with mineral and vitamin supplement. The experiment lasted for five months and approximate weight at end of the experiment was about 300 kg.

Slaughtering And Dissecting Procedure

The animals were fasted for approximately 24 hours before slaughtering, however drinking water was provided. Empty liveweight was recorded prior to slaughter. After slaughtering, the head was decapitated at the atlanto-occipital joint and the limbs disarticulated at the carpo-metacarpal and tarso-metatarsal joints. Weights were taken of the head, foreshanks and hindshanks. Weight of long-cut-tongue (L.C.T.) and short-cut-tongue(S.C.T.) was also recorded. The skin was removed following which the viscera and kidneys were removed. Other weights recorded included full rumen, empty rumen, liver, spleen and kidneys. Hot carcass weight was obtained after carcass was split into two halves using a meat-band saw. Cold carcass weight was obtained after chilling for 24 hours.

The carcasses were dissected according to procedure of Butterfield and May (1966); Butterfield and Berg (1966a). In this technique, individual muscle were removed, trimmed of fat, severed from tendon at the last vestige of muscle and the weight recorded. The sum of all the muscle weight of a side, and of some scrap of muscle, equalled total muscle weight. Bones trimmed of fat and tendons were weighed. Fat tissues were dissected and weighed in two categories; subcutaneous and intermuscular. Tendons and connective tissue were weighed together.

This study is aimed at improving the prediction of the carcass components namely muscle, bone and fat by the use of non-carcass parts as predictors.

RESULTS

Muscle

Total side muscle weight was predicted from simple and multiple regression analysis by using tongue weights and chilled side weight (Appendices 1, 2, 3 and 4). The weights of individual muscles have been widely recognised as accurate predictors of total side muscle (Butterfield 1962) and the biceps femoris and longissimus dorsi have been included in the analysis as a comparison. Results of combined parameters of both breeds are shown in Tables 1 and 2.

Bone

A number of non-carcass parts and chilled side weight all available on the slaughter floor, were used alone or in combination to predict total side bone weight. The results are shown in Appendices 5, 6, 7 and 8 and Tables 3 and 4 show results of combined parameters of both breeds.

Connective Tissue

Right shanks weight was also used to predict the weight of the other structural component of the carcass, connective tissue. As commercial consideration of the non-carcass parts technique would be favoured by fewer prediction equations, the use of shanks to predict total side bone plus connective tissue weight is shown on Table 5.

Fat

The weight of the fourth carcass tissue, fat was calculated by difference from the predicted weights of the other three side components and side recovery weight, according to the equation:

Side fat weight = Side recovery weight - (predicted side muscle weight + predicted side bone weight + connective tissue weight)

Table 8 shows the regression equations that were derived from the analysis. The results of prediction of muscle, bone and fat are shown in Table 9. Table 10 shows the comparison between accuracy of prediction of fat using the non-carcass parts technique and the direct measurement of fat thickness at the 10th rib.

Table 1: Simple Regression Analysis of Total Side Muscle Weight (Y) Over Chilled Side Weight, L.C.T. Weight, S.C.T. Weight, Biceps Femoris Weight And Longissimus Dorsi Weight

Breed DM + KK N = 11 Ymean = 38455 (g)

Indep. Variables	Xmean (g)	b		SE(b)	SEE	R
Side Weight	56778	0.594	**	0.986	1680	0.98
L.C.T.	1002	20.762	**	0.852	5322	0.85
S.C.T.	560	107.720	**	0.870	5007	0.87
Biceps Femoris	2613	16.685	**	0.981	1951	0.98
Longissimus	2779	13.587	**	0.972	2350	0.97

** $P < 0.01$

Table 2: Multiple Regression Analysis of Total Side Muscle Weight (Y) Employing Chilled Side Weight, Individual Muscle Weights, L.C.T. Weight And S.C.T. Weight

Breed DM + KK N = 11 Ymean = 38455

Indep. Variables	b	SE(b)	Probability	SEE	R
Chilled Side Weight +	0.788	1.308	**		
L.C.T. Weight	-8.523	-0.350	**	981	0.99
Chilled Side Weight +	0.521	0.864	**		
S.C.T. Weight	17.877	0.144	**	1567	0.98
Chilled Side Weight +	0.339	0.563	**		
Biceps Femoris	7.490	0.440	**	1194	0.99
Chilled Side Weight +	0.421	0.698	**		
Longissimus	4.154	0.297	**		

** $P < 0.01$

Table 3: Simple Regression Analysis of Total Bone (Y) Employing Data Available On The Slaughter Floor

Breed DM + KK N = 11 Ymean = 10692 (g)

Indep. Variables	Ymean(g)	b		SE(b)	SEE	R
Side Weight	56778	0.196	**	0.937	1237	0.93
Right Shanks Weight	2635	3.952	**	0.961	975	0.96
Head Weight	1231	10.406	NS	0.545	2972	0.55

** $P < 0.01$

Table 4: Multiple Regression Analysis of Total Side Bone (Y) Employing Side Weight, Right Shanks Weight, And Head Weight

Breed DM + KK N = 11 Ymean = 10692

Indep. Variables	b	SE(b)	Probability	SEE	R
Chilled Side Weight +	0.057	0.271	**		
Right Shanks Weight	2.897	0.704	**	977	0.96
Chilled Side Weight +	0.226	1.078	**		
Head Weight	-0.387	-0.203	**	1191	0.94
Right Shanks Weight +	3.801	0.924	**		
Head Weight	1.371	0.071	**	1007	0.96

** $P < 0.01$

Table 5: Simple Regression Analysis of Total Side Bone Plus Connective Tissue Weight Employing Shank Weight

Breed DM + KK N = 11 Ymean = 12543

Indep. Variable	Xmean (g)	b	SE(b)		SEE	R
Right Shanks Weight	2635	4.50	0.964	**	1130	0.96

** $P < 0.01$

Table 6: Simple Regression Analysis of Total Side Fat Weight (Y) Employing Fat Thickness Measurement At The 10th Rib

Breed	N	Independent Variable	Xmean (mm)	Ymean (g)	b	SE(b)	SEE	R
KK	6	Fat Thickness	3.33	3705	247	0.754	3503	0.75
DM	5	Fat Thickness	5.67	7809	1614	0.745	4210	0.74
KK + DM	11	Fat Thickness	4.45	5781	1846	0.866	3001	0.87

Table 7: Equations For The Prediction of Side Fat Weight Employing Fat Thickness Measurement At The 10th Rib

Side Component (Y) (g)	Predictor (mm)	Equation
Total Side Fat Weight	Fat Thickness	$Y = 1846.02x - 2442.19$

Table 8: Equations For The Prediction of Side Muscle, Bone, Bone + Connective Tissue And Fat

Side Component (Y) (g)	Predictor (g) X_1	X_2	Equation
Total Side Muscle Weight	Chilled Side + Weight	S.C.T.	$Y = 0.769X_1 - 2.927X_2$
Total Side Bone Weight	Chilled Side + Weight	Right Shanks Weight	$Y = 0.0198X_1 + 2.652X_2 + 1864$
Total Side Bone Weight	Head Weight		$Y = 10.406X - 2126$
Total Side Bone + Conn. Tissue Weight	Right Shanks Weight		$Y = 4.50X + 682.65$
Total Side Fat Weight			Y = 0.98 (Side Wt) - (Predicted side muscle wt + Predicted side bone wt + Predicted side conn. tissue wt)

Table 9: Accuracy of Prediction of Muscle, Bone And Fat

Breed	Parameter	Dissected (g)	Predicted (g)	Accuracy
KK	Muscle	32823	32166	98 %
DM	Muscle	45215	44581	98.6 %
KK	Bone	8111	7786	96 %
DM	Bone	13789	13251	96.1 %
KK	Fat	3437	3577	96 %
DM	Fat	8233	8501	96.8 %

Table 10: Accuracy of Fat Prediction of Non-Carcass Parts Technique Compared With Fat Thickness At The 10th Rib

Breed	Dissected (g)	Non-Carcass Parts Technique	Accuracy	Fat Thickness At 10th Rib (g)	Accuracy
KK	3437	3577	96 %	3787	90.7 %
DM	8233	8501	96.8 %	6732	76 %

DISCUSSION

Muscle

For the Kedah-Kelantan breed long-cut tongue (r = 0.93) and chilled side weight (r = 0.99) were both highly correlated with total side muscle weight. Short-cut tongue was not as highly correlated (r = 0.77) probably due to large variation in dissection technique. When combined in multiple regression analysis chilled side weight plus short-cut tongue gave the best estimate (SEE 969g; Ymean 32823g). The standard error of estimation was greatly reduced (SEE 4196g; Ymean 32823g) relative to short-cut tongue.

For the Draughtmaster breed it was also found that long-cut tongue (r = 0.95) and chilled side weight (r = 0.99) to be highly correlated with total side muscle weight. When combined in multiple regression analysis chilled side weight plus long-cut tongue gave the best estimate (SEE 1210g; Ymean 45215g) although chilled side weight plus short-cut tongue didn't differ very much (SEE 1212g; Ymean 45215g). The standard error of estimate was greatly reduced relative to long-cut tongue (SEE 3003g; Ymean 45215g). The weight of both muscles biceps femoris and longissimus dorsi combined with chilled side weight gave good estimates but neither is likely to be useful commercially since both are time consuming and cause carcass devaluation.

When values for both the breeds were combined it was found that chilled side weight (r = 0.98) and short-cut tongue weight (r=0.87) were highly correlated to total side muscle weight in simple regression analysis. This result is similar to that reported by Johnson (1979). When combined in a multiple regression analysis, chilled side weight plus long-cut tongue weight gave the best estimate. The standard error of estimate was reduced (SEE 981g; Ymean 38455g) relative to their individual predictions.

Bone

Of the non-carcass parts examined for total side bone weight prediction, head weight (r = 0.86) was superior in the Kedah-Kelantan breed. Multiple regression of chilled side weight plus head weight (SEE 783g ;Ymean 8111g) and shanks weight plus head weight (SEE 780g ; Ymean 8111g) gave similar estimates. In the Draughtmaster breed chilled side weight (r = 0.91) and head weight (r = 0.91) gave similar estimates. In multiple regression analysis chilled side weight plus right shanks weight and chilled side weight plus head weight both gave same estimates (r = 0.92) (SEE 1103g ; Ymean 13789g). The standard error of estimate of chilled side weight plus right shanks weight was reduced relative to right shanks weight (SEE 1234g ; Ymean 13789g). In both the breeds the right shanks, (foreshank weight plus hindshank of the right side) gave less superior estimates compared to Johnson's (1979) estimates who obtained more superior estimates for the foreshanks weight.

When both the breeds were combined, chilled side weight (r = 0.93) and right shanks weight (r = 0.96) were both highly correlated with total side bone weight. When combined in multiple regression analysis chilled side weight plus right shanks weight gave the best estimate (SEE 977g ; Ymean 10692g). The standard error of estimation was reduced relative to chilled side weight (SEE 1237g ; Ymean 10692g).

Apart from the shanks being readily available on the slaughter floor for bone weight prediction.,this part has the added advantage of being able to be used to predict connective tissue weight. Johnson (1979) found that the correlation between foreshanks weight and side connective tissue weight was not high (r = 0.69) but since connective tissue only formed 1.1 - 4.3 % of side weight, a more practical approach seems to be to use right shanks weight to predict side bone plus connective tissue weight, since these are tissues of similar derivation.

Table 5 shows the results of using right shanks weight to predict for bone + connective tissue weight (r = 0.96). Table 9 shows the accuracy of prediction of muscle and bone compared to dissected values. For both the breeds muscle estimation was accurate to within 98%. Bone estimation accurate to within 96%. Therefore this study clearly indicates that non-carcass parts can indeed be used to predict the muscle and bone weight accurately.

The calculation of fat by difference relies on the prediction of the other three carcass components and therefore contains all the errors associated with each prediction. To test the accuracy of fat estimation by difference, the values obtained were compared with dissected fat weight (Table 9). Accuracy of prediction was found to be about 96%. When compared with prediction of fat by direct measurement of fat thickness at the 10th rib, it was found that the indirect method was superior. The prediction by measurement of fat thickness at the 10th rib gave an accuracy of only 90.7% for the Kedah-Kelantan breed and 76% for the Draughtmaster breed. The results obtained in this study was similar to that obtained by Johnson (1979). He found that the non-carcass parts technique was superior compared to the Australian beef carcass appraisal system and Butterfield's technique.

This study shows that short-cut tongue, foreshanks weight and chilled side weight, give a comparatively accurate estimate of the weight of the carcass components. In addition other benefits are evident.

(i) The technique allows all four major carcass tissues to be predicted. This would seem to be valuable information for processor, butcher and producer alike. Processors and butchers would have a much clearer indication of yield than that now implied from current classification measurements. For the grower the information should provide selection tool.

(ii) Weights of the non-carcass parts can be easily recorded without upsetting abattoir routine because non-carcass parts are on a different line from the carcass.

(iii) The carcass measurement and the non-carcass parts used in prediction cause no commercial loss of carcass, offals or by-products

(iv) All recorded measurements for the prediction of carcass composition are weights, the simplest and potentially the most accurate method may be applied to the hotside ticket, either as weights of the chilled side or as percentages. The percentage form would overcome anomalies resulting from differential carcass shrinkage.

The beef carcass consists of three major components. An accurate prediction of any two should provide an estimate of the third. Nineteen years of carcass growth investigations have generally failed to improve the correlations between fat measurements and total carcass fat (Charles and Johnson 1976). This may be because of the great variability in fat growth and deposition. As found in this study the accuracy of the indirect prediction of carcass fatness, already more accurate than direct prediction methods, can probably be improved. If so, it will be done by improving the accuracy of prediction of muscle and bone, thus contributing to the totality of improvement of objective carcass measurement. This is because any small improvement in the accuracy of muscle and bone weight prediction tends to result in a much more accurate indirect calculation of side fat weight.

The correlations between the various measurements recommended in this study and the three major carcass components were very high. More research should be extended into the field of non-carcass parts using a larger number of animals and a wider selection of breeds.

This study shows that beef carcass classification could provide more objective data with perhaps less technology and Lower costs.

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APPENDICES

Appendix 1

Simple Regression Analysis Of Total Side Muscle Weight (Y) Over Chilled Side Weight, L.C.T. Weight, S.C.T. Weight And Weight Of Individual Muscles

Breed - Kedah Kelantan   N = 6   Ymean = 32823g

Independent Varaible	Xmean(g)	b		SE(b)	SEE	R
Side Weight	46050	0.754	**	0.991	845	0.99
L.C.T.	673	59.960	**	0.930	2436	0.93
S.C.T.	532	92.225	NS	0.774	4196	0.77
Biceps Femoris	2309	16.482	**	0.967	1674	0.96
Longissimus	2363	12.482	NS	0.861	3364	0.86

** $P < 0.01$ NS - Not significant

Appendix 2

Multiple Regression Analysis Of Total Side Muscle Weight (Y) Employing Chilled Side Weight, L.C.T. Weight, S.C.T. Weight And Individual Muscle Weights

Breed - Kedah Kelantan   N = 6   Ymean = 32823g

Independent Variables	b	SE(b)	Probability	SEE	R
Chilled Side Weight +	0.753	0.990	**		
L.C.T.	0.08	0.001	**	976	0.99
Chilled Side Weight +	0.769	1.011	**		
S.C.T.	-2.927	-0.024	**	969	0.99
Chilled Side Weight +	0.596	0.784	**		
Biceps Femoris	3.693	0.216	**	849	0.99
Chilled Side Weight +	0.665	0.875	**		
Longissimus Dorsi	2.055	0.142	**	755	0.99

** $P < 0.01$

Appendix 3

Simple Regression Analysis Of Total Side Muscle Weight (Y) Over Chilled Side Weight, L.C.T. Weight, S.C.T. Weight And Weight Of Individual Muscles

Breed - Draughtmaster N = 5 Ymean = 45215g

Independent Variable	Xmean(g)	b		SE(b)	SEE	R
Side Weight	69651	0.671	**	0.995	1004	0.99
L.C.T.	1397	54.753	**	0.959	3003	0.95
S.C.T.	594	87.484	NS	0.930	3907	0.93
Biceps Femoris	2977	15.158	**	0.976	2273	0.97
Longissimus	3279	14.224	**	0.995	957	0.99

** $P < 0.01$ NS - Not significant

Appendix 4

Multiple Regression Analysis Of Total Side Muscle Weight (Y) Employing Chilled Side Weight, L.C.T. Weight, S.C.T. Weight And Individual Muscle Weights

Breed - Draughtmaster N = 5 Ymean = 45215.2g

Independent Variables	b	SE(b)	Probability	SEE	R
Chilled Side Weight +	0.714	1.059	**		
L.C.T.	-3.782	-0.066	**	1210	0.99
Chilled Side Weight +	0.7011	1.039	**		
S.C.T.	-4.387	-4.664	**	1212	0.99
Chilled Side Weight +	0.570	0.846	**		
Biceps Femoris	2.380	0.153	**	1139	0.99
Chilled Side Weight +	0.257	0.382	**		
Longissimus	8.777	0.614	**	1129	0.99

** $P < 0.01$

Appendix 5

Simple Regression Analysis Of Total Side Bone (Y)
Employing Data Available On The Slaughter Floor

Breed - Kedah Kelantan N = 6 Ymean = 8111g

Independent Variables	Xmean(g)	b	SE(b)		SEE	
Side Weight	46050	0.117	0.722	NS	979	0.72
Right Shanks Weight	2010	3.097	0.771	NS	900	0.77
Head Weight	1208	6.279	0.865	**	708	0.86

** $P < 0.05$ NS - Not significant

Appendix 6

Multiple Regression Analysis Of Total Side Bone (Y)
Employing Chilled Side Weight, Right Shanks Weight and
Head Weight

Breed - Kedah Kelantan N = 6 Ymean = 8111

Independent Variables	b	SE(b)	Probability	SEE	R
Chilled Side Weight + Right Shanks Weight	0.019 2.652	0.122 0.660	NS	1036	0.77
Chilled Side Weight + Head Weight	-0.054 8.479	-0.335 1.169	NS	783	0.87
Right Shanks Weight + Head Weight	0.963 4.914	0.240 0.677	NS	780	0.87

** $P < 0.05$ NS - Not significant

Appendix 7

Simple Regression Analysis Of Total Side Bone (Y) Employing Data Available On The Slaughter Floor

Breed - Draughtmaster N = 6 Ymean = 13789g

Independent Variables	Xmean(g)	b	SE(b)		SEE	R
Side Weight	69651	0.140	0.918	**	951	0.91
Right Shanks Weight	3386	3.495	0.858	**	1234	0.85
Head Weight	1260	9.781	0.915	**	967	0.91

** $P < 0.05$

Appendix 8

Multiple Regression Analysis Of Total Side Bone (Y) Employing Chilled Side weight, Right Shanks Weight And Head Weight

Breed - Draughtmaster N = 5 Ymean = 13789

Independent Variable	b	SE(b)	Probability	SEE	R
Chilled Side Weight +	0.106	0.698	NS	1103	0.92
Right Shanks Weight	1.036	0.254			
Chilled Side Weight +	0.076	0.500	NS	1103	0.92
Head Weight	4.669	0.437			
Right Shanks Weight +	1.284	0.315	NS	1065	0.93
Head Weight	6.982	0.653			

** $P < 0.05$ NS - Not significant

Appendix 9

Mean Values And Range Of Parameters

Breed	No. Of Animals	Parameter	Mean (g)	Range (g)
Draught Master	6	Empty Live Wt (Kg)	264	222 - 313
		Dressing %	55.3	52 - 59
		Side Wt.	48016	56400- 86302
		L.C.T.	1397	1255 - 1610
		S.C.T.	594	500 - 740
		Biceps Femoris	2977	2390 - 3698
		Longissimus	3279	2620 - 4020
		Head Wt.	12600	10000 - 15000
		Shank Wt.	3386	2810 - 4040
		Fat Weight	8428	5807 - 11835
		Muscle Wt.	45215	36900 - 55623
		Bone Wt.	13789	11500 - 16520
Kedah Kelantan	5	Empty Live Wt.(Kg)	170	141 - 183
		Dressing %	53.6	52.5 - 56
		Side Weight	73200	35574 - 57689
		L.C.T.	673	530 - 760
		S.C.T.	532	480 - 605
		Biceps Femoris	2309	1840 - 2760
		Longissimus	2363	1655 - 2920
		Head Weight	12080	9400 - 14000
		Shank Weight	2010	1710 - 2570
		Fat Weight	3571	2205 - 4605
		Muscle Wt.	32823	24309 - 41789
		Bone Wt.	8111	5893 - 9785