Title: Evaluation of lean content and trim of cull sows on their value at harvest **(NPB #08-010)**

Revised

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Industry Summary

A study was conducted to estimate the lean content from the four USDA grades of cull sows, determine if standardized prediction equations for estimating cull sow lean content is possible and to estimate the type, weight and value of trim loss from cull sows at harvest. A total of 212 cull sows were processed at Old McDonald Meats, Ogden UT. Cull sows were obtained from area commercial pork producers. The genetic background of the sows consisted of commercially available maternal lines. Prior to harvest, ultrasonic backfat and loin muscle estimates were obtained and body weight was obtained from individual sows. On each harvest day, 6 to 10 sows were processed under USDA inspection. After the animal was rendered unconscious using electrical stunning procedures, each sow was exanguinated and eviscerated. Any tissue that was required to be trimmed from the carcass due to abscesses, bruises, or any other reason, was weighed and its location recorded to evaluate trim losses. Following processing, each carcass was weighed, split down the spine using an electrical meat processing saw and chilled overnight at 20 F. The following day ½ of the carcass was weighed and divided into primal cuts including the loin, belly, ham, shoulder and ribs. If the two halves of the carcass were not equally split (carcass weight of the two halves within 5 lbs. or ~2.5 kg) the data were not used in subsequent analyses. The ribs were divided into knife separable bone, lean, fat and skin tissue components. Individual components were weighed and percentages of primal, carcass and live weight calculated. If the total primal weight and individual component weights were not equal, the data were not used in subsequent analyses. This information was used to determine the lean and fat percentage by primal cut within each USDA cull sow live-weight class. All data were adjusted to a mean carcass weight within each USDA weight classification to reduce the variation within each weight class due to carcass weight.

Differences among the lean, fat, skin and bone weight from sows in different market weight classes were observed in the current study. Similarly, the percent lean and fat by carcass and total body weight for each of the primal cuts by weight class were calculated. There were percent lean and percent fat differences when each primal was evaluated across USDA cull sow weight category. However, the percent lean and percent fat expected for market weight class (MWC) 1 and MWC 2 were not significantly different for each primal cut. The same was true for MWC 3 and MWC 4. In general, the two lighter market weight classes had a higher percent lean and lower percent fat than the two heavier weight classes. This information could be used by

processors to better identify cull sows that are more likely to have appropriate lean to fat ratios either from individual primal or from entire carcasses in order to more closely meet the lean to fat ratios of food products they might manufacture (brats, sausage, etc.).

Analyses predicting carcass lean mass were developed within each USDA cull sow weight class and across classes (ignoring USDA class). Models utilized backfat and loin muscle area measured ultrasonically on live animals and manually on carcasses. It appeared that either the ultrasonic values or the carcass measures could be used to develop lean mass prediction equations for cull sows carcasses and arrive at similar endpoints.

Hot carcass weight and backfat were the best two variables for predicting carcass lean content. Across USDA cull sow classes the resulting r-square value was 0.90. This means hot carcass weight and backfat explained 90% of the variation in lean mass. When lean mass prediction equations were developed within USDA cull sow weight classes, r-square values reached approximately 0.80, slightly lower than the models ignoring weight class. Loin muscle area only improved lean mass prediction in the lightest weight sows. The relatively large influence of hot carcass weight on the prediction of lean mass helps explain the similarity of equations that were derived regardless of whether ultrasonic or carcass measures of backfat and loin muscle area were used.

Of the 212 sows in the data set, trim loss was only recorded for four sows. The records of trim loss occurred on separate collection dates. From this data, it would be difficult to predict trim loss or to associate trim loss with a certain cause. Further studies are necessary to find a relationship between trim loss and factors influencing cull sow trim losses.

In summary, hot carcass weight and 10^{th} rib backfat measures resulted in a prediction equation that had an r-square greater than 0.90. Results indicated prediction equations should be developed across USDA cull sow weight categories, thus ignoring category. The lean and fat weights by primal within and across the USDA cull sow weight categories could be used by cull sow processors to identify primal and cull sow weight categories to develop processed pork products like brats, sausage and other products with defined lean:fat content. The trim loss from sows involved in this study was insufficient to draw any conclusions. Further studies should be conducted to identify both primary trim loss locations and causes from cull sows.

I. Scientific Abstract

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Analyses predicting carcass lean mass were developed within each USDA cull sow weight class and across classes (ignoring USDA class). Models utilized backfat and loin muscle area measured ultrasonically on live animals and manually on carcasses. It appeared that either the ultrasonic values or the carcass measures could be used to develop lean mass prediction equations for cull sows and arrive at similar endpoints.

Hot carcass weight and backfat were the best two variables for predicting carcass lean content. Across USDA cull sow classes the resulting r-square value was 0.90. This means hot carcass weight and backfat explained 90% of the variation in lean mass. When lean mass prediction equations were developed within USDA cull sow weight classes, r-square values reached approximately 0.80, slightly lower than the models ignoring weight class. Loin muscle area only improved lean mass prediction in the lightest weight sows. The relatively large influence of hot carcass weight on the prediction of lean mass helps explain the similarity of equations that were derived regardless of whether ultrasonic or carcass measures of backfat and loin muscle area were used.

Of the 212 sows in the data set, trim loss was only recorded for four sows. The records of trim loss occurred on separate collection dates. From this data, it would be difficult to predict trim loss or to associate trim loss with a certain cause. Further studies are necessary to find a relationship between trim loss and factors influencing cull sow trim losses.

In summary, hot carcass weight and 10^{th} rib backfat measures resulted in a prediction equation that had an r-square greater than 0.90. Results indicated prediction equations should be developed across USDA cull sow weight categories, thus ignoring category. The lean and fat weights by primal within and across the USDA cull sow weight categories could be used by cull sow processors to identify primal and cull sow weight categories to develop processed pork products like brats, sausage and other products with defined lean:fat content. The trim loss from sows involved in this study was insufficient to draw any conclusions. Further studies should be conducted to identify both primary trim loss locations and causes from cull sows.

II. Introduction

Market cull sow value is a significant contributor of income to the commercial sow operation. Annually, nearly 3.3 million sows are harvested in the USA. Improving cull sow value can increase farmer and processor profitability.

An additional challenge relates to new regulations on transport duration which may place restrictions on the ability to efficiently market cull sows. Sows are harvested at limited locations dispersed throughout the USA. Sow well-being can be compromised when efficient marketing and harvest channels are not available.

Through evaluation of current cull sow harvest and processing schemes and accurate determination of lean content and value by condition score and USDA classification, more efficient sow buying and pork marketing programs can be determined with incentives to create a more rapid and value-added process to sow harvest.

III. Objectives

The objective of this study were three fold: 1) Estimate the lean content from the four USDA grades of cull sows, 2) Establish standardized prediction equations for estimating cull sow lean content, 3) Estimate the type, weight, and value of trim loss from cull sows at harvest.

IV. Materials and Methods

The project utilized post-mortem sow carcasses which originated from the cull sow pool from area commercial pork producers near Ogden Utah and harvested at a commercial abattoir (Old McDonalds Meats). Carcasses were classified based on the live weight of sows (USDA cull sow weight categories I, II, III, and IV). Cull sows from area pork producers were purchased. After the sows were purchased, they were weighed and harvested at Old McDonalds Meats, an area commercial abattoir. Prior to harvest, ultrasonic backfat and loin muscle area were obtained by a trained technician.

After harvest, several carcass measures were obtained including: 1) live weight, 2) carcass weight 3) 10^{th} rib backfat measured approximately 2.5 inches off-midline, 4) 10^{th} rib loin muscle depth measured directly below the backfat measurement approximately 2.5 inches off-midline, 5) 10^{th} rib loin muscle area (done by measurement with an ISU grid or tracing the loin on acetate paper and measuring the tracing at a later time), and 6) last rib back fat measured at the midline of the carcass (where carcass is split). Additionally, any trim that was removed from the carcass was weighed and the location where the trim occurred was recorded. When possible, the cause of trim (bruise, open wound, abscess, blood splatter, broken limb, mechanical, etc) was recorded.

After the carcass was split, ½ of the carcass was dissected into the primals (shoulder, loin, ham and belly) and primal weights were recorded. Primals were then dissected into knife separable lean, fat, skin and bone and respective weights recorded. Equations for predicting lean content of the cull sows were constructed by utilizing a combination of the measures obtained including live weight, carcass weight and various fat and muscle measures obtained from the carcass. These equations were constructed by using stepwise regression analyses and maximum r options in order to determine the best equation. Trim loss was weighed and location occurrence recorded.

Evaluation of cull sows across the four USDA weight categories was accomplished. At least 40 carcasses per weight category were collected, slightly lower than the targeted 50 carcasses per category. However, this is not likely to disrupt the evaluation to obtain the estimates of lean, fat, and bone by complete dissection . Additionally, each sow will have a body condition score recorded within the respective USDA weight category or a simple classification as boner, medium fleshly, and fleshly or fancy.

To accomplish the above tasks, the harvest facility crew dissecting the carcasses was trained at the Iowa State University Meat Laboratory by Dr. Steven Lonergan. Training ensured that accurate carcass measures of fat and muscle are obtained and properly recorded. The harvest facility was provided the necessary equipment (scales, recording tools, etc.) to identify the carcass, weigh trim loss, and record the location on the carcass where the trim loss occurred.

After data were collected, equations for predicting carcass lean content were constructed. Equations were constructed using stepwise regression analyses and maximum r options in order to determine the most predictive equation. The PROC GLM procedure in SAS was used to develop a model to predict the pounds of lean expected from the harvest of a cull sow. Fixed effects included hot carcass weight, loin eye area, and backfat. Five models were developed, one using data from each USDA weight class as well as an equation using all of the sows. Percent lean was predicted by using the intercept and b-values from the model for pounds of lean and dividing by the hot carcass weight. R-square values were obtained to determine the amount of variation explained by the equation. Originally it was planned that the lean equations would be adjusted for any trim loss that occurred. However, only four carcasses required trim and adjustments to the prediction equations were not deemed necessary.

V.Results

Table 1 shows the number of carcasses processed and the carcass data used by USDA weight class. Our original goal was to obtain 50 carcasses per weight class. Table 1 shows that in the light USDA cull sow weight class we exceed evaluating 50 carcasses. However, in USDA cull sow weight classes II, III, and IV the total number of sows process was within 10 of attaining our goal of 50. Because of bad carcass splits (resulting is substantially unequal carcass halves) and data errors about 70 percent of the data were utilized in the final analyses. This still represents the largest data set of cull sow carcasses ever processed into lean, fat, bone, and skin tissue components. Because the project involved complete dissection of ½ of each carcass, only a limited number of sow carcasses could be processed on an individual day. Table 2 shows the number of carcass halves by processing day.

Table 3 shows the average live weight, BCS, backfat depth, and loin eye area by market weight class. These measures increased with increasing market weight class. Backfat depth and loin muscle area measurements were taken at the tenth rib using an ultrasound scan. The average body condition score increased as USDA cull sow weight class increased. This may be expected as sows increase in body weight they gain backfat, muscling, or both. It is clear that ultrasonic and carcass backfat and loin muscle values differ depending on whether the measures were obtained live or whether they were obtained on the carcass. The correlations between ultrasound and carcass measurements for loin muscle area and backfat were 0.53 and 0.65, respectively. This is consistent with previous literature where the correlations between ultrasonic and carcass 10th rib backfat is higher than that between ultrasonic and carcass loin muscle area.

Table 4 shows the average pounds of lean, fat, skin, and bones produced from sow in the each market weight class. The LSMEANS for table 4 are from a model with fixed effects of collection date, and hot carcass weight. Each market weight class was modeled individually. Based on the data in Table 4, there is a difference among the expected weight of the pounds of lean, pounds of fat, pounds of skin and pounds of bone produced by sows in different market weight classes. This would be expected as sows become heavier and move into a new weight class. Similarly, the percent lean and fat by carcass and total body weight for each of the primal cuts by weight class were calculated. These results are shown in tables

5, 6, and 7. Primal percent lean and percent fat differed across USDA cull sow weight categories. However, the percent lean and percent fat for market weight class (MWC) 1 and MWC 2 did not differ. The same was true for MWC 3 and MWC 4. In general, the two lighter market weight classes had a greater percent lean and lower percent fat than the two heavier weight classes.

Because we know actual carcass lean content based on the knife separable components, we were able to utilize other measured traits to develop lean equations similar to what is commonly used to calculate percent lean in most market hog buying programs. In order to develop carcass lean prediction equations, a stepwise regression analysis incorporating a maximum r option was utilized to determine the optimum components to be included in the prediction equation. The maximum r option was used to maximize the predictive ability of the equation. These equations were developed by individual USDA cull sow market weight class and across the entire data. Estimates of intercepts, fixed effects, and r-squared values are shown for ultrasound and carcass measures in Tables 8 and 9, respectively. The idea was to examine the slopes of the equations from each weight class. The equation from each weight class was used to predict carcass lean from sows in the other weight classes. If the lines or slopes were parallel then the equation would be considered equal in predicting carcass lean with the difference being a scaling effect. Across the USDA cull sow weight class categories, two primary traits, hot carcass weight and 10^{th} rib backfat, contributed to lean prediction equations that resulted in the greatest r-square values (greater than 0.60 and as high as 0.80). One could argue that the USDA cull sow weight classification artificially divides the sows into categories that really have little predictive value relative to the carcass lean within each carcass. Hence, an analysis predicting carcass lean irrespective of USDA cull sow weight class was conducted. Again, hot carcass weight and backfat were the two most predictive variables for predicting carcass lean content resulting in an r-square value of 0.90.

The amount of variation explained by the pounds lean calculation using ultrasound measurements for each market weight class are shown in table 10. The table shows the r-squared value for the overall and the specific market weight class equation for each market weight class. Hot carcass weight and backfat were consistently the variables accounting for the greatest amount of variation as they were the only significant ($P<0.05$) when predicting carcass lean weight with one exception. Loin muscle area was a significant variable in the prediction equation developed within USDA cull sow weight class I, the lightest cull sow class. Only slightly more variation is explained by individual class equations compared to the overall equation used for each class.

Tables 9 and 11 are similar to tables 8 and 10. The only difference is that the backfat and loin muscle area measurements used for the model to predict pounds of lean by weight class and overall were measured on the carcass directly. Like the equations developed from ultrasonic data, backfat was the most consistent significant ($P <0.05$) measure other than hot carcass weight for predicting lean weight in the carcass by USDA cull sow weight class. Like the equations developed based on the ultrasonic data, loin muscle area was a significant ($P <0.05$) source of variation in the prediction of carcass lean mass within the lightest USDA cull sow weight class, Class I. However, the difference between the lean mass prediction equations based on the use of ultrasonic and carcass backfat and loin muscle measures was the fact that loin muscle area was a significant ($P <0.05$) source of variation in the overall equation where it did not enter into the prediction equation when ultrasound values were used. The slopes for HCW which explains most of the variation of pounds lean is similar using either measurement ultrasound or the carcass backfat and loin muscle area. The r-squared value for the overall equation is greater than the r-squared value for the class equation for two classes. This would further add to the argument of using an overall equation for all weight classes.

Figures 1 through 10 plot the lean equations by USDA cull sow weight class and across the entire data set from ultrasonic and carcass measured backfat and loin muscle area. Figures 1-5 show the prediction based on each equation across all weight classes as well as the overall equation and the equation for each weight class only on weights for each weight class using ultrasound measurements for loin eye area and backfat. Figures 6-10 show the prediction based on each equation across all weight classes as well as the overall equation and the equation for each weight class only on weights for each weight class using carcass measurements for loin eye area and backfat.

These plots were provided to give graphical representation of the lean prediction equations. While it appears there are substantial differences between the lean equations, the scale of the graphs magnifies this difference. There is little dissimilarity between the overall equation and the equation specific to certain weight classes. It appears that equations between ultrasonic and carcass measured backfat and loin muscle area result in very similar end points for lean mass prediction equations. Similarly, when examining the lean mass prediction equations between the USDA cull sow categories, it appears that a single equation could be used to predict lean mass among sows falling into USDA cull sow class I and II. Similarly, a single equation could be used to predict lean mass among sows falling into USDA cull sow class III and IV. However, an overall equation using all of the data and ignoring the USDA cull sow category results in a lean mass prediction equation with the greatest r-squared (~0.90) regardless whether backfat and loin muscle area are measured ultrasonically or directly on the carcass (Tables 8 and 9). Hence, an overall equation used across market weight classes is suggested to predict the pounds of lean expected as opposed to separate equations for each market weight class. The overall equation is as accurate as the equations for each market class. The amount of variation in pounds lean explained by the prediction is only slightly different for the overall equation and the equation specific to each weight class.

Of the 212 sows in the data set, trim loss was only recorded for four sows. Table 11 below shows the distribution of trim loss weight (lbs.) for each sow where trim was required. There was one sow from each weight class with trim loss recorded. The records of trim loss occurred on separate collection dates. Fortunately for the processor and the producers supplying cull sows to this market but unfortunately for this study, too few trim loss measures were observed in this study to draw any conclusions. From this data, it would be difficult to predict trim loss or to associate trim loss with a certain cause. Further study would be necessary to find a relationship between trim loss and factors influencing cull sow trim losses.

In conclusion, hot carcass weight and 10^{th} rib backfat measures resulted in a prediction equation that had an r-square greater than 0.90 which was greater than any equation developed attempting to incorporate the USDA cull sow weight categories. The lean and fat weights by primal within and across the USDA cull sow weight categories could be used by cull sow processors to identify primal and cull sow weight categories to develop processed pork products like brats, sausage and other products with defined lean:fat content. Finally, the trim loss from sows involved in this study was insufficient to draw any conclusions. Further studies should be conducted to identify both primary trim loss locations and causes from cull sows.

VI. Discussion

There is little information pertaining to the prediction of lean content of cull sows. A prediction equation for estimating lean and fat in meat of carcasses from cull sows was reported in 1989, nearly 20 years ago by Jungst and co-workers (1989).This study evaluated 104 fourth parity Duroc-Landrace, Hampshire-Landrace, and Yorkshire-Landrace sows. The sows averaged 227 kg or approximately 500 lbs live weight. The application of this data has limitations for several reasons. First, today's cull sow population is predominately Yorkshire-Landrace or some similar genetic composition. Secondly, due to relatively high replacement rates, not all sows harvested reach the fourth parity. Lastly, the average weight of cull sows from the Jungst et al. (1989) study was within a single USDA weight range and does not reflect the variability in live weight and hence, carcass weights that are commonly seen at the cull sow harvest facilities today. The present finding do expand the knowledge relative to modern cull sow

Aziz and co-workers (1993a, b) published a more recent study of Canadian cull sows. They harvested 204 sows from seven different weight classes ranging from 99.9 kg or less to 225 kg and above carcasses in 25 kg increments. These carcasses ranged from 9.9 mm or less to 55 mm or greater backfat in increments of 5 mm at approximately the 10^{th} rib using a fat-o-meter type probe. Additionally, fat thickness was measured using a ruler at the midline at the maximum fat depth over the lumbar vertebrae, last rib, and approximately the 10th rib. The investigators cut ½ of the cull sow carcass into the four primals of shoulder, ham, loin and belly. The shoulder, ham and loin were further separated into trimmed commercial cuts to determine commercial yield. Following this procedure all of the cuts were separated into lean, fat, and bone; yield was calculated for each of the three components. The researchers reported a significant weight class x fat class interaction for belly yield.

The findings of Aziz and co-workers is likely not substantially different than those from the present study. The findings from the present study where the carcasses were divided based upon USDA Cull Sow weight class (based on live weight). In the present study there were differences in weight of lean and fat tissue by live weight cull sow class for the majority of the primal cuts and the individual components (bone, fat, lean and skin tissue).

Weight class only was significant for the percentage of lean and bone yield from the Azix et al. (1993 a & b) work. Furthermore, carcass composition of cull sows was better correlated to backfat thickness than carcass weight, since the increasing carcass weight as live weight increased was primarily composed of fat. When evaluating various prediction equations based on the measurements evaluated in this study, it seems to suggest that prediction accuracy for the percentage lean yield was greatest when the probe fat measure was utilized (R^2=0.77). The probe lean had the lowest coefficient of determination (R^2=0.01). Among the ruler measurements taken, the maximum fat depth at the lumbar region was the most accurate predictor of lean content and had a similar R^2 value to the probe fat (R^2=0.71). When examining the effects of weight, carcass weight yielded the highest coefficient of determination (R^2=0.82) when compared to all other single measurement relationships to lean yield. The addition of probe fat to carcass weight improved the R^2 to 0.93. It appears from this work that a single measure of fat (probe or ruler) when combined with the carcass weight of cull sows is sufficiently accurate to predict lean content of sows. However, there was no discussion of the impact that trim loss could have on the value of these carcasses. This study appears to have the greatest application to today's modern genetics but still is almost 15 years old and maternal genetic lines have certainly changed during this period. Additionally, the way the study was designed may not be reflective of the type of sow culled and harvested by sow operations today.

The results from Aziz et al. (1993) appear to differ from those in the present study. Regardless of the trait we were predicting pounds of lean from the carcass or percentage of carcass lean and whether we used live ultrasonic measures or carcass backfat and loin muscle area measures, hot carcass weight was the driving force in the prediction equations. That being said, the present findings are similar to the Aziz and co-workers (1993) findings in that the second and only other significant trait to enter into the prediction equation when evaluating using Stepwise regression was backfat. Furthermore, similar r-square predictive results were obtained regardless of whether carcass or ultrasonic backfat was used in the equation. This is likely the result of the influence of hot carcass weight on the entire predictive ability of the equation.

Another Canadian study (Aziz et al., 1990) evaluated the relationships between carcass weight, backfat and loin muscle depth in cull sows. This survey found that 85 percent of the sows were between 100 and 200 kg or 220 and 440 lbs. They also reported that 4.5 percent of sows weighed less than 100 kg and 10.5 percent weighed over 200 kg. Furthermore, backfat depth was between 15 and 20 mm for over 25 percent and between 20 and 25 mm for almost 30 percent of the sows. The greatest percentage of sows fell into these two backfat categories when compared to all other designated categories. The study concluded that cull sows are very diverse. The present findings would support this report in that it is still quite easy to obtain sows fitting into the 4 USDA cull sow weight categories.

Several other studies have reported methods to estimate pork carcass composition. However, these studies predominantly focused on market hogs and even lighter pigs rather than cull sows (Fahey et al., 1977; Prince et al., 1981; Brannaman et al., 1984; and Grisdale et al., 1984). The findings in these previous studies focusing primarily on market hogs do support the present work with respect to the importance of hot carcass weight on the any equation to predict carcass lean weight or carcass lean percentage.

The carcass lean mass prediction equations appear to divide out into two categories. The first equation predicts carcass lean mass from USDA cull sow weight classes I and II and another predicts lean mass from cull sow weight classes III and IV (Tables 8 and 9 and Figures 1 and 6. This may fit the current cull sow buying system in that the U.S. cull sow processing industry tends to focus on buying certain kinds of sows. In other words a processor typically does not purchase sows from all 4 USDA weight classes. Instead each processor has developed a niche for a certain product mix and tends to either buy thin sows or "boner" sows or they might buy what some call "fancy" sows. In this sense the information from the present study breaks quite nicely. Those sows generally considered boner sows typically are from the two lightest cull sow weight classes and the fancy sows are usually from cull sow weight classes III and IV. A previously mentioned alternative would be to drop the USDA cull sow weight classifications. In this manner cull sow processor could base their buying system based on a lean mass prediction equation like that developed in the current study or something very similar that includes hot carcass weight, backfat, and possibly some measure of loin muscle. In the present study, hot carcass weight and backfat are the drivers to predict lean mass. In some cases loin muscle area significantly entered into the equation. In the present study, loin muscle area was measured either ultrasonically or directly on the carcass. In practice measuring loin muscle area at line processing speeds for most cull sow processors would be impractical. Hence, the choice would be to implement a cull sow carcass lean mass equation using only hot carcass weight and backfat. This equation would typically predict the variation in carcass lean content from cull sows quite accurately. If a measure of muscle is needed it would be required to examine loin depth similarly to the way backfat and loin muscle depth is currently measured on the carcasses from market hogs.

One of the objectives from the present study was to examine the relative lean to fat ratios from each primal cut within and across USDA cull sow weight category. The actual weight and percentage of lean and fat from each primal and cull sow weight category could be used by processors to improve efficiency of brat, sausage and other product development. This could be accomplished by purchasing sows from a specific USDA cull sow weight category or mix of categories that result in the best lean to fat ratio required to produce the processed pork products they desire.

The present researchers could find no scientific literature regarding trim loss from the carcasses of cull sows. Furthermore, no information regarding trim loss from market hog carcasses was found in the scientific literature. Unfortunately the present study will not supply new knowledge to the scientific community because so few sow carcasses required trim in order to evaluate the relative weight of trim loss and associated economic costs.

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Table 1. The number of carcasses processed and carcass data used in analyses by weight class in a study of knife separable lean, fat, bone and skin weight by USDA cull sow weight class[1]

Weight Class	Carcasses	Carcass Information Used
1	84	67
2	43	38
3	41	34
4	44	37
Total	212	176

1 USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 2. The number of carcasses processed and carcass data used in analyses by collection date in a study of knife separable lean, fat, bone and skin weight by USDA cull sow weight class

Collection Date	**Carcasses**	**Carcass Information Used**
09/17/2008	6	4
09/25/2008	8	8
10/02/2008	2	2
10/03/2008	6	5
10/09/2009	8	7
10/16/2008	8	7
10/29/2008	6	4
12/04/2008	14	11
12/11/2008	10	7
01/07/2009	6	3
01/08/2009	9	6
01/14/2009	4	4
01/15/2009	11	10
01/16/2009	9	8
01/22/2009	15	9
01/29/2009	13	13
05/21/2009	4	4
05/25/2009	2	2
05/26/2009	1	1
05/27/2009	4	2
05/28/2009	4	3
07/23/2009	5	4
07/28/2009	3	2
08/06/2009	4	3
08/12/2009	2	2
08/13/2009	4	4
08/20/2009	6	6
08/27/2009	5	4
09/03/2009	5	5
10/01/2009	6	5
10/02/2009	4	4
10/15/2009	5	4
10/22/2009	5	5
02/04/2010	5	5
02/05/2010	3	3
Total	212	176

Table 3. The average live weight, backfat and loin eye are of carcasses used in analyses of study of knife separable lean, fat, bone and skin weight by USDA cull sow weight class

Weight Class[1]	**Live Weight**	**BCS**	**Ultrasonic Backfat[3]**	**Ultrasonic Loin Muscle Area[3]**	**Carcass Backfat[4]**	**Carcass Loin Muscle Area[4]**
MWC 1	390.5	2.70	0.37	5.64	0.66	7.70
MWC 2	476.4	2.80	0.40	6.64	0.81	8.84
MWC 3	525.7	3.34	0.44	7.05	1.25	9.32
MWC 4	610.1	4.12	0.64	7.37	1.75	9.67

[1]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)
[2]Body condition scoring was based on a 1 to 5 scale where 1 = an excessively thin animal and 5 is an excessively fat animal (Patience and Thacker, (Patience and Thacker, 1989)
[3]Ultrasonic measurements taken at the tenth rib
[4]Carcass measurements taken at the tenth rib

Table 4. Primal lean, fat, bone and skin LS means (± SE) by USDA cull sow market weight class from a study evaluating knife separable components from cull sow carcasses [1]

	LS Means by Market Weight Class[2]			
Carcass component	**MWC 1[3]**	**MWC 2[3]**	**MWC 3[3]**	**MWC 4[3]**
Shoulder				
Total weight	78.8 (± 0.18) [a]	97.0 (± 1.56) [a]	106.2 (± 1.65) [a]	122.9 (± 1.58) [a]
Skin weight	6.8 (± 0.23) [ab]	9.2 (± 0.31) [a]	9.9 (± 0.33) [b]	11.6 (± 0.31) [ab]
Fat weight	7.2 (± 0.43) [a]	7.8 (± 0.57)[b]	9.4 (± 0.60) [a]	13.8 (± 0.58) [ab]
Lean weight	55.5 (± 0.93) [a]	70.4 (± 1.23) [a]	76.5 (± 1.30) [a]	85.1 (± 1.24) [a]
Bone weight	9.3 (± 0.29) [a]	9.6 (± 0.38)[b]	10.0 (± 0.40) [c]	11.6 (± 0.39)[abc]
Neck bones weight	6.2 (± 0.36)[abc]	9.4 (± 0.48) [a]	8.9 (± 0.50) [b]	8.8 (± 0.48) [c]
Loin				
Total weight	56.4 (± 1.05) [a]	69.5 (± 1.39) [a]	74.2 (± 1.47) [b]	89.0 (± 1.41)[ab]
Skin weight	3.9 (± 0.17) [ab]	5.3 (± 0.22) [a]	5.0 (± 0.24) [b]	6.0 (± 0.23) [b]
Fat weight	7.6 (± 0.61) [a]	8.7 (± 0.81) [b]	11.4 (± 0.85) [a]	19.5 (± 0.82) [ab]
Boneless loin weight	25.4 (± 0.76) [ab]	31.3 (± 1.00) [b]	28.7 (± 1.06) [c]	33.7 (± 1.02) [ac]
Tenderloin weight	4.0 (± 0.14) [ab]	5.0 (± 0.18) [b]	4.4 (± 0.19) [c]	5.4 (± 0.18) [ac]
Loin trim weight	3.2 (± 0.49) [ac]	4.2 (± 0.65) [bc]	8.7 (± 0.69) [c]	7.5 (± 0.66) [ab]
Loin bone weight	12.3 (± 0.33)[abc]	14.7 (± 0.43) [b]	15.7 (± 0.46) [c]	16.3 (± 0.44) [a]
Ham				
Total weight	67.3 (± F1.15) [a]	83.3 (± 1.53) [a]	101.2 (± 1.62) [a]	114.9 (± 1.55) [a]
Skin weight	5.7 (± 0.16) [a]	7.4 (± 0.22) [a]	8.8 (± 0.23) [a]	9.9 (± 0.22) [a]
Lean weight	46.1 (± 0.84) [a]	57.1 (± 1.12) [a]	67.3 (± 1.18) [a]	74.8 (± 1.13) [a]
Fat weight	4.4 (± 0.42) [a]	5.4 (± 0.56) [b]	9.9 (± 0.59) [ab]	14.6 (± 0.57) [ab]
Bone weight	11.2 (± 0.20)[ab]	13.2 (± 0.26) [ab]	14.5 (± 0.28) [a]	15.1 (± 0.27) [b]
Rib and Belly				
Total weight	40.4 (± 0.93) [a]	48.2 (± 1.24) [a]	59.5 (± 1.31) [a]	71.8 (± 1.26) [a]
Lean weight	29.8 (± 0.63) [a]	34.1 (± 0.83) [a]	39.1 (± 0.88) [a]	45.9 (± 0.84) [a]
Bone weight	3.8 (± 0.13) [ab]	4.4 (± 0.18) [ab]	5.7 (± 0.19) [a]	5.4 (± 0.18) [b]
Skin weight	4.8 (± 0.19) [ab]	5.7 (± 0.26) [ab]	7.3 (± 0.27) [a]	7.4 (± 0.26) [b]
Fat weight	1.8 (± 0.56) [a]	3.4 (± 0.74) [b]	7.3 (± 0.79) [ab]	12.2 (± 0.75) [ab]

[1]data adjusted to a constant carcass weight within a cull sow market weight class.
[2]row means with different superscripts are different ($P<0.05$).
[3]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 5. Percentage of lean and fat by USDA cull sow weight class and carcass primal [1]

Primal	Primal component	Total	MWC1[2]	MWC2	MWC3	MWC4
Loin	**Lean of Loin, %**	49.1	52.4 [ab]	52.6 [bd]	55.3 [ab]	43.8 [cd]
	Fat of Loin,%	15.0	13.0 [a]	11.9[b]	15.5[c]	21.6[abc]
	Lean of Carcass,%	10.6	11.4[ac]	11.5[bd]	9.2[ab]	9.4[cd]
	Fat of Carcass,%	3.3	2.9[a]	2.7[b]	3.2[c]	4.6[abc]
Shoulder	**Lean,%**	70.8	70.1[a]	72.5 [ab]	72.0 [c]	69.3 [bc]
	Fat,%	9.3	9.2 [a]	8.0 [b]	8.9 [c]	11.1 [abc]
	Lean of Carcass, %	21.4	21.5 [a]	22.3 [b]	21.4	20.4 [ab]
	Fat of Carcass,%	2.8	2.8	2.5 [a]	2.6 [b]	3.3 [ab]
Ham	**Lean, %**	67.4	68.5[ac]	68.5[b]	66.6[a]	65.2[bc]
	Fat, %	8.4	6.5[a]	6.5[b]	9.7[ab]	12.5[ab]
	Lean of Carcass, %	18.2	18.0	18.1	18.8	18.0
	Fat of Carcass, %	2.3	1.7[a]	1.7[b]	2.8[ab]	3.5[ab]
Rib and Belly	**Lean ,%**	69.9	73.8[ac]	70.8[bd]	66.8[ab]	64.7[cd]
	Fat, %	8.7	4.4[a]	6.8[b]	11.4[ab]	16.0[ab]
	Lean of Carcass, %	11.2	11.6[a]	10.8[a]	10.9	11.0
	Fat of Carcass, %	1.5	0.7[a]	1.1[b]	2.1[ab]	2.9[ab]

[1]Row means with different superscripts are significantly different (P<0.05).
[2] USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 6. Percentage of lean and fat by USDA cull sow weight class and pairs of carcass primals [1]

Primal	Primal component	Total	MWC1	MWC2	MWC3	MWC4
Loin and Shoulder	**Lean, %**	61.8	62.7^{ac}	64.2^{bd}	60.7^{ab}	58.6^{cd}
	Fat, %	11.7	10.9^{a}	9.7^{b}	11.6^{c}	15.5^{abc}
	Lean of Carcass, %	32.0	32.9^{ac}	33.8^{bd}	30.6^{ab}	29.8^{cd}
	Fat of Carcass, %	6.1	5.7^{a}	5.2^{b}	5.8^{c}	7.9^{abc}
Loin, Rib and Belly	**Lean, %**	57.9	61.2^{ac}	59.9^{bd}	54.2^{ab}	53.0^{cd}
	Fat , %	12.5	9.5^{a}	9.9^{b}	13.9^{ab}	19.2^{ab}
	Lean of Carcass, %	21.8	23.0^{ac}	22.3^{bd}	20.2^{ab}	20.4^{cd}
	Fat of Carcass, %	4.8	3.6^{a}	3.8^{b}	5.2^{ab}	7.5^{ab}
Loin and Ham	**Lean, %**	59.3	61.1^{ac}	61.3^{bd}	57.3^{ab}	55.9^{cd}
	Fat, %	11.4	9.5^{a}	9.0^{b}	12.2^{ab}	16.5^{ab}
	Lean of Carcass, %	28.8	29.4^{ac}	29.6^{bd}	28.0^{ab}	27.4^{cd}
	Fat of Carcass, %	5.5	4.6^{a}	4.4^{b}	5.9^{ab}	8.1^{ab}
Shoulder, Rib and Belly	**Lean, %**	70.4	71.4^{a}	71.9^{b}	70.0^{c}	67.5^{abc}
	Fat, %	9.2	7.6^{a}	7.6^{b}	9.9^{ab}	13.0^{ab}
	Lean of Carcass, %	32.6	33.1^{a}	33.1^{b}	32.3	31.4^{ab}
	Fat of Carcass, %	4.3	3.5^{a}	3.5^{b}	4.7^{ab}	6.1^{ab}
Shoulder and Ham	**Lean, %**	69.2	69.4^{a}	70.7^{b}	69.4^{c}	67.3^{abc}
	Fat , %	8.9	7.9^{a}	7.3^{b}	9.3^{b}	11.8^{ab}
	Lean of Carcass, %	39.6	39.5	40.5^{a}	40.2^{b}	38.4^{ab}
	Fat of Carcass, %	5.1	4.5^{a}	4.2^{b}	5.4^{b}	6.8^{ab}
Rib, Belly and Ham	**Lean, %**	68.3	70.5^{ac}	69.4^{bd}	66.5^{ab}	64.9^{cd}
	Fat, %	8.5	5.6^{a}	6.6^{b}	10.4^{ab}	14.0^{ab}
	Lean of Carcass, %	29.3	29.5	28.9	29.7	29.0
	Fat of Carcass, %	3.8	2.4^{a}	2.8^{b}	4.8^{ab}	6.3^{ab}
Loin, Shoulder, Rib and Belly	**Lean, %**	63.6	65.2^{ac}	65.6^{bd}	62.1^{ab}	60.1^{cd}
	Fat, %	11.1	9.4^{a}	9.1^{b}	11.7^{ab}	15.7^{ab}
	Lean of Carcass, %	43.2	44.5^{ac}	44.6^{bd}	41.5^{ab}	40.2^{cd}
	Fat of Carcass, %	7.6	6.4^{a}	6.2^{b}	7.9^{c}	10.8^{abc}

[1]Row means with different superscripts are significantly different ($P<0.05$). USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater).

Table 7. Percentage of lean and fat by USDA cull sow weight class and carcass primals[1]

Primal	Primal component	Total	MWC1[2]	MWC2	MWC3	MWC4
Loin, Shoulder and Ham	**Lean, %**	63.7	64.6[a]	65.6[bc]	62.8[b]	60.9[ac]
	Fat, %	10.6	9.4[a]	8.7[b]	10.9[c]	14.5[abc]
	Lean of Carcass, %	50.2	50.9[a]	51.9[bc]	49.4[b]	47.8[ac]
	Fat of Carcass, %	8.3	7.4[a]	6.9[b]	8.6[c]	11.4[abc]
Loin, Rib, Belly and Ham	**Lean, %**	61.9	64.2[ac]	63.5[bd]	59.5[ab]	58.1[cd]
	Fat, %	10.8	8.2[a]	8.5[b]	12.1[ab]	16.5[ab]
	Lean of Carcass, %	39.9	41.0[ac]	40.4[bd]	38.9[ab]	38.4[cd]
	Fat of Carcass, %	7.0	5.3[a]	5.5[b]	8.0[ab]	10.9[ab]
Shoulder, Rib, Belly, and Ham	**Lean, %**	69.3	70.3[a]	70.7[b]	68.7[ab]	66.6[ab]
	Fat, %	8.9	7.1[a]	7.2[b]	8.9[ab]	12.9[ab]
	Lean of Carcass, %	50.7	51.0[a]	51.2[b]	51.1[c]	49.4[abc]
	Fat of Carcass, %	6.6	5.2[a]	5.2[b]	7.4[ab]	9.6[ab]
Total	**Lean of Carcass, %**	61.3	62.5[ac]	62.7[bd]	60.3[ab]	58.8[cd]
	Lean of BWT, %	41.0	41.1	41.5	41.1	40.2
	Fat of Carcass, %	9.8	8.1[a]	7.9[b]	10.6[ab]	14.2[ab]
	Fat of BWT, %	6.6	5.4[a]	5.3[b]	7.2[ab]	9.7[ab]

[1]Row means with different superscripts are significantly different ($P<0.05$).
[2]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 8. Models to predict carcass pounds of lean by USDA cull sow market weight class using all market weight classes and ultrasound backfat and loin muscle area[1]

USDA Cull Sow Weight Class[2]	Intercept	HCW[4]	BF[4]	LMA[4]	R-Squared
1	-11.51	0.66	-40.04	3.11	0.84
2	-4.89	0.72	-59.31	*[3]	0.72
3	26.74	0.60	-59.20	*	0.60
4	15.65	0.61	-39.24	*	0.61
Overall	23.20	0.60	-44.51	*	0.90

[1]R-Square values represent model R-Squares
[2]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)
[3]fixed effects with * are not significant ($P<0.05$)
[4]HCW= hot carcass weight, BF= backfat and LMA = loin muscle area. Traits were measured at the 10th rib using an Aloka 500v Real Time ultrasound machine.

Table 9. Models to predict carcass pounds of lean by USDA cull sow market weight class using all market weight classes and carcass measured backfat and loin muscle area[1]

Prediction Equation	**Intercept**	**HCW[4]**	**BF[4]**	**LMA[4]**	**R-Squared**
1	-13.46	0.60	-12.96	3.72	0.84
2	-29.12	0.76	-17.61	*[3]	0.76
3	1.45	0.63	-7.85	*	0.48
4	37.05	0.50	*	*	0.52
Overall	6.48	0.57	-9.69	1.78	0.89

[1]R-Square values represent model R-Squares
[2]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)
[3]fixed effects with * are not significant ($P<0.05$)
[4] HCW= hot carcass weight, BF= backfat, and LMA = loin muscle area. Traits were measured at the 10th rib using an Aloka 500v Real Time ultrasound machine.

Table 10. Models to predict pounds lean by USDA cull sow market weight class using ultrasonic backfat and loin eye area[1]

USDA Cull Sow Weight Class[2]	Class Equation	Overall Equation
MWC 1	0.84	0.81
MWC 2	0.72	0.71
MWC 3	0.60	0.60
MWC 4	0.61	0.61

[1]R-Square values represent model R-Squares for sow in the MWC for which the class equation was developed
[2]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 11. Models to predict pounds lean by USDA cull sow market weight class using carcass backfat and loin eye area[1]

USDA Cull Sow Weight Class[2]	Class Equation	Overall Equation
MWC 1	0.84	0.81
MWC 2	0.76	0.61
MWC 3	0.48	0.48
MWC 4	0.52	0.55

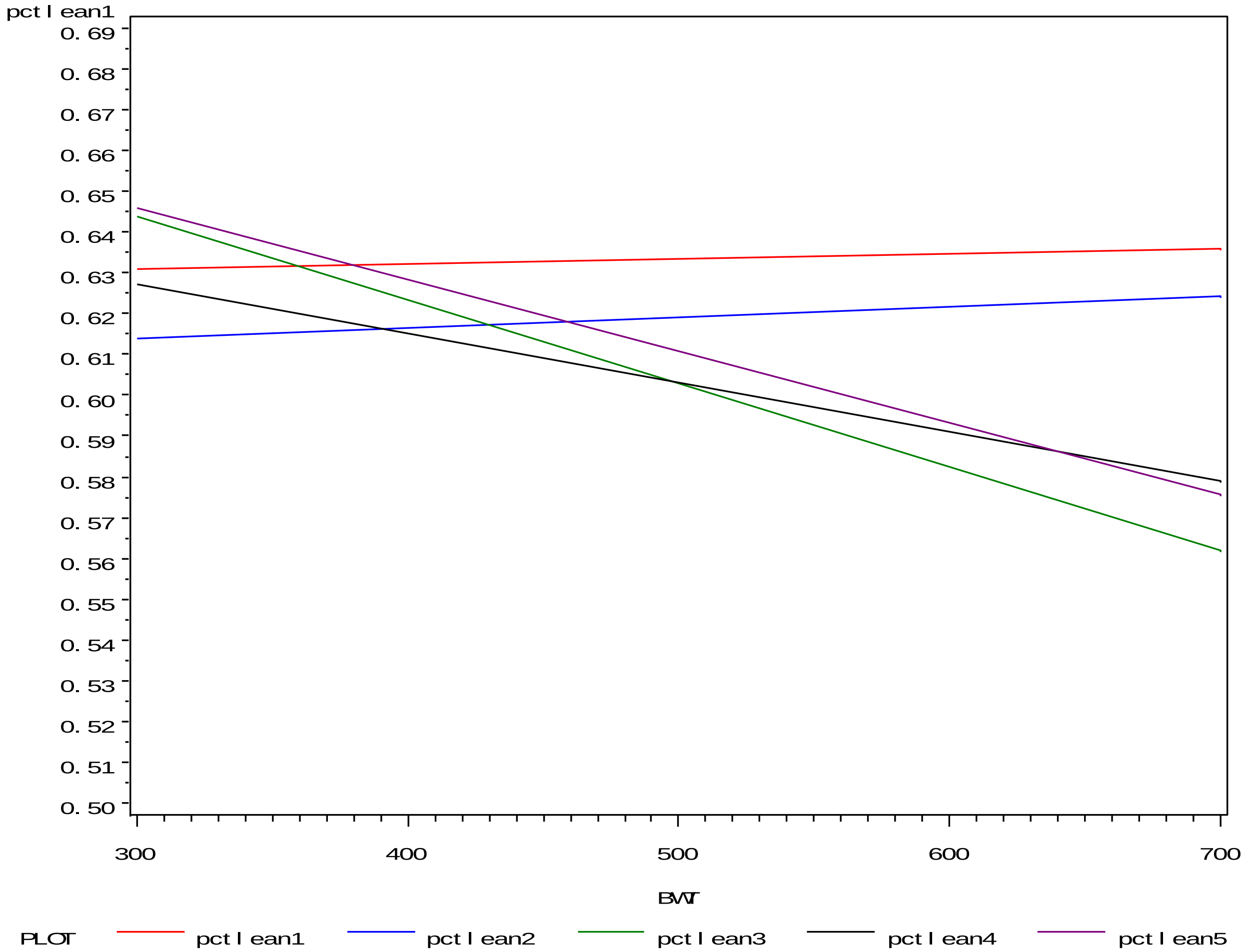
[1]R-Square values represent model R-Squares for sow in the MWC for which the class equation was developed
[2]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Table 12. Trim loss and its location from a study to estimate lean, fat, skin and bone tissue from cull sows. [1]

Collection Date	Weight Class of Sow	Trim Loss	Lbs. of trim loss
09/30/08	4	R. Shoulder; R. Hip	2.85 (± sh. 2.1, hip 0.75)
10/14/08	1	Front Shoulder	4.25
08/03/09	3	Front left	11.2
09/29/09	2	Belly	16

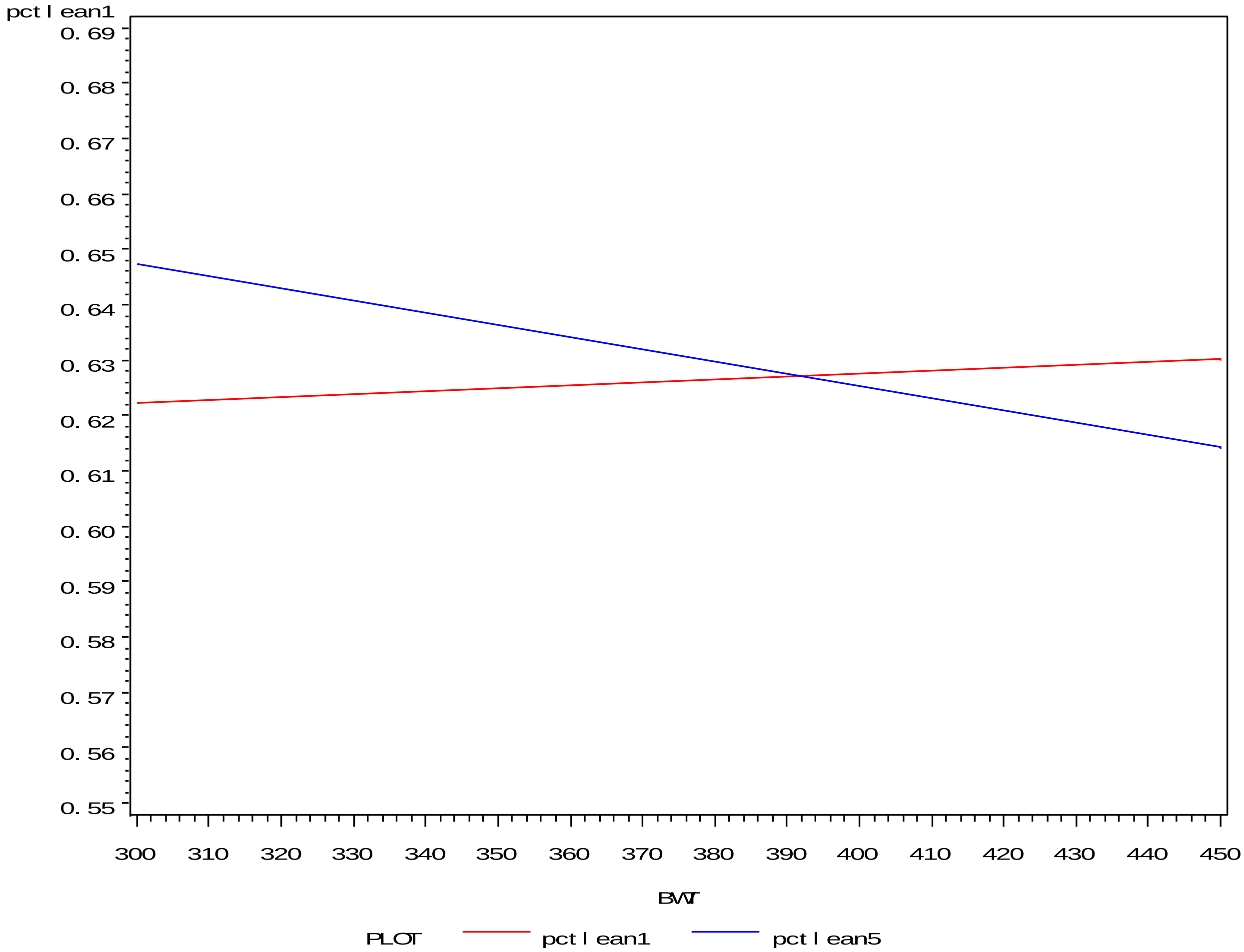
[1]USDA cull sow weight classes are based on the following live weight categories live weight class I (300 to 450 lbs. or 136.1 to 204.1 kg live weight), live weight class II (451 to 500 lbs. or 204.2 to 226.8 kg), live weight class III (501 to 550 lbs. or 226.9 to 249.5), and class IV (551 lbs. and greater or 250 kg and greater)

Figure 1. Plot of prediction equations across all live weights using ultrasound backfat and loin eye area[1]



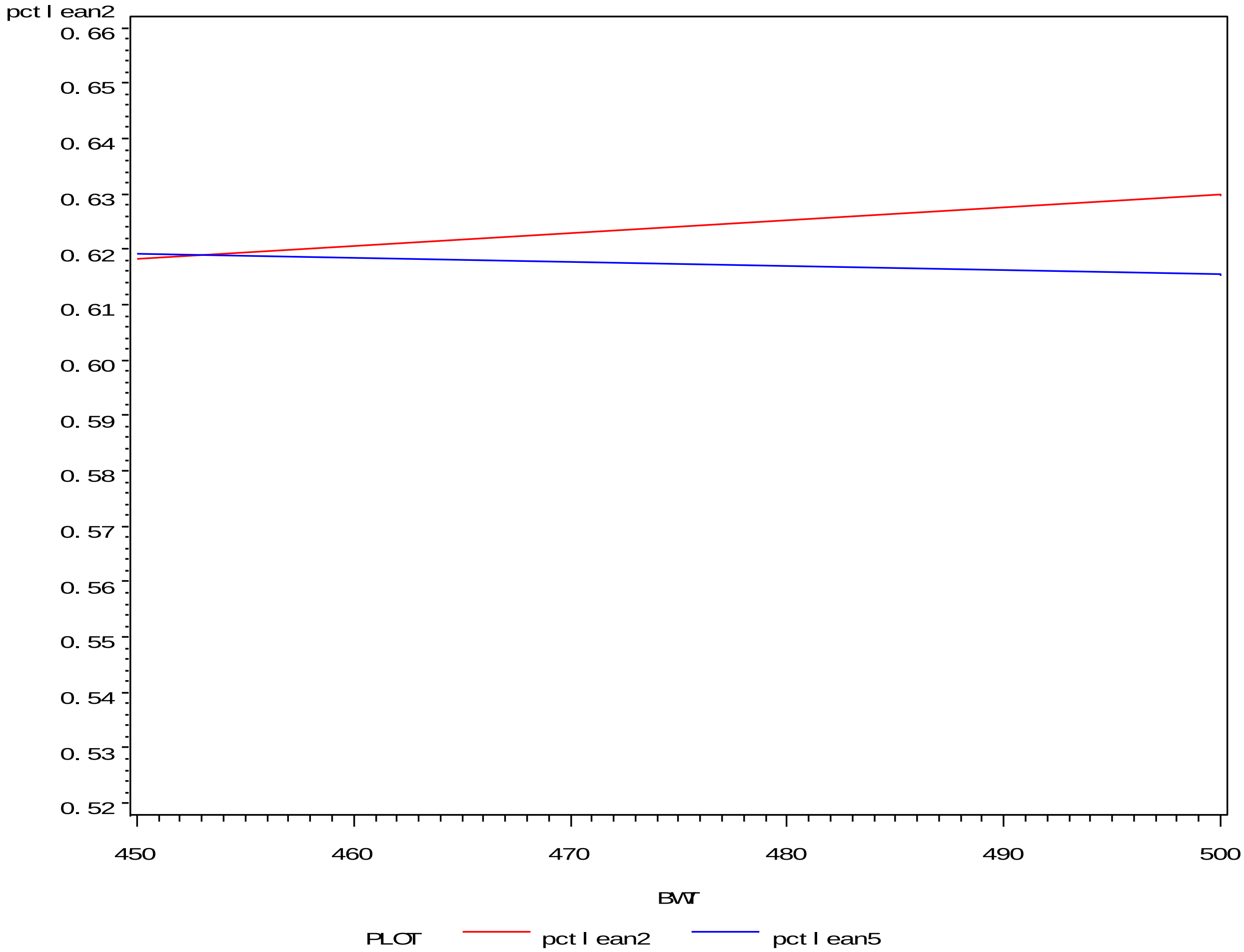
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 2. Plot of prediction equation for MWC 1 and the overall equation over the live weight for MWC 1 using ultrasound backfat and loin eye area [1]



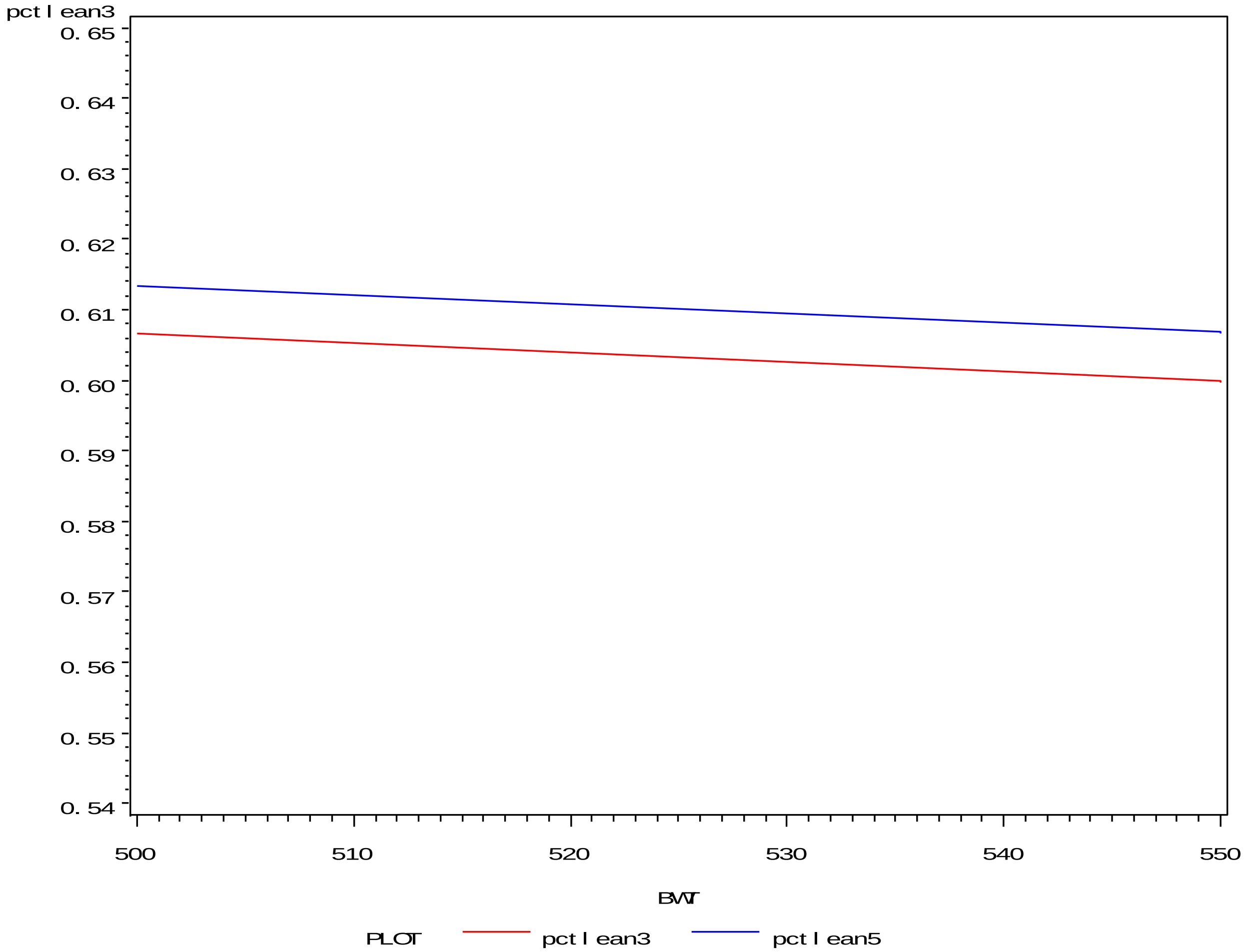
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 3. Plot of prediction equation for MWC 2 and the overall equation over the live weight for MWC 2 using ultrasound backfat and loin eye area [1]



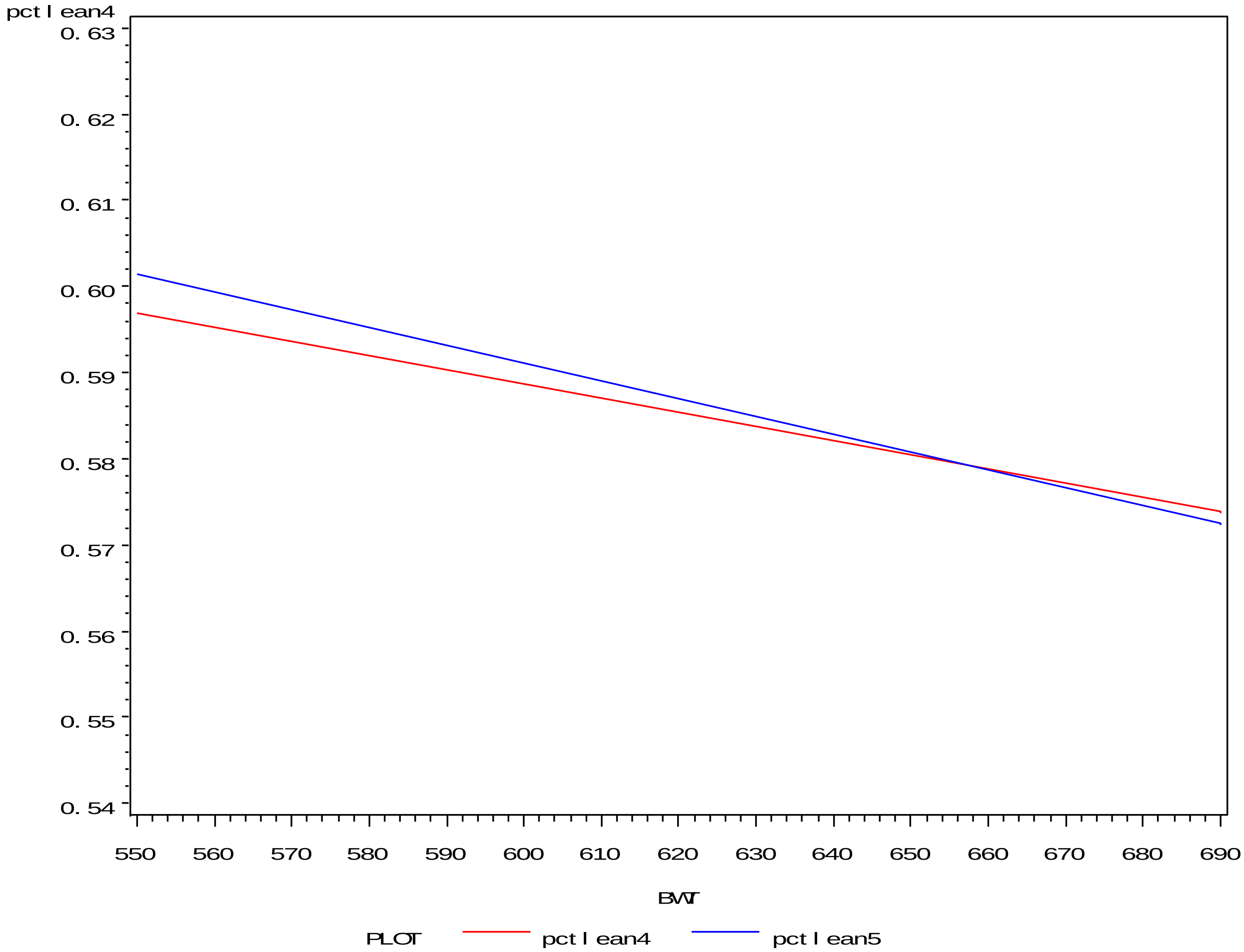
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 4. Plot of prediction equation for MWC 3 and the overall equation over the live weight for MWC 3 using ultrasound backfat and loin eye area [1]



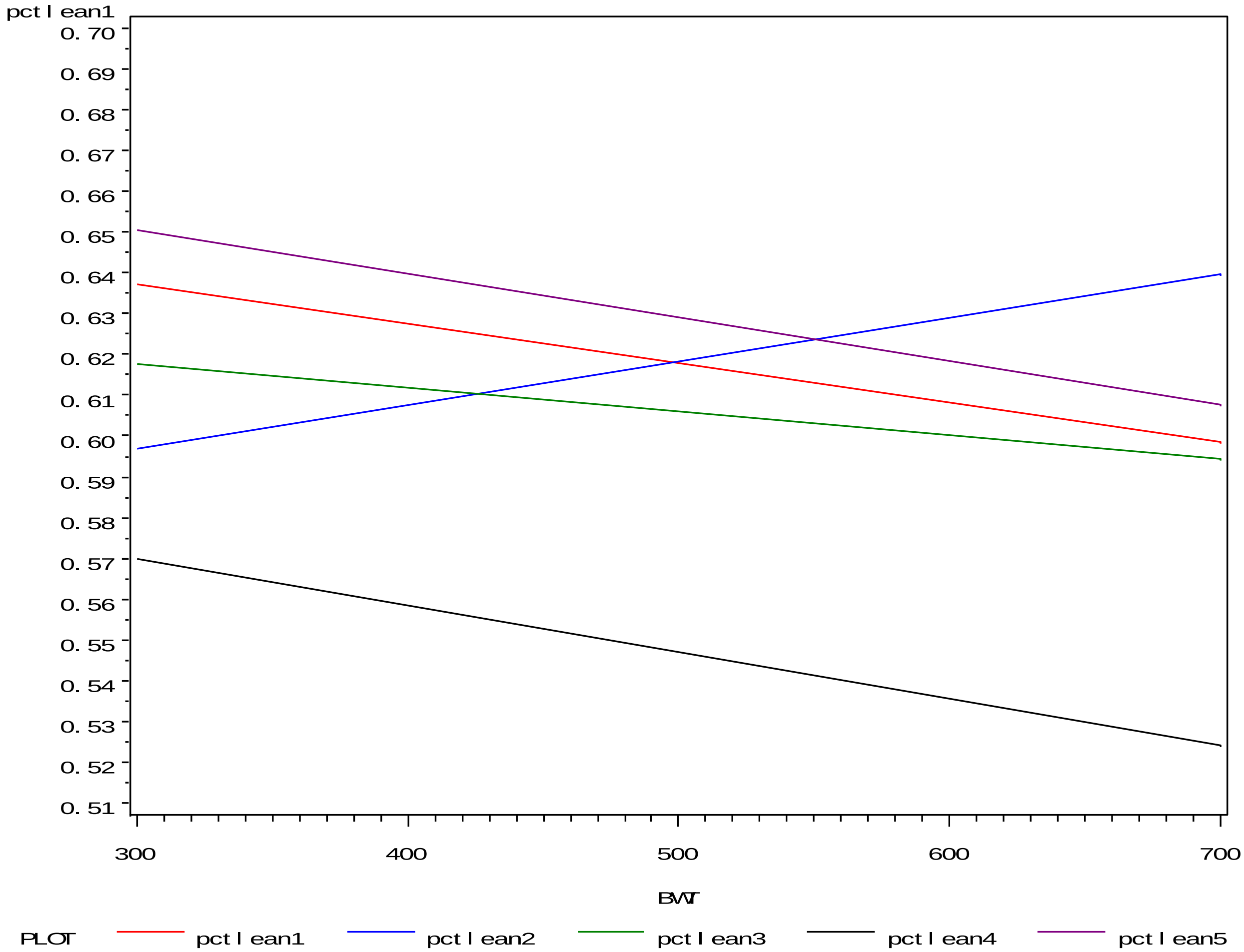
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 5. Plot of prediction equation for MWC 4 and the overall equation over the live weight for MWC 4 using ultrasound backfat and loin eye area [1]



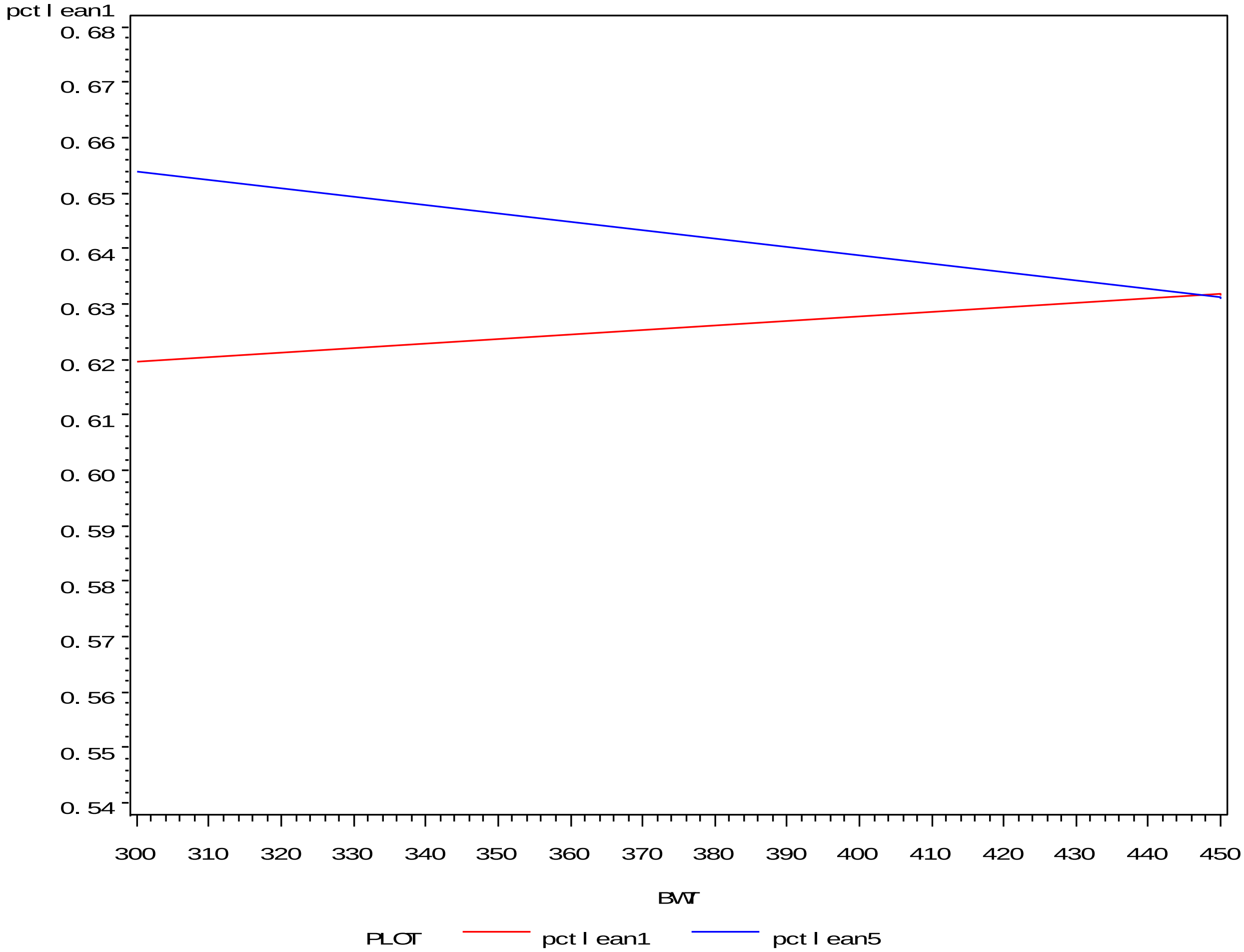
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 6. Plot of prediction equations across all live weights using carcass backfat and loin eye area [1]



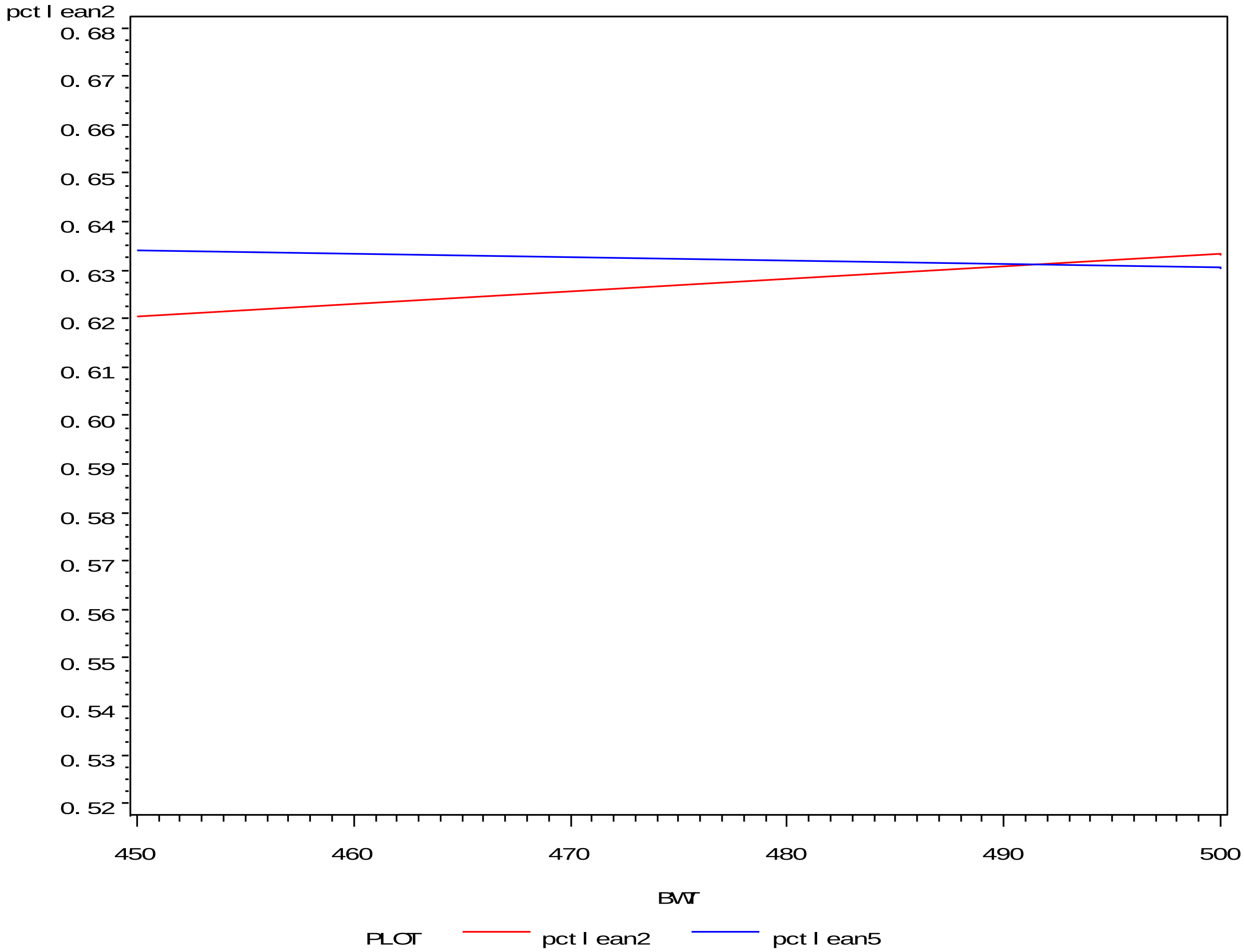
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 7. Plot of prediction equation for MWC 1 and the overall equation over the live weight for MWC 1 using carcass backfat and loin eye area [1]



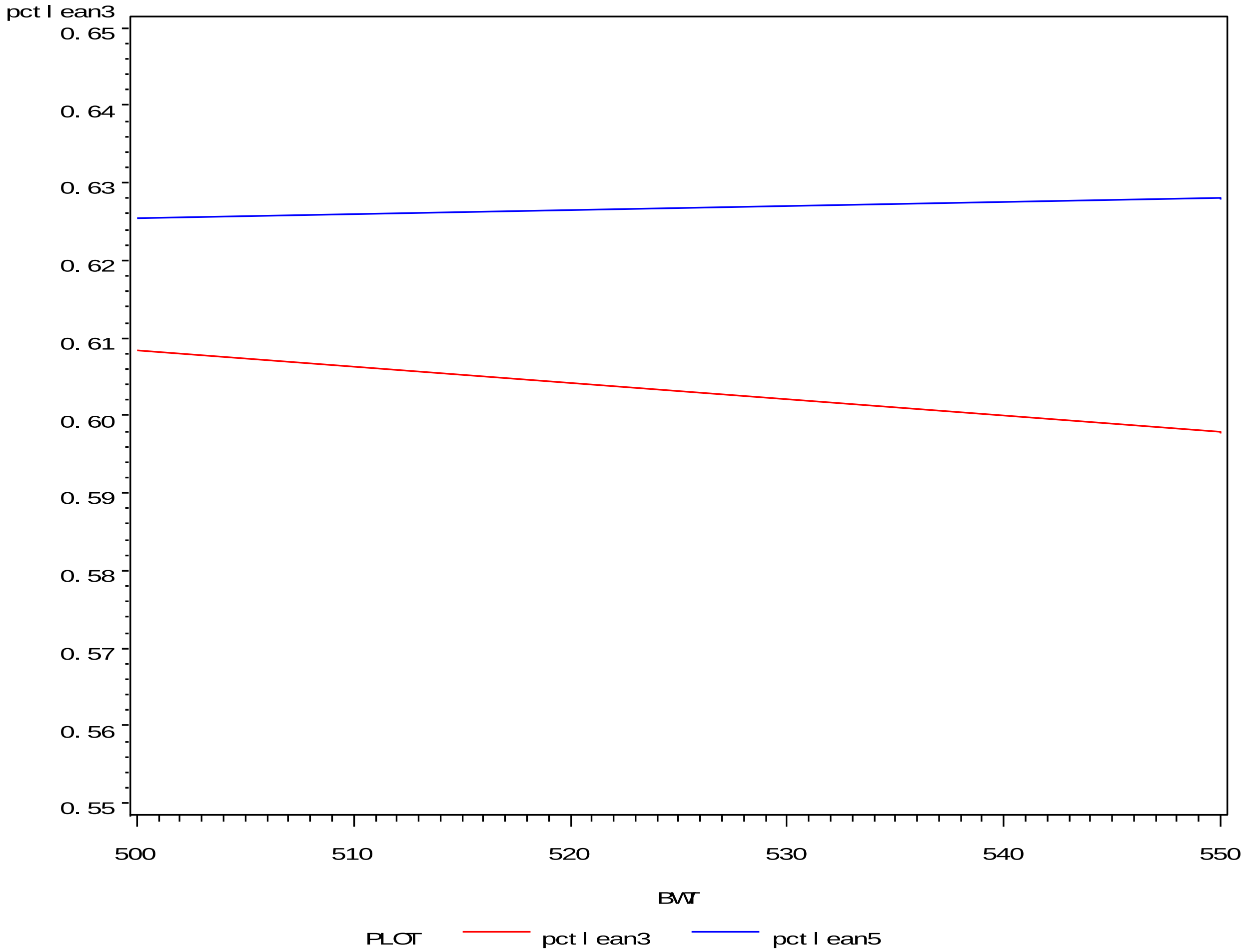
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 8. Plot of prediction equation for MWC 2 and the overall equation over the live weight for MWC 2 using carcass backfat and loin eye area [1]



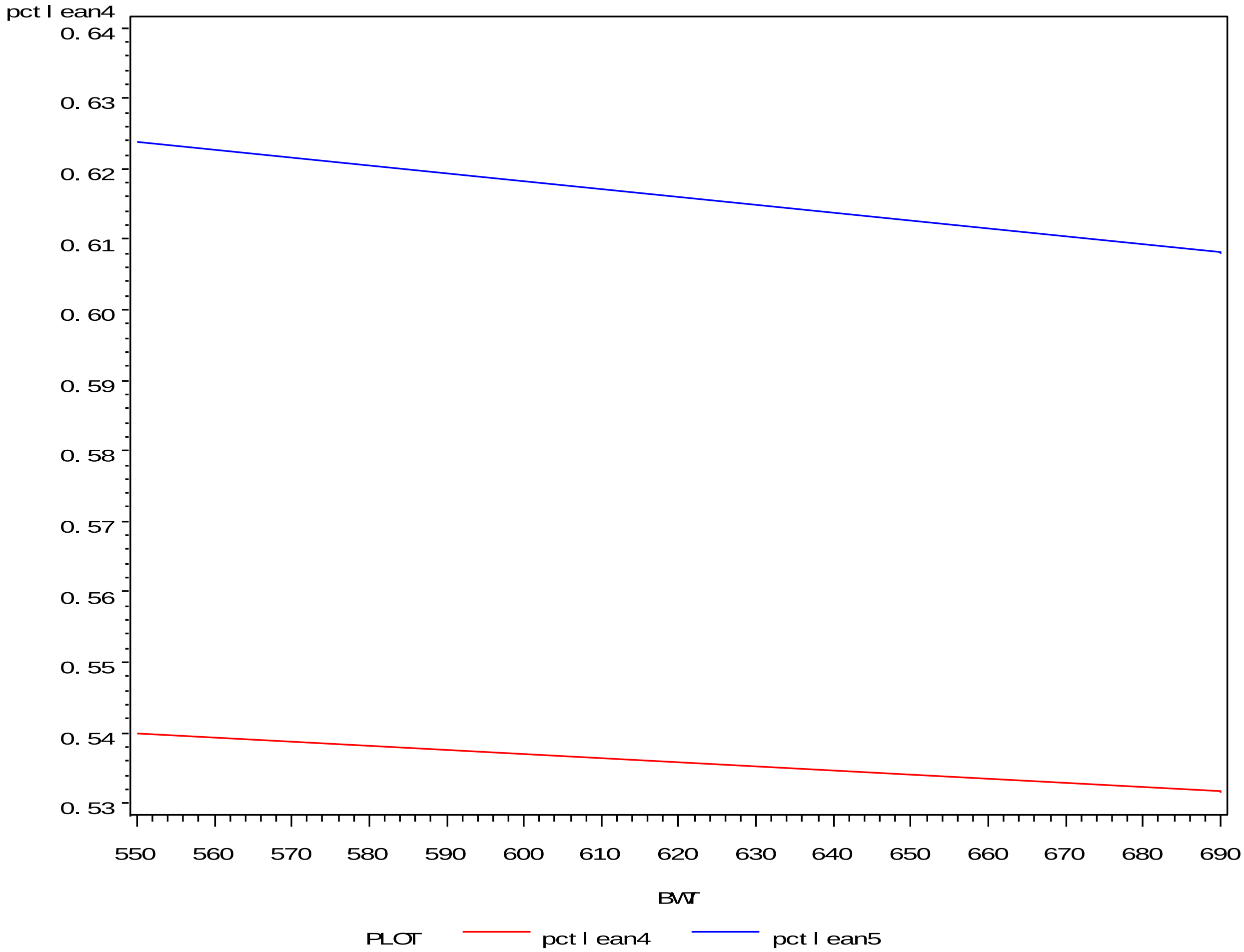
[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 9. Plot of prediction equation for MWC 3 and the overall equation over the live weight for MWC 3 using carcass backfat and loin eye area [1]



[1]Live body weight on x-axis, predicted percent lean on y-axis

Figure 10. Plot of prediction equation for MWC 4 and the overall equation over the live weight for MWC 4 using carcass backfat and loin eye area [1]



[1]Live body weight on x-axis, predicted percent lean on y-axis