# Prediction of retail product and trimmable fat yields from the four primal cuts in beef cattle using ultrasound or carcass data[1]

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**ABSTRACT:** The most widely used system to predict percentage of retail product from the four primal cuts of beef is USDA yield grade. The purpose of this study was to determine whether routine ultrasound measurements and additional rump measurements could be used in place of the carcass measurements used in the USDA yield grade equation to more accurately predict the percentage of saleable product from the four primals. This study used market cattle (n = 466) consisting of Angus bulls, Angus steers, and crossbred steers. Live animal ultrasound measures collected within 7 d of slaughter were 1) scan weight (SCANWT); 2) 12th- to 13th-rib s.c. fat thickness (UFAT); 3) 12th- to 13th-rib LM area (ULMA); 4) s.c. fat thickness over the termination of the biceps femoris in the rump (URFAT; reference point); 5) depth of gluteus medius under the reference point (URDEPTH); and 6) area of gluteus medius anterior to the reference point (URAREA). Traditional carcass measures collected included 1) HCW; 2) 12th- to 13th-rib s.c. fat thickness (CFAT); 3) 12th- to 13th-rib LM area (CLMA); and 4) estimated percentage of kidney, pelvic, and heart fat (CKPH). Right sides of carcasses were fabricated into subprimal cuts, lean trim, fat, and bone. Weights of each component were recorded, and percentage of retail product from the four primals was expressed as a percentage of side weight. A stepwise regression was performed using data from cattle (n = 328) to develop models to predict percentage of retail product from the four primals based on carcass measures or ultrasound measures, and comparisons were made between the models. The most accurate carcass prediction equation included CFAT, CKPH, and CLMA ($R^2$ = 0.308), whereas the most accurate live prediction equation included UFAT, ULMA, SCANWT, and URAREA ($R^2$ = 0.454). When these equations were applied to a validation set of cattle (n = 138), the carcass equation showed $R^2$ = 0.350, whereas the ultrasound data showed $R^2$ = 0.460. Ultrasound measures in the live animal were potentially more accurate predictors of retail product than measures collected on the carcass.

Key Words: Beef, Carcass Composition, Meat Yield, Prediction, Ultrasound

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## Introduction

Retail product yield from the four primal cuts (chuck, rib, loin, and round) is an economically important trait for the beef industry. Abraham et al. (1980) found that retail sales value was highly correlated with measures of retail yield from the four primals (r = 0.97) and retail yield from the whole side (r = 0.99), with 25% fat content in lean trim. Several studies have evaluated the ability of carcass traits to predict retail product yield from beef cattle (Epley et al., 1970; Crouse and Dikeman, 1976; Abraham et al., 1980). More recently, ultrasound has been used to evaluate retail product yield in beef cattle by measuring comparable traits to the well-established carcass measures used to predict retail product yield (Williams et al., 1997; Realini et al., 2001; Greiner et al., 2003). In addition, researchers using ultrasound technology have investigated novel sites to be measured and found these new measurements to be relevant in predicting percentage of retail product (Williams et al., 1997; Realini et al., 2001; Greiner et al., 2003). Therefore, the objective of this study was to investigate the relative capabilities of ultrasound and carcass measurements to predict retail product yield from the four primals. A second objective was to determine whether measures of depth of gluteus medius and/or area of gluteus medius in the rump of fed cattle could help augment prediction of retail product yield from the four primal cuts.

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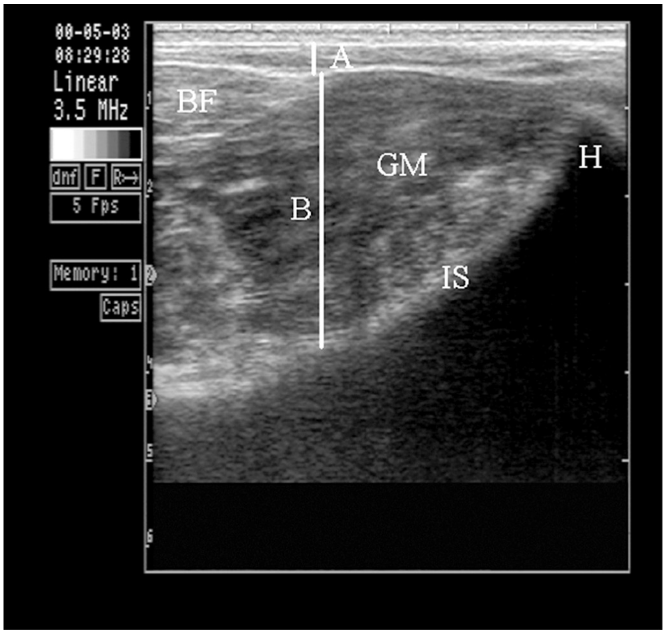


**Figure 1.** Classic scanner 200 (Classic Medical Co., Tequesta, FL) longitudinal ultrasound image collected over the rump of the animal. A = subcutaneous rump fat thickness (URFAT); B = depth of gluteus medius (URDEPTH); BF = biceps femoris; GM = gluteus medius; H = head of the ileum (hook); and IS = ileum shaft (termination of the biceps femoris is referred to as the reference point).

## Materials and Methods

Data for this study were obtained from calf-fed bulls and steers (n = 466) over two summers (2000 and 2001). All bulls were from the Angus breed, whereas steers were either unregistered Angus or crossbred (Angus, Simmental, Red Angus, or Limousin sires mated to commercial cows). These data were then subdivided randomly using a random number generator into a model development data set (n = 328; 66.5% steers and 33.5% bulls) and a model validation data set (n = 138; 65.2% steers and 34.8% bulls).

Real-time ultrasound images were collected by a centralized ultrasound processing-qualified technician within 1 wk of slaughter. Images were collected using one of two ultrasound technologies: 1) a Classic scanner 200 (Classic Medical Co., Tequesta, FL) equipped with a 3.5-Mhz, 18-cm linear array transducer (n = 382); or 2) an Aloka 500V (Aloka USA, Wallingford, CT) equipped with a 3.5-Mhz, 17.2-cm linear array transducer (n = 84). Ultrasound images were digitized and saved with a BlackBox image capturing system (Biotronics, Inc., Ames, IA). There were three types of images collected at that time: 1) a cross-sectional image between the 12th to 13th ribs; 2) a longitudinal image collected slightly above a line from the hooks to the pins in line with the shaft of the ileum (Figure 1); and 3) at least four independent longitudinal images collected over the 12th to 13th ribs, approximately one-half to three-quarters of the distance laterally across the LM. The percentage of i.m. fat measurements from the four independent longitudinal images was subsequently averaged to provide a single i.m. fat percent measurement for each steer/bull. Our protocol for location of image collection in the rump area was investigated in a previous study (Tait et al., 2000). All images were evaluated and interpreted by centralized ultrasound processing-qualified interpretation technicians in a laboratory at Iowa State University using software developed by Iowa State University.

Live animal ultrasound measurements obtained were 1) live weight (**SCANWT**; shrunk weight on scan date at time of scanning); 2) s.c. fat thickness at three-quarters of the lateral distance across the LM between the 12th to 13th ribs (**UFAT**); 3) LM area between the 12th to 13th ribs (**ULMA**); 4) s.c. fat thickness over the termination point of the biceps femoris in the rump (**URFAT**; reference point); 5) depth of the gluteus medius beneath the reference point (**URDEPTH**); 6) area of the gluteus medius anterior to the reference point (**URAREA**); and 7) i.m. fat percent within the LM between the 12th to 13th ribs (**UPFAT**).

Slaughter dates were selected based on ultrasound estimates of an animal's ability to reach the USDA Choice grade and prevention of carcass weight or yield grade discounts. Cattle were slaughtered according to standard industry protocol, and routine carcass measurements were collected by experienced individuals at approximately 24 to 48 h postmortem, including 1) HCW; 2) s.c. fat thickness at three-quarters of the lateral distance across the LM between the 12th to 13th ribs (**CFAT**); 3) LM area using plastic dot grid overlay between the 12th and 13th ribs (**CLMA**); 4) estimated percentage of kidney, pelvic, and heart fat (**CKPH**); and 5) USDA marbling score (**MARB**) to the nearest 10 marbling score units. Fat thickness over the 12th rib was only adjusted if there were an obvious disruption of the fat thickness at the location of measurement, but overall fat distribution of the carcass was not used as an adjustment criterion for fat thickness over the 12th rib. Yield grade (**YG**) was then calculated from these carcass measurements using the following equation: YG = 2.5 + (0.984 × CFAT, cm) + (0.2 × CKPH, %) + (0.0084 × HCW, kg) − (0.05 × CLMA, $cm^2$).

Carcasses were transported from commercial slaughter facilities to a fabrication site (Jim's Wholesale Meats, Harlan, IA). This facility was chosen because of the experience exhibited by the work force, and their commitment to quality and consistency of data collection over time. Many of the same employees were present during all the fabrication dates, and the same employee fabricated the same cut across fabrication dates whenever feasible.

The right side of each carcass was fabricated into retail cuts, with weights recorded for subprimal cuts, lean trim, fat, and bone. Cuts were trimmed to 0.64 cm of external fat, except for the knuckle and tenderloin, which were trimmed completely. The four primals were fabricated

**Table 1.** Abbreviations used for traits

| Trait | Definition |
|---|---|
| Live animal measurements | |
| SCANWT, kg | Live weight of the animal (shrunk weight on scan date) |
| UFAT, cm | Ultrasound s.c. fat thickness between 12th and 13th ribs |
| ULMA, $cm^2$ | Ultrasound LM area between 12th and 13th ribs |
| UPFAT, % | Ultrasound predicted i.m. fat percent |
| URFAT, cm | Ultrasound s.c. rump fat thickness over the reference point |
| URDEPTH, cm | Ultrasound depth of the gluteus medius below the reference point |
| URAREA, $cm^2$ | Ultrasound area of the gluteus medius anterior to the reference point |
| Carcass measurements | |
| HCW, kg | Hot carcass weight |
| CFAT, cm | Carcass fat thickness between the 12th and 13th ribs |
| CLMA, $cm^2$ | Carcass LM area between the 12th and 13th ribs |
| CKPH, % | Carcass estimated kidney, pelvic, and heart fat percent |
| MARB[a] | USDA marbling score |
| YG | Calculated yield grade based on carcass measurements |
| PRP4P, % | Percentage of retail product from the four primals (cold side wt basis) |
| KGRP, kg | Weight of retail product from the four primals (whole carcass basis) |
| PFT4P, % | Percentage of trimmable fat from the four primals (cold side wt basis) |
| KGFT, kg | Weight of trimmable fat from the four primals (whole carcass basis) |

[a]3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; and 9.00 = Moderately Abundant[00]

according to National American Meat Processors (**NAMP**) guidelines (NAMP, 1997), and included the shoulder clod (NAMP #114), lip-on ribeye roll (NAMP #112A), chuck roll (NAMP #116), peeled knuckle (NAMP #167A), top round (NAMP #168), gooseneck round (NAMP #170), boneless strip loin (NAMP #180), boneless top sirloin butt (NAMP #184), bottom sirloin ball-tip (NAMP #185B), tri-tip (NAMP #185C), and defatted full tenderloin (NAMP #189A). Trim was visually determined to be either 85% lean:15% fat or 50% lean:50% fat by experienced meat-cutting staff at the processing facility. These two versions of trim were marketed as such by the processing facility. Weight of the 85% lean trim was included directly in the calculation of retail product weight. Weight of 50% lean trim was not included in the calculation of retail product or trimmable fat. Weight of retail product (**KGRP**) from the four primals was calculated as the sum of the NAMP-identified cuts, and 85% lean trim derived from the four primal cuts, and this measure was then doubled in order to be expressed on a whole carcass basis. Percentage of retail product from the four primals (**PRP4P**) was determined as the weight of retail product from the four primals divided by the sum of the primal weights (chuck, rib, loin, round, brisket, plate, and flank) of the cold carcass side immediately before dissection. Weight of fat trim (**KGFT**) was the weight of all fat removed from the four primal cuts, and it was then doubled to represent the whole carcass. The weight of trimmable fat also was expressed as a percentage (**PFT4P**) of the cold side weight in the same manner as percentage of retail product. Calculation of these fat measures was included because Herring et al. (1994) suggested that predicting excess, trimmable fat rather than lean retail product would be an appropriate tool in decreasing excess fat production.

All data were analyzed using PROC MEANS, CORR, STEPWISE, and GLM of SAS (v. 8.2; SAS Inst., Inc., Cary, NC). Correlations were calculated between carcass and real time ultrasound measures. Stepwise regression was used to develop prediction equations for PRP4P or PFT4P either from live animal or carcass measures. Significance level for variables to remain in stepwise regression prediction equations was set at $P < 0.10$. We report herein the order of trait inclusion, trait, coefficient, *P*-value of that trait, partial $R^2$, total model $R^2$ up to that step, and $C_p$ statistic for each stepwise regression analysis. Ultrasound-collected traits that were eligible for inclusion into stepwise-developed regression equations included SCANWT, UFAT, ULMA, URFAT, URDEPTH, URAREA, and sometimes UPFAT. Carcass traits that were eligible for inclusion into stepwise-developed regression equations included HCW, CFAT, CLMA, CKPH, and sometimes MARB. Environmental and genetic factors were not included in the modeling process.

## Results and Discussion

Abbreviations for the measurements collected in this study are provided in Table 1. Means, standard deviations, and ranges for live animal and carcass traits are presented in Table 2. Although some cattle were selected for slaughter to meet set goals, there was still large variation in some traits. In comparison, Greiner et al. (2003) worked with a set of very genetically diverse steers, and observed similar SD in ultrasound 12th- to 13th-rib fat thickness, ultrasound rump fat thickness, adjusted carcass 12th- to 13th-rib fat thickness, carcass LM area, and YG (0.35 cm, 0.32 cm, 0.42 cm, 8.7 $cm^2$, and 0.73, respectively). Surprisingly, cattle in the current study tended to have a larger standard deviation in ULMA (8.2 vs. 7.6 $cm^2$) than that observed by Greiner

**Table 2.** Summary statistics for live animal and carcass measures (n = 466)

| Trait[a] | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Live animal measurements | | | | |
| SCANWT, kg | 550.3 | 43.7 | 412.8 | 698.5 |
| UFAT, cm | 1.05 | 0.32 | 0.28 | 2.11 |
| ULMA, $cm^2$ | 83.8 | 8.2 | 61.3 | 111.6 |
| UPFAT, % | 4.80 | 1.20 | 2.24 | 8.92 |
| URFAT, cm | 0.96 | 0.33 | 0.33 | 2.01 |
| URDEPTH, cm | 8.86 | 0.84 | 6.58 | 11.35 |
| URAREA, $cm^2$ | 66.1 | 9.7 | 41.9 | 104.5 |
| Carcass measurements | | | | |
| HCW, kg | 336.4 | 27.6 | 249.5 | 434.5 |
| CFAT, cm | 1.06 | 0.40 | 0.25 | 3.56 |
| CLMA, $cm^2$ | 82.1 | 8.8 | 60.6 | 108.4 |
| CKPH, % | 1.98 | 0.34 | 1.00 | 3.50 |
| MARB[b] | 5.38 | 1.02 | 3.00 | 9.20 |
| YG | 2.69 | 0.68 | 0.89 | 5.33 |
| PRP4P, % | 50.05 | 2.22 | 44.01 | 57.69 |
| KGRP, kg | 166.0 | 15.5 | 121.7 | 222.2 |
| PFT4P, % | 4.36 | 1.02 | 2.26 | 7.65 |
| KGFT, kg | 14.5 | 3.8 | 5.8 | 25.3 |

[a]See Table 1 for definition of abbreviations.
[b]3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; and 9.00 = Moderately Abundant[00].

**Table 3.** Simple correlations of ultrasound and carcass traits with percentage and weight of retail product and fat trim (n = 466)

| Trait[a] | PRP4P | KGRP | PFT4P | KGFT |
|---|---|---|---|---|
| Live animal measurements | | | | |
| SCANWT | –0.12** | 0.74*** | 0.10* | 0.37*** |
| UFAT | –0.58*** | –0.17*** | 0.39*** | 0.37*** |
| ULMA | 0.30*** | 0.62*** | –0.12** | 0.06 |
| UPFAT | –0.42*** | –0.23*** | 0.15** | 0.11* |
| URFAT | –0.43*** | –0.20*** | 0.18*** | 0.15** |
| URDEPTH | 0.02 | 0.14** | –0.03 | 0.01 |
| URAREA | 0.09* | 0.18*** | –0.01 | 0.03 |
| Carcass measurements | | | | |
| HCW | –0.06 | 0.87*** | 0.17*** | 0.46*** |
| CFAT | –0.44*** | –0.09† | 0.22*** | 0.23*** |
| CLMA | 0.33*** | 0.51*** | –0.07 | 0.05 |
| CKPH | –0.34*** | 0.00 | 0.51*** | 0.51*** |
| MARB[b] | –0.34*** | –0.11* | 0.20*** | 0.19*** |
| YG | –0.53*** | –0.08† | 0.29*** | 0.31*** |
| PRP4P | 1.00*** | 0.43*** | –0.68*** | –0.61*** |
| KGRP | | 1.00*** | –0.15** | 0.15** |
| PFT4P | | | 1.00*** | 0.95*** |

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; †$P < 0.10$.
[a]See Table 1 for definition of abbreviations.
[b]3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; and 9.00 = Moderately Abundant[00].

et al. (2003). In comparison, our study did not adjust fat thickness over the LM in the carcass, and we included both bull and steer data. Correlations between ultrasound-measured traits and carcass-measured traits were as follows: SCANWT and HCW, r = 0.92; UFAT and CFAT, r = 0.68; ULMA and CLMA, r = 0.56; and UPFAT and MARB, r = 0.64.

Simple correlations of live animal and carcass measurements to carcass cutout variables are presented in Table 3. The traits most strongly associated with PRP4P were ultrasound and carcass fat measurements (r = –0.43 to –0.58). This was in agreement with the work of many researchers (Crouse et al., 1975; Crouse and Dikeman, 1976; Greiner et al., 2003), who also found fat measurement to be the trait most strongly related to retail product yield. The calculated trait of YG also was quite strongly correlated with PRP4P (r = –0.53); however, this was a smaller correlation than that observed by Herring et al. (1994) and Greiner et al. (2003), but still larger than that reported by Williams et al. (1997). In our data, CLMA and ULMA were similar (r = 0.33 and 0.30, respectively) in their relationships to PRP4P. Herring et al. (1994) and Greiner et al. (2003) found similar correlations for CLMA, whereas live measures of LM area had a smaller correlation with PRP4P in both of these studies. Williams et al. (1997) found no relationship between either measure of LM area and PRP4P. Another trait that was strongly associated with PRP4P was CKPH (r = –0.34), and the relationship between PRP4P and CKPH in the present study was consistent with the results of Williams et al. (1997) and Greiner et al. (2003), but was weaker than values observed by Epley et al. (1970) and Herring et al. (1994). Both measures of i.m. fat, UPFAT and MARB, were strongly associated with PRP4P (r = –0.42 and –0.34, respectively). Because UPFAT has only recently been obtainable with reasonable accuracy (the first BIF certification for UPFAT was in 1996), there were no studies available to compare our observed relationships. Others have looked at the relationship between MARB and PRP4P, and have found generally stronger correlations (Crouse and Dikeman, 1976; Herring et al., 1994; Greiner et al., 2003) than those in our study.

Weight variables (SCANWT and HCW) had the strongest correlations to KGRP (r = 0.74 and 0.87, respectively). These relationships between live animal weight or HCW and KGRP were consistent with the work of Williams et al. (1997) and Greiner et al. (2003). Measures of LM area showed the next strongest relationships to KGRP (r = 0.62 and r = 0.51 for ULMA and CLMA, respectively). Both Williams et al. (1997) and Greiner et al. (2003) demonstrated strong correlations between KGRP and measures of LM area; however, both observed a stronger correlation between carcass measures of LM area to KGRP than to ultrasound-measured LM area.

Not surprisingly, CKPH was the carcass trait with the strongest relationship (r = 0.51) with PFT4P. This was within the range of correlations for CKPH to trimmable fat observed by Herring et al. (1994) and Williams et al. (1997). The ultrasound trait with the strongest relationship to PFT4P was UFAT (r = 0.39). Williams et al. (1997) also found UFAT to be the live animal measurement with the strongest correlation to percentage of trimmable fat, with URFAT a close second. Miller et al. (1988) found ultrasound-measured fat over the

**Table 4.** Stepwise regression to predict percentage of retail product from the four primals using ultrasound data (n = 328)

| Order | Trait[a] | Coefficient | *P*-value | Partial $R^2$ | Model $R^2$ | $C_p$ |
|---|---|---|---|---|---|---|
| Without i.m. fat percent as a possible trait<br>SCANWT, UFAT, ULMA, URFAT, URDEPTH, and URAREA as possible traits | | | | | | |
| Intercept | | 49.343 | | | | |
| 1 | UFAT | −3.604 | <0.001 | 0.319 | 0.319 | 79.1 |
| 2 | ULMA | 0.1083 | <0.001 | 0.092 | 0.410 | 26.9 |
| 3 | SCANWT | −0.01153 | <0.001 | 0.032 | 0.442 | 10.2 |
| 4 | URAREA | 0.0266 | 0.007 | 0.013 | 0.454 | 4.8 |
| With i.m. fat percent as a possible trait:<br>SCANWT, UFAT, ULMA, URFAT, URDEPTH, URAREA, and UPFAT as possible traits | | | | | | |
| Intercept | | 49.874 | | | | |
| 1 | UFAT | −3.326 | <0.001 | 0.318 | 0.318 | 104.3 |
| 2 | ULMA | 0.0936 | <0.001 | 0.092 | 0.411 | 48.5 |
| 3 | UPFAT | −0.401 | <0.001 | 0.037 | 0.447 | 27.5 |
| 4 | SCANWT | −0.01037 | <0.001 | 0.025 | 0.472 | 13.8 |
| 5 | URDEPTH | 0.387 | 0.001 | 0.017 | 0.490 | 5.0 |

[a]See Table 1 for definition of abbreviations.

shoulder to have the strongest relationship to fat percent.

When considering body composition as consisting of lean, fat, and bone in the carcass, it was not surprising that PRP4P was strongly correlated to PFT4P (r = −0.68). Although both Herring et al. (1994) and Williams et al. (1997) calculated percentage of retail product and percentage of trimmable fat, neither of these studies reported the correlation between these traits. The traditional predictor of percentage of retail product yield from the four primals, YG, showed a modest correlation to PFT4P (r = 0.29). However, others have found stronger relationships between calculated YG and percentage of trimmable fat (Herring et al., 1994; Williams et al., 1997).

Stepwise regression equations based on the development data set for prediction of PRP4P from either live animal measures or carcass measures are presented in Tables 4 and 5, respectively. The first variable among ultrasound measurements to enter the prediction equation was UFAT, and accounted for 31.9% of the variation in PRP4P. Addition of ULMA, SCANWT, and URAREA accounted for an additional 13.5% of the variation in PRP4P. This ultrasound-based equation had an $R^2$ value of 0.454 and a standard error of prediction (**SEP**) of 1.62%. Realini et al. (2001) also investigated ultrasound measures of rump fat and depth of the gluteus medius, but these ultrasound measurements were not included in their prediction equation for percentage of retail product. However, the Realini et al. (2001) study was limited in size (n = 32) and scope (Hereford-sired steers only). Williams et al. (1997) obtained significant variables of ULMA, UFAT, and URFAT, and could account for 31.8% of the variation in percentage of retail product. Moreover, Greiner et al. (2003) was able to account for 60% of the variation in percentage of retail product by using UFAT, URFAT, ULMA, and SCANWT. When our ultrasound-based equation was tested on the validation group of cattle, it yielded an $R^2$ value of 0.460 and a SEP of 1.70%.

Of the carcass data (Table 5), CFAT was the first variable to enter the prediction equation, but accounted for only 17.4% of the variation in PRP4P. Other significant ($P < 0.10$) carcass variables to enter the prediction equation were CKPH and CLMA, and these traits accounted for an additional 13.4% of the variation in PRP4P. This carcass data equation had a model $R^2$ = 0.308 and a SEP of 1.82%. The lower capability of the carcass traits to predict percentage of retail product was in contrast to the work of Greiner et al. (2003), who observed higher $R^2$ values for carcass measurement-derived prediction equations for percentage of retail product compared with ultrasound measurement-derived prediction equations. Williams et al. (1997) observed nearly identical $R^2$ values for carcass- and ultrasound-derived equations. The USDA yield grade equation trait of HCW was not a significant ($P > 0.10$) predictor of PRP4P. Consistent with the results of this study, both Abraham et al. (1968) and Crouse and Dikeman (1976) found HCW to be of questionable value as a predictor of percentage of retail product. When our carcass-based equation was tested on the validation group of cattle, it yielded an $R^2$ value of 0.350 and a SEP of 1.87%.

These initial PRP4P equations did not include UPFAT or MARB as possible predictors of cutability. When percent i.m. fat measures were included in the stepwise analysis (data also included in Tables 4 and 5), UPFAT was the third trait to come into the live animal equation (after ULMA and before SCANWT), and MARB was the second trait to come into the carcass equation (after CFAT and before CKPH). Incorporation of MARB or UPFAT increased the accuracy of percentage of retail product prediction equations from carcass ($R^2$ = 0.375 and SEP = 1.73% vs. $R^2$ = 0.308 and SEP = 1.82%) and ultrasound ($R^2$ = 0.490 and SEP = 1.57% vs. $R^2$ = 0.454

**Table 5.** Stepwise regression to predict retail product percent from the four primals using carcass data (n = 328)

| Order | Trait[a] | Coefficient | *P*-value | Partial $R^2$ | Model $R^2$ | $C_p$ |
|---|---|---|---|---|---|---|
| Without marbling score as a possible trait: HCW, CFAT, CLMA, and CKPH as possible traits | | | | | | |
| Intercept | | 50.085 | | | | |
| 1 | CFAT | –1.746 | <0.001 | 0.174 | 0.174 | 62.9 |
| 2 | CKPH | –1.723 | <0.001 | 0.068 | 0.242 | 32.9 |
| 3 | CLMA | 0.0638 | <0.001 | 0.066 | 0.308 | 4.1 |
| With marbling score as a possible trait: HCW, CFAT, CLMA, CKPH, and MARB as possible traits | | | | | | |
| Intercept | | 53.808 | | | | |
| 1 | CFAT | –1.548 | <0.001 | 0.174 | 0.174 | 101.4 |
| 2 | MARB[b] | –0.580 | <0.001 | 0.086 | 0.259 | 59.3 |
| 3 | CKPH | –1.724 | <0.001 | 0.070 | 0.329 | 25.5 |
| 4 | CLMA | 0.0537 | <0.001 | 0.046 | 0.375 | 4.1 |

[a]See Table 1 for definition of abbreviations.
[b]3.00 = Traces$^{00}$; 4.00 = Slight$^{00}$; 5.00 = Small$^{00}$; 6.00 = Modest$^{00}$; 7.00 = Moderate$^{00}$; 8.00 = Slightly Abundant$^{00}$; and 9.00 = Moderately Abundant$^{00}$.

and SEP = 1.62%) measures. Crouse and Dikeman (1976) also found MARB to be a useful predictor of percentage of retail product, and reduced the necessity of including muscling score in the model. Interestingly, the last trait to come into the stepwise regression when including UPFAT changed from URAREA to URDEPTH. When prediction equations including UPFAT or MARB were applied to the validation data set, the ultrasound equation ($R^2$ = 0.511 and SEP = 1.62%) was a more accurate predictor of percentage of retail product than the carcass equation ($R^2$ = 0.395 and SEP = 1.80%).

There is a trend in the beef industry today to increase i.m. fat, while at the same time trying to limit s.c. fat deposition on the same animal to maintain cutability. The negative phenotypic correlation of MARB and UPFAT to PRP4P (r = –0.34 and –0.42, respectively) would make PRP4P equations using these traits antagonistic to this current industry trend.

Stepwise regression equations developed from the development data set to predict PFT4P from live animal measurements are presented in Table 6, whereas stepwise regression developed equations to predict PFT4P from the development data set carcass measures are shown in Table 7. Equations developed to predict PFT4P showed an advantage for the carcass trait equations ($R^2$ = 0.259 to 0.281 and SEP = 0.88 to 0.87%) compared with the ultrasound trait equations ($R^2$ = 0.179 to 0.181 and SEP = 0.92% for both). For prediction of PFT4P, UPFAT was not a significant trait ($P > 0.50$) in live animal equations, whereas MARB replaced CFAT in the prediction of PFT4P from carcass measures and increased the $R^2$ by 0.021. When predicting the percentage of chemical fat in fed cattle, Miller et al. (1988) found that the best live animal equation included UFAT, URFAT, and ULMA, and the best carcass equation included CFAT, HCW, CKPH, and CLMA. Williams et al. (1997)

**Table 6.** Stepwise regression to predict trimmable fat percent from the four primals using ultrasound data (n = 328)

| Order | Trait[a] | Coefficient | *P*-value | Partial $R^2$ | Model $R^2$ | $C_p$ |
|---|---|---|---|---|---|---|
| Without i.m. fat percent as a possible trait: SCANWT, UFAT, ULMA, URFAT, URDEPTH, and URAREA as possible traits | | | | | | |
| Intercept | | 4.473 | | | | |
| 1 | UFAT | 1.365 | <0.001 | 0.124 | 0.124 | 21.2 |
| 2 | ULMA | –0.0310 | <0.001 | 0.033 | 0.158 | 10.1 |
| 3 | URFAT | –0.519 | 0.014 | 0.013 | 0.171 | 6.9 |
| 4 | SCANWT | 0.00282 | 0.043 | 0.011 | 0.181 | 4.8 |
| With i.m. fat percent as a possible trait: SCANWT, UFAT, ULMA, URFAT, URDEPTH, URAREA, and UPFAT as possible traits | | | | | | |
| Intercept | | 4.435 | | | | |
| 1 | UFAT | 1.357 | <0.001 | 0.123 | 0.123 | 19.6 |
| 2 | ULMA | –0.0307 | <0.001 | 0.032 | 0.155 | 9.0 |
| 3 | URFAT | –0.517 | 0.014 | 0.013 | 0.168 | 6.0 |
| 4 | SCANWT | 0.00284 | 0.042 | 0.011 | 0.179 | 3.8 |

[a]See Table 1 for definition of abbreviations.

**Table 7.** Stepwise regression to predict trimmable fat percent from the four primals using carcass data (n = 328)

| Order | Trait[a] | Coefficient | *P*-value | Partial $R^2$ | Model $R^2$ | $C_p$ |
|---|---|---|---|---|---|---|
| Without marbling score as a possible trait: HCW, CFAT, CLMA, and CKPH as possible traits | | | | | | |
| Intercept | | 1.347 | | | | |
| 1 | CKPH | 1.391 | <0.001 | 0.250 | 0.250 | 6.1 |
| 2 | CFAT | 0.248 | 0.049 | 0.009 | 0.259 | 4.2 |
| With marbling score as a possible trait: HCW, CFAT, CLMA, CKPH, and MARB as possible traits | | | | | | |
| Intercept | | 0.563 | | | | |
| 1 | CKPH | 1.433 | <0.001 | 0.250 | 0.250 | 15.3 |
| 2 | MARB[b] | 0.180 | <0.001 | 0.031 | 0.281 | 3.3 |

[a]See Table 1 for definition of abbreviations.
[b]3.00 = Traces$^{00}$; 4.00 = Slight$^{00}$; 5.00 = Small$^{00}$; 6.00 = Modest$^{00}$; 7.00 = Moderate$^{00}$; 8.00 = Slightly Abundant$^{00}$; and 9.00 = Moderately Abundant$^{00}$.

found a small advantage for carcass measures over ultrasound measures to predict trimmable fat. Furthermore, Herring et al. (1994) found carcass traits were more accurate for predicting percent trimmable fat than live animal measures; however, Herring et al. (1994) only included UFAT, SCANWT, and a subjective visual appraisal of trimness as the live traits collected. When evaluated on our validation group of cattle, the ultrasound equations had $R^2$ = 0.160 and SEP = 0.94% for both equations. When applied to our validation group, the carcass-based equations including MARB had an $R^2$ value of 0.318 and SEP of 0.85%, indicating that carcass-based prediction equations were more accurate in predicting PFT4P. This is probably due to CKPH being an available trait for carcass-based regression prediction, whereas CKPH could not be measured in the live animal.

## Implications

Results of the current study demonstrate that ultrasound measures can more accurately estimate percentage of retail product in beef cattle than carcass measures. Utilization of centralized ultrasound processing-qualified ultrasound technicians accustomed to having their images and/or interpretations routinely reviewed may be one reason for this advantage. Although ultrasound measures of subcutaneous fat in the rump of cattle did not come into stepwise regression analysis of this data, it should not be dismissed because it was moderately correlated with percentage of retail product yield from the four primals, and was included in the prediction of percentage of trimmable fat from the four primals. These results indicate that ultrasound measures of muscle in the rump can be implemented to better predict percentage of retail product, but are not valuable in predicting percentage of trimmable fat from the four primals.

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## Appendix

Tables 8 and 9 display the various equations based on our development data set to predict percent of retail product from the four primals from ultrasound measures and carcass measures, respectively. These equations are reported as a reference for other individuals to determine the best prediction equation available to them for the costs of obtaining these data. For example, feedlot operators can determine whether an equation with only 12th- to 13th-rib s.c. fat thickness is sufficiently accurate or whether they would benefit from also including 12th- to 13th-rib LM area in the prediction. In other cases, researchers may be inclined to include as many traits as possible to obtain the highest degree of accuracy to determine effects of a dietary treatment. Probability values for each coefficient also are included to help identify when certain combinations of traits are not relevant.

**Table 8.** Ultrasound derived equations to predict percentage of retail product (n = 328)[a]

| $R^2$ | RMSE, % | Intercept | UFAT, cm | ULMA, $cm^2$ | SCANWT, kg | UPFAT, % | URFAT, cm | URDEPTH, cm | URAREA, $cm^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Without ULMA as a measure of muscle: | | | | | | | | | |
| 0.151 | 2.019 | 52.596*** | — | — | — | — | −2.7055*** | — | — |
| 0.153 | 2.019 | 53.779*** | — | — | −0.002241 | — | −2.6480*** | — | — |
| 0.162 | 2.012 | 52.841*** | — | — | −0.003356 | — | −2.586*** | — | 0.0225† |
| 0.163 | 2.012 | 52.309*** | — | — | −0.003687 | — | −2.7857*** | 0.2695† | — |
| 0.319 | 1.809 | 54.004*** | −3.7821*** | — | — | — | — | — | — |
| 0.319 | 1.812 | 54.103*** | −3.7771*** | — | −0.000189 | — | — | — | — |
| 0.334 | 1.794 | 52.881*** | −3.7715*** | — | −0.001561 | — | — | — | 0.0297** |
| 0.336 | 1.795 | 52.945*** | −3.5762*** | — | −0.001359 | — | −0.3350 | — | 0.0287** |
| 0.352 | 1.770 | 51.297*** | −4.1387*** | — | −0.002798 | — | — | 0.5199*** | — |
| 0.355 | 1.768 | 51.297*** | −3.8415*** | — | −0.002590 | — | −0.5172 | 0.5263*** | — |
| With ULMA as a measure of muscle: | | | | | | | | | |
| 0.079 | 2.103 | 43.700*** | — | 0.0762*** | — | — | — | — | — |
| 0.410 | 1.686 | 47.217*** | −3.8574*** | 0.0820*** | — | — | — | — | — |
| 0.442 | 1.642 | 50.395*** | −3.6067*** | 0.1095*** | −0.010420*** | — | — | — | — |
| 0.454 | 1.628 | 48.910*** | −3.7032*** | 0.1013*** | −0.011191*** | — | −0.2498 | 0.3299** | — |
| 0.454 | 1.627 | 48.889*** | −3.8443*** | 0.1022*** | −0.011362*** | — | — | 0.3251** | — |
| 0.472 | 1.602 | 51.562*** | −3.0879*** | 0.1030*** | −0.009339*** | −0.3693*** | — | — | — |
| 0.485 | 1.584 | 50.503*** | −3.0827*** | 0.1016*** | −0.010454*** | −0.3709*** | — | — | 0.0269** |
| 0.490 | 1.578 | 49.874*** | −3.3257*** | 0.0936*** | −0.010370*** | −0.4007*** | — | 0.3867** | — |
| 0.491 | 1.578 | 49.810*** | −3.2662*** | 0.0953*** | −0.010617*** | −0.3939*** | — | 0.2936† | 0.0120 |

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; †$P < 0.10$.
[a]See Table 1 for definition of abbreviations.

**Table 9.** Carcass data derived equations to predict percentage of retail product (n = 328)[a]

| $R^2$ | RMSE, % | Intercept | CFAT, cm | CLMA, $cm^2$ | HCW, kg | MARB[b] | CKPH, % |
|---|---|---|---|---|---|---|---|
| Without MARB: | | | | | | | |
| 0.099 | 2.080 | 43.773*** | — | 0.0769*** | — | — | — |
| 0.114 | 2.063 | 54.220*** | — | — | — | — | −2.0881*** |
| 0.174 | 1.992 | 52.490*** | −2.3029*** | — | — | — | — |
| 0.233 | 1.922 | 47.255*** | −2.0588*** | 0.0607*** | — | — | — |
| 0.242 | 1.911 | 55.456*** | −2.0160*** | — | — | — | −1.6479*** |
| 0.308 | 1.829 | 50.085*** | −1.7462*** | 0.0638*** | — | — | −1.7228*** |
| 0.310 | 1.829 | 50.920*** | −1.6696*** | 0.0701*** | −0.004477 | — | −1.6834*** |
| With MARB: | | | | | | | |
| 0.127 | 2.047 | 54.254*** | — | — | — | −0.7808*** | — |
| 0.259 | 1.889 | 55.681*** | −2.0361*** | — | — | −0.6495*** | — |
| 0.300 | 1.839 | 50.972*** | −1.8615*** | 0.0506*** | — | −0.5792*** | — |
| 0.329 | 1.801 | 58.698*** | −1.7445*** | — | — | −0.6543*** | −1.6630*** |
| 0.374 | 1.741 | 53.808*** | −1.5484*** | 0.0537*** | — | −0.5797*** | −1.7244*** |
| 0.375 | 1.744 | 53.998*** | −1.5300*** | 0.0554*** | −0.001157 | −0.5758*** | −1.7142*** |

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; $P < 0.10$.
[a]See Table 1 for definition of abbreviations.
[b]3.00 = Traces[00]; 4.00 = Slight[00]; 5.00 = Small[00]; 6.00 = Modest[00]; 7.00 = Moderate[00]; 8.00 = Slightly Abundant[00]; and 9.00 = Moderately Abundant[00].