Meat and Muscle Biology™

Short Communication: Relationships Between Kidney, Pelvic, and Heart (KPH) Fat and Beef Carcass Yield

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Abstract: The contribution of kidney, pelvic, and heart (KPH) fat to predicting carcass yield in the official USDA Yield Grade equation has been questioned in the modern U.S. slaughter cattle population and has not been extensively studied. Many U.S. beef processors remove KPH fat at harvest to facilitate faster chilling and easier fabrication. The objective of this study was to understand the modern-day relationship of KPH fat to subprimal yield (SY). Fabrication data from carcasses ($N = 816$) evaluated across multiple studies in the last 15 y were summarized. SY, subprimal cutout value (SCO), and KPH percentage were adjusted to account for study effects. Values for SY, SCO, and KPH percentage were computed on a conventional (hot side weight [HSW] including KPH) and alternate (HSW without KPH) basis, and variance among these measures was tested. Relationships among HSW and carcass components, carcass components themselves, and conventional and alternate calculations of SY and KPH percentages were evaluated using linear and quadratic models. Variance in alternate KPH percentage was greater ($P = 0.01$) than conventional KPH, suggesting that variance in KPH was independent from variance associated with HSW. Among carcass components, KPH weight was least related (R^2 linear = 0.167, and R^2 quadratic = 0.201) to HSW. Subprimal (SUB) and fat, bone, and trimmings (FBT) weight were each more directly related ($R^2 = 0.899$ to 0.953) to HSW. Weight of KPH was poorly related to weight of SUB ($R^2 = 0.074$) and FBT ($R^2 = 0.127$), although quadratic relationships of these same metrics were slightly stronger. Therefore, to increase accuracy, future models predicting carcass yield should incorporate an accurate measure of KPH or exclude KPH altogether from the denominator of the yield calculation.

Key words: bone, internal fat, muscle, subprimal, Yield Grade
Meat and Muscle Biology 8(1): 18253, 1–6 (2024) **doi:10.22175/mmb.18253**
Submitted 28 June 2024 Accepted 26 September 2024

Introduction

An estimate of kidney, pelvic, and heart (KPH) fat, expressed as a percentage of hot carcass weight (HCW), is one factor used to calculate USDA Yield Grade to predict the percentage of boneless, closely trimmed retail cuts from the round, loin, rib, and chuck (Murphey et al., 1960). The weight of the kidney is traditionally included in this estimate of KPH fat. In developing the original Yield Grade equation, the researchers included estimated KPH percentage because it explained variance in yield that seemingly was not explained by external fat thickness, supposing its relationship to intermuscular fat.

Assessment of KPH fat at commercial beef processing facilities in the U.S. has traditionally occurred after chilling and at the time of official USDA grade assignment. Today, many U.S. beef processing facilities remove KPH fat at the time of harvest to speed up chilling rate and to improve carcass fabrication efficiency. Facilities conducting such a practice have been permitted to determine USDA Yield Grade from a measure of KPH fat removed at the time of harvest obtained from two scales—one that captures HCW and another that captures HCW without KPH fat (USDA AMS, 2009). Some facilities remove additional fat (e.g., cod fat, fat over the inside round, external plate fat; known as hot fat trimming) at the time of harvest with disregard to capturing measurement of KPH fat alone. These facilities have adapted their own internal yield grades, which typically assume a fixed percentage of KPH fat or an estimation of KPH fat from subcutaneous fat measurement. USDA grade standards for beef carcasses allow for independent assignment of Yield and Quality Grades, such that assigning one is not contingent upon assigning the other (USDA, 2017). In 2023, official USDA Yield Grades were assigned to only 22% of the total pounds of beef carcasses graded in the U.S. (USDA AMS, n.d.).

Inconsistency regarding assessment of KPH fat amount and the lack of use of official USDA Yield Grades has prompted questions on the significance of KPH fat in predicting carcass yield in today's U.S. beef industry. Further, KPH fat amount has been reported to vary considerably among cattle of different biological types, namely beef and dairy breeds (Callow, 1961; Kempster et al., 1976; Tatum et al., 1986). Hence, a standard account of KPH fat in the payment schedule across cattle types is most certainly not representative of the non-KPH portion of HCW from which processors generate cutout value. Meanwhile, the USDA Yield Grade has been questioned for its ability to accurately predict carcass yield in the modern cattle population (Lawrence et al., 2008; Lawrence et al., 2010). Issues associated with KPH measurement have been suggested as a contributing factor to this inaccuracy, and evaluation of yield on a KPH-removed basis has been suggested as one solution to increasing accuracy of carcass yield prediction. Carcass yield was identified in the most recent National Beef Quality Audit (National Cattlemen's Beef Association, 2022) as a missed opportunity for the industry; thus, the ability to more accurately predict carcass yield will be increasingly important in the future.

This study aimed to evaluate absolute measures of KPH, subprimal yield (SY), and subprimal cutout value (SCO) calculated on a conventional (KPH included) and alternate (KPH removed) basis from carcasses fabricated across multiple studies within the past 15 y. Relationships among these measures and other carcass components were also assessed. We hypothesized that KPH contributed greater variance to the measurement of SY on a conventional than alternate basis and, correspondingly, that KPH accounted for very minimal variation in SY.

Materials and Methods

Carcass fabrication data were obtained from multiple previously conducted studies representing a wide variety of cattle types where KPH fat (either alone or combined with multiple fat sources trimmed at harvest) was measured. Studies included the following: (1) Mendizabal (2023), $n = 91$, Wagyu-influence; (2) Foraker et al. (2024), $n = 176$, conventional beef, beef × dairy, and Holstein; (3) Wesley (2020) and Pillmore et al. (2024), $n = 32$, Charolais × Angus; (4) Farrow et al. (2009), $n = 80$, conventional beef; (5) Howard et al. (2014), $n = 342$, Holstein; (6) Pillmore et al. (2019) and Wesley et al. (2019), $n = 10$, Jersey; (7) Voyles (2012), $n = 44$, dairy-type; (8) Schmitz et al. (2018) and Walter et al. (2018), $n = 41$, Hereford crossbreds. Data represented one carcass side ($N = 816$) and included hot side weight (HSW), chilled side weight, weight of KPH fat (including kidney), weights of individual subprimals, and weights of total fat, total bone, and trimmings. Individual subprimals were generated by trained personnel in a cutout style specific to each study. When KPH weight was captured on a carcass basis (and not on a side basis), it was divided by 2 to represent one carcass side. Carcasses were included in the study only if cutout components (subprimals, trimmings, fat, and bone) weighed back to 98% to 101% of chilled side weight. When HSW was not available, HSW was calculated as the fabricated side weight divided by 0.98, which is a common U.S. industry average shrink for carcasses chilled 24 to 30 h (personal industry communication).

Conventional subprimal yield (SY_{CONV}) percentage was calculated as the summation of subprimal weights divided by HSW multiplied by 100. Because cutout style differed and the types of subprimals generated among studies varied, a linear model predicting SY_{CONV} was fit using the fixed effect of study. Model residuals were added to its intercept to calculate an adjusted SY_{CONV} which was used for analyses.

Conventional KPH fat (KPH_{CONV}) percentage was calculated as KPH fat weight divided by HSW multiplied by 100. Two studies (Foraker et al., 2024, and Mendizabal, 2023) measured KPH fat in combination with additional fat sources trimmed during harvest, while the remainder of the studies captured KPH fat independently. To account for these differences in measurement of KPH, a linear model predicting KPH_{CONV} was fit using the fixed effect of measurement method. Model residuals were added to its intercept to compute an adjusted KPH_{CONV} which was used for analyses.

Alternate subprimal yield (SY_{ALT}) and KPH (KPH_{ALT}) were calculated on a KPH-removed basis by dividing the summations of the weight of all subprimals and KPH, respectively, by HSW without KPH, then multiplying by 100. Adjustment was made to SY_{ALT} for study effect and to KPH_{ALT} for effect of measurement method similar to procedures described for SY_{CONV} and KPH_{CONV}.

Within each study, the total value of the subprimal portion of each carcass was calculated by the summation of the weight of each subprimal multiplied by its corresponding weighted average cutout value reported in 2023 for USDA Choice cuts (USDA AMS, 2023). Conventional subprimal cutout value (SCO_{CONV}) was calculated as the total value of the subprimal portion for a carcass divided by HSW, multiplied by 100. An alternate subprimal cutout value (SCO_{ALT}) was calculated on a KPH-removed basis, where total value of the subprimal portion was divided by the HSW without KPH, multiplied by 100. Adjustment was made to SCO_{CONV} and SCO_{ALT} for the fixed effect of study, in the manner previously described.

Weights of carcass components were calculated from model-adjusted percentages. Subprimal weight (SUB) was calculated as adjusted SY_{CONV} percentage multiplied by HSW, divided by 100. Weight of KPH was calculated as adjusted KPH_{CONV} percentage multiplied by HSW, divided by 100. The weight of fat, bone, and trimmings (FBT) was calculated as HSW minus SUB minus KPH.

Data were analyzed using R statistical software, version 4.4.1 (R Core Team, 2024). Mean and standard deviations were calculated for HSW, SY_{CONV}, SY_{ALT}, KPH_{CONV}, KPH_{ALT}, SCO_{CONV}, and SCO_{ALT}. An F-test was used to test for homogeneity of variance between SY_{CONV} and SY_{ALT}, KPH_{CONV} and KPH_{ALT}, and SCO_{CONV} and SCO_{ALT}. Relationships between HSW and carcass components, individual carcass components, SY_{CONV} and KPH_{CONV}, and SY_{ALT} and KPH_{ALT} were evaluated using adjusted R^2 values from linear and quadratic models. Model significance was considered at $P \leq 0.05$.

Results and Discussion

Mean values for KPH, SY, and SCO, each expressed on a conventional (KPH included) and alternate (KPH removed) basis, are presented in Table 1. Alternate KPH was 20% more variable ($P < 0.01$) than conventional KPH, indicating that variance in KPH does not always align with variance in HSW. Therefore, variance introduced to HSW from KPH should be accounted in models predicting carcass yield on a HSW basis with KPH included. Otherwise, the ability to predict the subprimal portion of HSW will be diminished by variance in KPH that does not align with variance in other carcass traits. Crouse et al. (1988) demonstrated greater correlations between cutability and Yield Grades that accounted for KPH (r = 0.825 to 0.818) than cutability and Yield Grades that accounted for a standardized 3.5% KPH (r = 0.795), further underpinning the importance of an accurate account of KPH in cutability calculations.

Table 1. Mean and standard deviation of hot side weight (HSW), kidney, pelvic, and heart fat (KPH) percentage, subprimal yield (SY) percentage, and subprimal cutout value (SCO) of carcasses ($N = 816$) from multiple studies.

Item	Mean	SD	*P*-value[1]
Hot side weight[2], kg	193.2	27.22	—
KPH_{CONV}, %	3.09	1.142	0.01
KPH_{ALT}, %	3.21	1.251	
SY_{CONV}, %	43.26	1.973	0.22
SY_{ALT}, %	46.05	1.890	
SCO_{CONV}[3], USD	227.7	9.83	0.45
SCO_{ALT}, USD	242.4	9.58	

Homogeneity of variance between alternate calculations of traits was assessed. KPH_{CONV} = KPH as percentage of HSW. KPH_{ALT} = KPH as a percentage of HSW with KPH removed. SY_{CONV} = SY as percentage of HSW. SY_{ALT} = SY as a percentage of HSW with KPH removed. SCO_{CONV} = expressed as U.S. dollars (USD) per 45.4 kg HSW. SCO_{ALT} = expressed as USD per 45.4 kg HSW with KPH removed.

[1]F-test for homogeneity of variance (null hypothesis: ratio of variances = 1 among like variables (e.g., KPH_{conv} and KPH_{alt}).).

[2]Includes KPH weight.

[3]Average carcass cutout value in 2023 was 299.0 USD per 45.4 kg.

Conventional and alternate calculations for SY and SCO were not different ($P > 0.05$) in variance (Table 1). Hence, variance existed in SY and SCO independent from the contribution of KPH to the denominator of these calculations. The SCO_{CONV} in this study represented about 76% of the total carcass cutout value reported by the USDA in 2023; thus, changes in SCO would largely affect the total carcass cutout value. Values for SCO_{ALT} were approximately 6% greater than SCO_{CONV}. Assuming a direct relationship between carcass cutout value and carcass value, a market adjustment of similar magnitude might be expected if carcasses were valued on a basis of HSW with KPH removed.

Among carcass components, KPH was least related (R^2 linear = 0.167, and R^2 quadratic = 0.201) to HSW, and SUB and FBT were each more directly related (R^2 = 0.899 to 0.953) to HSW (Table 2). The combination of SUB and FBT explained nearly all (R^2 = 0.994) the variance in HSW. Linear and quadratic relationships of SUB and FBT, respectively, to HSW were nearly the same (R^2 less than 0.002 different), whereas the negative

Table 2. Relationships between hot side weight (HSW, kg), subprimal weight (SUB, kg), fat, bone, and trimmings weight (FBT, kg), and kidney pelvic and heart fat weight (KPH, kg) from carcasses (*N* = 816) in multiple studies.

	Linear			Quadratic		
Dependent Variable	Model	Adjusted R^2	*P*-Value	Model	Adjusted R^2	*P*-Value
HSW	$7.1 + 2.2 \times SUB$	0.899	<0.01	$193.2 + 736.7 \times SUB - 26.5 \times SUB^2$	0.900	<0.01
HSW	$4.5 + 2.1 \times SUB + 1.9 \times KPH$	0.923	<0.01	$177.3 + 643.7 \times SUB - 40.6 \times SUB^2 - 47.7 \times KPH - 18.7 \times KPH^2 + 0.03 \times SUB \times KPH$	0.925	<0.01
HSW	$1.0 + 1.0 \times SUB + 1.1 \times FBT$	0.994	<0.01	$202.8 + 357.8 \times SUB + 1.7 \times SUB^2 + 515.7 \times FBT + 11.0 \times FBT^2 - 0.001 \times SUB \times FBT$	0.994	<0.01
HSW	$17.6 + 1.7 \times FBT$	0.951	<0.01	$193.2 + 757.9 \times FBT - 27.5 \times FBT^2$	0.953	<0.01
HSW	$17.2 + 1.7 \times FBT + 0.8 \times KPH$	0.955	<0.01	$193.8 + 743.1 \times FBT - 32.7 \times FBT^2 + 59.1 \times KPH + 11.0 \times KPH^2 - 0.0008 \times FBT \times KPH$	0.957	<0.01
HSW	$329.1 + 9.6 \times KPH$	0.167	<0.01	$386.4 + 635.0 \times KPH - 294.3 \times KPH^2$	0.201	<0.01
SUB	$17.1 + 0.6 \times FBT$	0.752	<0.01	$83.5 + 286.4 \times FBT - 30.1 \times FBT^2$	0.756	<0.01
SUB	$75.3 + 1.4 \times KPH$	0.074	<0.01	$83.5 + 90.7 \times KPH - 59.0 \times KPH^2$	0.105	<0.01
FBT	$89.3 + 2.4 \times KPH$	0.127	<0.01	$103.8 + 160.4 \times KPH - 88.2 \times KPH^2$	0.165	<0.01
SY_{CONV}	$45.3 - 0.7 \times KPH_{CONV}$	0.148	<0.01	$43.3 - 21.8 \times KPH_{CONV} + 9.1 \times KPH_{CONV}^2$	0.173	<0.01
SY_{ALT}	$47.1 - 0.3 \times KPH_{ALT}$	0.043	<0.01	$46.1 - 11.3 \times KPH_{ALT} + 7.0 \times KPH_{ALT}^2$	0.059	<0.01

KPH_{CONV} = KPH as percentage of HSW.

KPH_{ALT} = KPH fat as a percentage of HSW with KPH removed.

SY_{CONV} = SUB as percentage of HSW.

SY_{ALT} = SUB as a percentage of HSW with KPH removed.

quadratic effect ($R^2 = 0.201$) of KPH on HSW was slightly more explanatory than the linear relationship ($R^2 = 0.167$) of the same metrics. Hence, increases in KPH were not always concomitant with proportionally equal increases in HSW, suggesting that, even at constant HSW, other factors—perhaps cattle type and sex—contributed to variation in KPH.

Weight of KPH was poorly related to weight of SUB ($R^2 = 0.074$) and FBT ($R^2 = 0.127$), although quadratic relationships of these same metrics were slightly stronger (Table 2). When measuring the yield of retail cuts, it has been proposed that KPH is more related to the amount of intermuscular fat than external fat, which is why KPH was originally included in the USDA Yield Grade equation (Murphey et al., 1960; Abraham et al., 1980). Subprimals, and not retail cuts, were generated in this study, making it hard to discern a relationship between KPH and fat depots, like intermuscular fat, contained within subprimals. Additional research is needed to understand whether a relationship between KPH and intermuscular fat exists in modern cattle.

Conventional calculation of KPH percentage was more highly correlated ($R^2 = 0.148$) with SY percentage than alternate calculation of KPH percentage ($R^2 = 0.043$; Table 2). Quadratic relationships between conventional ($R^2 = 0.173$) and alternate ($R^2 = 0.059$) calculations of KPH and SY were only slightly more explanatory than linear relationships. These data demonstrated that the relationship between KPH percentage and SY was hinged more on their relationship to the denominator, HSW, than a true biological relationship. Farrow et al. (2009) showed that including KPH percentage, whether actual or estimated, in the Yield Grade equation provided minimal, if any, improvement to the ability of the equation to predict salable meat yield.

Together, these data suggest that KPH is a highly variable carcass component and shares minimal relationship with other carcass components. As a percentage, the part–whole relationship of KPH with carcass weight likely contributes more to the prediction of SY than a direct relationship between KPH and SY. While this study only evaluated the KPH component of the Yield Grade equation, it is possible that relationships of KPH with other carcass variables may provide additive predictability of carcass yield. Additionally, the original Yield Grade equation was developed to predict cutability at the retail cut level, not at the subprimal level, as was measured in this study. Nevertheless, future prediction models developed to improve the accuracy of yield estimation should either include a highly accurate assessment of KPH or exclude KPH altogether from the denominator in the calculation of carcass yield.

Acknowledgments

This research was coordinated by the National Cattlemen's Beef Association, a contractor to the Beef Checkoff.

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