RELATIONSHIP BETWEEN LIVE BODY CONDITION SCORE AND INTERNAL KIDNEY, PELVIC, AND HEART FAT MEASUREMENTS IN EQUINE CARCASSES

By

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ABSTRACT

The relationship between live BCS and carcass fat measurements have not been well documented in equine, due to the limited access to equine processing plants, and economic interest in the data in this country. This study was designed to establish the relationship between BCS and carcass fat measurements from equine carcasses. Live horses (n = 429) were evaluated at a commercial equine processing facility (Bouvry Exports, Fort Macleod, Alberta, Canada).

Horses were identified independently assigned a BCS by three evaluators from the West Texas A&M University (WTAMU) Equine Program. Horses were assigned a BCS by visual appraisal and by palpating the neck, withers, back, ribs, behind the shoulder and tailhead. Median BCS scores were calculated; frequencies of BCS were: 3.0 (n = 9); 4.0 (n = 43); 5.0 (n = 116); 6.0 (n = 86); 7.0 (n = 72); 8.0 (n = 76). Horses were processed according to industry-accepted procedures as outlined by the Canadian Food Inspection Agency (CFIA). During the harvest process, all KPH was trimmed and weighed by personnel from the WTAMU Beef Carcass Research Center. Quantity of KPH was expressed as a percentage of HCW. As BCS increased, HCW, KPH weight, KPH expressed as a percentage of HCW, marbling score, neck fat depth, cold carcass fat trim, and cold carcass fat trim expressed as a percentage of HCW increased ($P < 0.001$). A strong correlation (r = 0.74; $P < 0.001$) was observed between BCS and KPH weight. Similarly, the correlation observed between BCS and percentage of KPH was also good (r = 0.65; $P < 0.001$). These data indicate a strong relationship between subjective live BCS and objective internal carcass fat quantity in various equine breed types and genders.

Key Words: Body condition score, fat depots, equine, body composition

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TABLE OF CONTENTS

LIST OF TABLES

Chapter I

INTRODUCTION

Body composition is defined as the percentage of fat, muscle, and bone in the body. In all animals, body fat reserves are important because fat represents the amount of energy reserves the animal has for periods of nutritional stress. If fat reserves are low and energy is needed, muscle protein will be broken down to meet the energy requirements of the animal. However, the most variable of all of the body's components is body fat. (Lohman, 1971). The variability in fat mass is related to the gender and genetic makeup of the individual horse, and environmental factors such as nutrition or training the horse has received. Furthermore, genetic differences have been observed in body composition and fat content between breeds within several species, such as cattle, pigs, and sheep. The coefficient of variation of body composition and fat when estimated from empty-body weight, is generally greater than 15%. Relative differences in body composition and fat at the same empty-body weight have been reported as great as 50% between breed types in livestock. Nutritional factors have been observed to contribute to the variation in the increase in fat content associated with development, particularly in swine, where differences as great as 45% have been associated with plane of nutrition (Lohman, 1971).

The issue of breed-related differences is a concern when attempting to analyze the previous literature regarding horses (Kearns et al., 2002). There appears to be breed related differences in fat and muscle distribution of horses. This may be related to the fact that many breeds have been bred for specific purposes. Thoroughbreds were developed for speed and endurance; while Quarter Horses were developed for speed, and draft horses for power without speed (Julian et al., 1956). Thoroughbreds have been reported to be one of the leanest breeds while the various pony breeds have been observed to deposit more fat mass, when fed the same diet (Gunn, 1987).

Although body composition has been considered an important factor in the assessment of equine nutritional status, there is limited data available on equine body composition. This lack of published data is due primarily to the difficulties associated with previous methods used to assess body composition in the horse (Lawrence, 1994). Commonly used techniques in assessing body composition include dual energy X-ray absorption, specific gravity, bio-electrical impedance, air displacement, body condition scoring, cadaver dissection, and ultrasound (Lawrence, 1994).

There have been numerous studies on the relationship between live body fat measurements and carcass characteristics in livestock. However, there are no reported studies on the relationship between live body condition score and carcass fat measurements from equine carcasses. The purpose of this study was to quantify the relationship between live body condition score and actual internal and carcass fat measurements in equine.

Chapter II

REVIEW OF LITERATURE

Horse Meat Consumption

Horses are located on every continent in the world and the United States has the most with a total of about 10.2 million horses (Stull, 2013). Horses are used for racing, showing, competition, sport, breeding, recreation, and for work. The total horse population includes horses used both commercially and for pleasure. Consumption of horse meat in the U.S. is not considered culturally acceptable, so equine meat products are marketed in other countries such as Europe, Japan, Russia, South America, and Canada (North, 2004).

Demand is the highest for the cuts from the hindquarters: tenderloin, sirloin, fillet steak, rump steak, and rib. The remainder of the cuts (non-primal) are used for ground horsemeat (North, 2004). However, horsemeat quality varies depending on the breed. Horse breeds are loosely divided into three categories based on general temperament: (1) Hot-bloods, known for speed and endurance; (2) Cold-bloods, such as draft horses, suitable for slow, heavy work; and (3) Warm-bloods, developed from crosses between hot bloods and cold bloods (North, 2004). In heavier muscled cold-blooded horses, the muscle is hard and lighter in color and quality. Warm-blooded horses, on the other hand, have meat that is darker in color with less fat (North, 2004). Since horses are hind-gut fermenters, the red meat produced may contain mostly monounsaturated (18:1) or polyunsaturated fats when compared to other read meat (North, 2004). The fats produced in the meat can vary and change with diet. Horse meat has high concentrations of linoleic acid (18:3), and because it is classified as red meat, it has a high Fe content. Horse meat is also relatively low in fat and cholesterol (North, 2004). Aside from health aspects, it is a tender meat with strong red meat flavors and a tint of sweetness (North, 2004).

Processing of horses for human consumption ended in the U.S. in 2007 when the last three horse processing plants shut down due to political and consumer pressure, state laws, and elimination of federal funding for federal inspectors. Since the U.S. plants closed, most horses bound for processing plants travel to either Mexico or Canada. In 2012, a total of 158,657 U.S. horses were processed for human consumption, with 48,455 horses exported to Canada and 110,202 exported to Mexico (Stull, 2013).

Body Condition Scoring

The equine body condition scoring (BCS) system that was developed by Henneke et al. in 1983 is the most commonly used and most cited method for estimation of stored fat. The BCS system is used by industry professionals and producers, thus the scoring system is important to many different segments of the horse industry. The BCS scale is used to manage optimal reproduction efficiency in breeding farms, performance horse evaluation, feeding management, research, and animal welfare evaluation. The scoring system is based on a nine-point scale and is analogous to the scoring system used in beef cattle (Henneke et al, 1983). This system is based on visual appraisal and palpable fat cover over six specific areas: neck, withers, crease down the back, tailhead, ribs, and area behind the shoulder (Henneke et al., 1983). Description of the equine body condition scoring system is as follows:

- 1-Poor. Animal is extremely emaciated. Spinous processes (dorsal portion of the vertebra), ribs, tailhead, and bony protrusions of the pelvic girdle (hooks and pins) are prominent. Bone structure of withers, shoulders, and neck are easily noticeable. No fatty tissues can be felt.
- 2-Very Thin. Animal is emaciated. Slight fat covering over base of the spinous processes. Transverse processes (lateral portion of vertebrae) of lumbar (loin area) vertebrae feel rounded. Spinous processes, ribs, shoulders, and neck structures are faintly discernible.
- 3- Thin. Fat is built up about halfway on spinous processes. Transverse processes cannot be felt. Slight fat cover over ribs. Spinous processes and ribs are easily discernible. Tailhead is prominent, but individual vertebrae cannot be visually identified. Hook bones (protrusion of pelvic girdle appearing in upper, forward part of the hip) appear rounded, but are easily discernible. Pin bones (bony projections of pelvic girdle located toward rear, mid-section of the hip) are not distinguishable. Withers, shoulders, and neck are accentuated.
- 4-Moderately Thin. Negative crease along back (spinous processes of vertebrae protrude slightly above surrounding tissue). Faint outline of ribs is discernible. Fat can be felt around tailhead (prominence depends on conformation). Hook bones are not discernible. Withers, shoulders, and neck are not obviously thin.

- 5-Moderate. Back is level. Ribs cannot be visually distinguished, but can be easily felt. Fat around tailhead begins to feel spongy. Withers appear rounded over spinous processes. Shoulders and neck blend smoothly into body.
- 6-Moderate to Fleshy. May have slight crease down back. Fat over ribs feels spongy. Fat around tailhead feels soft. Fat begins to be deposited along the sides of the withers, behind the shoulders, and along sides of neck.
- 7-Fleshy. May have crease down back. Individual ribs can be felt, but with noticeable filling of fat between ribs. Fat around tailhead is soft. Fat is deposited along withers, behind shoulders, and along neck.
- 8-Fat. Crease down back. Difficult to feel ribs. Fat around tailhead is very soft. Area along withers is filled with fat. Area behind shoulder is filled in flush with rest of the body. Noticeable thickening of neck. Fat is deposited along inner buttocks.
- 9-Extremely fat. Obvious crease down back. Patchy fat appears over ribs. Bulging fat around tailhead, along withers, behind shoulders, and along neck. Fat along inner buttocks may rub together. Flank is filled in flush with rest of the body.

In the cattle industry, BCS is an effective tool for monitoring the energy intake of cows (NRC, 2000). Energy reserves in cattle are more often managed by observing changes in body condition, and all body composition systems developed use BCS to describe energy reserves (NRC, 2000). Body condition score is closely related to body fat and energy requirements (NRC, 2000). In horses, the BCS system developed by Henneke et al. (1983) is a proven method of evaluating body fat as most stock-type horses deposit fat on the body sequentially and in the same areas of the body.

Henneke et al. (1983) reported that body composition, or the degree of fattening, can influence the animals growth, reproduction, and health. Henneke et al. (1983) also reported that mares should be in a good condition at mating to achieve maximum reproductive efficiency. Pregnancy rates and cycles per conception were significantly lower in mares entering the breeding season or foaling at a BCS of less than 5.0 when compared with mares with higher initial condition scores.

Body Condition Score Used in Other Species

Sheep. Body condition scoring in sheep is a subjective assessment of the relative degree of muscling and fat deposition over the vertebrae in the loin region (Sanson et al., 1993). The scores used for sheep range from 0 (extremely thin) to 5 (obese). However, some authors have used a 9-point scale of 1 (emaciated) to 9 (obese; Sanson et al., 1993).

Sanson et al. (1993) evaluated the relationship between BCS and body composition using fourteen mature western-range ewes with an initial mean BW of 72 ± 4.5 kg and mean BCS of 7.5 ± 0.3. In this study, BCS was assigned using a scale of 1 (emaciated) to 9 (obese). Diets of chopped straw and alfalfa hay were formulated to provide either 100% or 60% maintenance energy requirements (ME) to induce changes in BW and BCS. After 180 d, ewes were weighed, BCS assessed, and slaughtered. All carcass components, viscera, and organs were analyzed for lipid, DM, and ash; protein was determined by difference. Body weight and BCS values were related by regression analysis to percentage of composition and weights of carcass components, carcass, and empty body. Body weight and BCS were highly correlated (r = 0.89) and analysis indicated that each increase in BCS score resulted in an increase of 5.1 kg of BW. Body condition score accounted for more variation of percentage of lipid in the empty body (R^2 = 0.95) and carcass (R^2 = 0.90) than did BW (R^2 = 0.84 and 0.80, respectively). The authors stated that BCS was highly related to carcass lipids and could be used to describe energy reserves available to ewes.

Teixeira et al. (1989) examined the relationships between body fat depots and BCS in 52 adult Rasa Aragonesa ewes, aged 10 (± 2) yr, with BCS from 1.5 to 4.5. Body condition scoring of each ewe was assessed by three people, the repeatability within individuals being 90% and between individuals 80%. The ewes were weighed before slaughter. After slaughter the omental, mesenteric, kidney, and pelvic fat were separated and weighed. The fat of the left side of the carcass was separated into subcutaneous and intermuscular depots. The relationship between live weight and BCS was semi-logarithmic and those between fat depots and BCS were logarithmic. Regression analysis was also used to describe the relationships between the various fat depots and BCS or live weight. Of the variation in total fat weight, 0.90 was accounted for by variation in BCS, while 0.84 was accounted for by variation in live weight. For individual fat depots respectively, 0.86 to 0.90 of the variation was accounted for in BCS, and 0.69 to 0.79 by in live weight. The authors concluded that BCS was a better predictor than live weight of the weight of both total body fat and the individual fat depots.

Stanford et al. (1994) measured longissimus muscle area, maximum depth, maximum width, and subcutaneous fat thickness ultrasonically at the first lumbar vertebra on l, l62 lambs to determine if ultrasound was an accurate predictor. Lambs were classified as rams, ewes, and wethers, ranging from 3 to 15 mo of age, with live weights ranging from 32.5 to 70.2 kg. Subjective conformation scores of the leg, loin, shoulder, and body-wall thickness at the grade rule site (11 cm from the carcass midline between the 12th and l3th ribs) were measured on warm carcasses and were used to determine saleable-meat yield. Saleable-meat yield and percentage of saleable-meat yield in each of the primal cuts were also determined by carcass dissection of 57 of the lambs. Ultrasound measurements of subcutaneous fat and longissimus depth in combination with live weight and age appeared to be valuable predictors of saleable-meat yield as determined by carcass dissection. Nonetheless, grade rule and lean-meat yield were observed to be less useful in the prediction of subjective muscling scores, except in the case of small-frame lambs (Standford et al., 1994).

Dairy Cattle. Body condition scores provide an indication of the energy status of dairy cattle (Houghton et al., 1990). The most commonly used system (Houghton et al., 1990) uses scores of 1.0 to 5.0, in increments of 0.1 or 0.25. One point of body condition equals 45 to 64 kg of gain in BW. When using or applying the BCS system in dairy cattle, one must evaluate the short ribs, sacral ligament, pins, thurl, hooks, and tailhead ligament (Houghton et al., 1990).

Lloyd et al. (1995) reported that BCS adequately reflected the subcutaneous fat of cows based on the relationship between BCS and ultrasound measurements obtained. The authors reported a significant relationship between ultrasound measurements of the thurl, lumbar, and tailhead regions and BCS. The authors stated that the scoring system was as valid as ultrasound techniques for measurements of subcutaneous fat.

Otto et al. (1991) observed that BCS is highly correlated with composition of the 9th to 11th rib tissue. Fifty-six cull Holstein dairy cows of various BCS were identified and followed to slaughter. Prior to slaughter, cows were weighed on a digital scale, hook to hook and hook to pin dimensions were measured, and age was estimated by dentition. Twenty-four hours after slaughter, 9th to 11th rib sections were collected and weighed, and bone-free tissue was dissected and weighed. Deboned tissue was freeze-dried, ground, and analyzed for DM, ether extract, CP, and ash. One unit increase of body condition change was associated with an increase of 56 kg live weight and 12.65% ether extract and a decrease of 12.20% CP. Tissue DM increased by 7.23% per unit of body condition increase, largely due to increased percentage of ether extract. The authors performed a regression of composition on BCS and reported an r^2 of 0.69 for DM, 0.61 for CP, and 0.57 for ether extract.

Beef Cattle. Optimum management of energy reserves is critical to economic success with cows (Ferguson and Otto, 1989). If too fat or too thin, cows are at risk of sub-acute and acute acidosis, laminitis, ketosis, fatty liver, decreased milk yield, low conception rates, and dystocia (Ferguson and Otto, 1989). Beef cattle BCS describe the relative fatness or body condition of a cow herd using a nine-point scale (NRC, 2000). A cow with a BCS of 1 is “extremely thin” while a cow with a score of 9 is “extremely fat and obese” (NRC, 2000). The key areas for evaluation are the backbone, ribs, hips, pin bones, tailhead, and brisket. A cow with a BCS of 5 is in "average flesh" and represents a logical target for most cow herds (NRC, 2000). Conception rates reach near maximum at a BCS 5 (NRC, 2000).

Tennant et al. (2002) weighed and assigned BCS to Angus females (n = 367) over 14 yr (1981 to 1994) to allow calculation of weight adjustments for different BCS. Data were collected at five time periods: prepartum, postpartum, prebreeding, postbreeding, and midgestation. In this study, BCS was assigned using a scale of 1 (emaciated) to 9 (obese). All cows had condition scores of between 2 to 8. In this trial, no 1 or 9 scores were assigned. Weight adjustments for BCS were calculated for each time period. Data from this study indicated that overall weight adjustments for cows with a BCS of 5 (kg ± SEM) were as follows: BCS = 2 (68 kg ± 12), BCS = 3 (50 kg ± 4), BCS = 4 (21 kg ± 1), BCS = 5 (0 kg), BCS = 6 (−24 kg ± 2), BCS = 7 (−51 kg ± 3), and BCS = 8 (−73kg ± 7).

Apple (1999) reported the influence of BCS on carcass and live-animal value (n = 88) of mature beef cows. Cows were weighed and assigned a BCS using a scale of 1 (emaciated) to 9 (obese), 24 hr prior to slaughter. Hide and by-product weights were recorded during processing. After a 48-h chill period, the right side of each carcass was fabricated into boneless subprimal cuts, minor cuts, lean trim, fat, and bone. Weights were recorded at all stages of fabrication. Carcasses from cows assigned BCS of 6 had the highest total carcass values comparable to cows assigned BCS of 7. Data from this study indicated that marketing cull beef cows at a BCS of 6 could optimize economic returns to both cow-calf producers and some beef processors.

Dransfield et al. (1994) stated that beef carcass grading systems have two objectives: first, to estimate the yield of saleable meat and secondly, to determine the palatability of the meat. Among the different parameters that determine palatability, marbling, or intramuscular fat content, is a major factor due to its relationship with beef flavor, tenderness, and juiciness (Dransfield et al., 1994). In 2009, Indurain et al. studied the relationship of carcass measurements to carcass composition in Spanish beef cattle. Forty beef carcasses were classified for conformation and fatness. Carcass weight, fat thickness, carcass dimension, marbling by computer image analysis, ultrasound readings and quality grade scores were recorded. The authors reported correlations for predicting IMF content, FT, number of intramuscular flecks and conformation increased; R^2-value from 0.19 to 0.64 compared to conformation alone. They also reported correlations for visual marbling, ultrasound readings and thoracic depth increased the R^2-value from 0.24 to 0.57 compared to fatness score. The authors stated that the best variable for predicting weight of fabricated subprimals was carcass weight (R^2 between 0.94 and 0.63). Fatness score was less accurate than FT for predicting yield of subprimal cuts from round (R^2 = 0.16 vs. 0.50) and ultrasound readings for less valuable subprimals (R^2 = 0.31 vs. 0.39). The data indicated that other variables could be used in combination with carcass fatness or conformation to achieve a more accurate estimation of fat and carcass yield.

Horse. Many researchers have reported that accurate estimation of horse body composition has been successfully correlated to subcutaneous fat measurements (Henneke et al., 1983; Carroll et al., 1988; Gentry et al., 2004). Carroll et al. (1988) performed a study evaluating body measurements of 372 horses of varying breeds, height and fatness. Horses were weighed, wither height recorded, and body condition scores assigned. They were assessed for condition score by adaptation of a previously published method. The heart girth and length of 281 horses were also measured. Weight of horses was moderately correlated with height ($r^2 = 0.62$), poorly correlated with condition score ($r^2 = 0.22$), and highly correlated with girth$^2 \times$ length ($r^2 = 0.90$). Several studies in cattle have shown that the use of ultrasonic measurements of subcutaneous fat, as well as marbling and longissimus muscle area, are very useful in predicting carcass merit at slaughter (Perkins et al, 1992).

Westervelt et al. (1976) evaluated the relationship between ultrasonic fat measurements and actual fat cover. The value of such measurements for the prediction of total body fat, and the effect of exercise and diet intake on fat cover were studied in both horses and ponies. In trial 1, 8 ponies were fed *ad libitum* and 7 ponies fed a limited amount of the same diet for 4 1/2 mo. The authors reported ultrasonic rump fat thickness in horses was highly correlated (r = 0.85) with actual rump fat thickness. Ponies fed *ad libitum* had greater live weights and rib and rump fat thickness as compared to ponies fed limited diets. In trial 2, 12 horses used by the Cornell Polo Team were evaluated for fat thickness over the shoulder, rib, and rump via ultrasound after 0, 30, and 90 d of exercise. The authors reported that shoulder fat and rump fat decreased from d 0 to 30, although rib fat and BW did not change throughout the trial.

Gentry (2004) conducted a study to determine the relationship between BCS with ultrasonic measurements of subcutaneous fat taken at 4 locations (tailhead, rump, 13th rib, and withers), and to determine which site might be the most reliable area of measurement. Twenty-four light-horse mares were assigned to either a high BCS group (8.0 to 9.0) or a low BCS group (3.0 to 3.5). Mares were placed on 2 dietary treatments, full grazed or restricted, to reach their respective targeted BCS. Low BCS mares lost subcutaneous fat, while high BCS mares deposited subcutaneous fat at all 4 locations. Gentry (2004) reported that the amount of subcutaneous fat over the tailhead area had the highest correlation with change in BCS. The author stated that as the animal gets progressively fatter, the tailhead acts as a repository for a greater extent of fat. Also, as the animal gets progressively thinner, fat is removed from the tailhead area to a greater extent than the other areas measured. Subcutaneous fat at the 13^{th} rib and withers also changed with changes in BCS. However, the magnitude of the change was less than at the tailhead.

In 2004, Znamirowska performed an analysis of meat quality from 107 horses aged 6 to 12 yr, purchased from individual farmers in the south-eastern region of Poland. The author reported that horse carcasses could be classified as “high” meat content, with a mean meat content of 68.45%. The lowest obtained meat content result was 60.63%, which is high compared to other animal species. Meat contents in cattle carcasses ranges from 45.4 to 55.1% (Znamirowska, 2004). The fat content between half-carcasses has the highest variability in respect to both mass and percentage. The difference is most probably caused by differing fattening/breeding conditions of animals. The author stated that the estimation of fat deposits in carcasses may be made more objective, and the measurement of nape fat thickness may be applied for the objective assessment of fat in the live animal (Znamirowska, 2004).

Vecchi et al. (2010) used 29 maiden Standardbred mares (7 ± 2 yr old) during the breeding season to identify an objective assessment, similar to BCS, that was easy to measure and able to improve fattening status assessment. Another objective was to assess whether a relationship with reproduction efficiency exists in subjects destined for a first-time insemination program. On January 15 (day 0), the same operator performed the following assessment on all subjects: the first gynecological and ultrasound examination, a BCS assessment (range 0 to 5), and an adiposity objective assessment (i.e., measurement of fat thickness by ultrasound). At day 0, all mares were in seasonal anestrous. On ovulation day, all subjects exited the study. Both techniques were shown to be significantly correlated (r = 0.976) to the first seasonal ovulation in maiden mares (-0.772 and -0.805, respectively, for fat thickness and BCS). Regression equations for the prediction of days to the first seasonal ovulation (y) were created. The best predictive equation was the following: $y= 26.714_{x3} - 202.44_{x2} + 446.04_{x} - 195.65$ ($R_2 = 0.783$), with an independent BCS variable. Data from this study suggested that increasing the plane of nutrition, starting approximately 3 wk before the breeding season, stimulates ovarian activity in stressed maiden mares.

Henneke et al. (1984) performed a study on 32 mares equally allotted to the following treatments: mares fed to: A) high body condition from 90 d prepartum to foaling and maintained in high body condition to 90 d postpartum, B) high body condition from 90 d prepartum to foaling and allowed to lose body condition to 90 d postpartum, C) lose body condition to 90 d postpartum, and D) lose body condition from 90 d prepartum to foaling and gain weight after foaling to attain a high body condition to 90 d postpartum. After 3 cycles, pregnancy rate at 30 d post-ovulation was lower in C mares (50%) than those in the other 3 groups (100%). Maintenance of pregnancy to 90 d was also reduced in C mares (25%) when compared to A, D (both 100%) and in B mares (88%). Foal growth to 90 d was similar in all treatments.

Henneke et al. (1984) performed a second trial using 927 mares that were evaluated for body condition and reproductive performance upon arriving at 4 breeding farms in Texas. Pregnancy rate was lower and number of cycles/conception was higher for barren and maiden mares entering the breeding season in thin body condition and for pregnant mares foaling in thin condition (condition score less than 5) when compared to mares with a higher level of condition (condition score 6 or greater). Breeding efficiency was enhanced in mares entering the breeding season or foaling at a condition score of 5 or above. The authors concluded in this study that mares with initial excess stores of body fat enhance fertility (Henneke et al. 1984).

Chapter III

MATERIALS AND METHODS

Purpose of Study

Nine representatives from the Meat Science and Equine Industry programs at West Texas A&M University (WTAMU, Canyon, TX) traveled to Bouvry Exports, a commercial equine harvest facility, in Fort Macleod, Alberta, Canada. Data collection took place from May 27 through June 2, 2012. This study was designed as an exploratory study to establish the relationship between live BCS and total trimmable fat from horse carcasses.

Animals

Live horses (n = 429) were evaluated upon entering the open-sided alley leading to the stunning chamber. Horses were identified by tag number and assigned a BCS; gender (stallion, mare, gelding) and breed type (draft, stock, pony, mule) were also recorded. Horses originated either from commercial equine feedyards or were hauled in from independent sellers. Origin of horses used in this study were observed but not recorded as an individual variable.

Body Condition Scoring

Over 2 d, all horses (n = 429) entering the facility were assigned a BCS according to the scoring system developed by Henneke et al. (1983) based on the 9-point scale (1 =poor; 2 = very thin; 3 = thin; 4 = moderately thin; 5 = moderate; 6 = moderately fleshy; 7 = fleshy; 8 = fat; 9 = extremely fat). All horses were scored by 3 trained personnel from the WTAMU Equine Industry Program; horses were assigned a score by visual appraisal and by palpating 6 locations (neck, withers, crease down the back, ribs, behind the shoulder) of the horse's body. Scores were entered into a common spreadsheet, and a median score was calculated.

Processing and Carcass Records

Horses were processed at Bouvry Exports in Fort Macleod, Alberta, Canada according to industry-accepted procedures as outlined by the Canadian Food Inspection Agency (CFIA). During the harvest process, all KPH were trimmed from the carcass and weighed (add scale resolution ± 0.00 kg). The quantity of KPH fat was also expressed as a percent of HCW.

Identified carcasses were chilled a minimum of 48 h at 0°C prior to fabrication. Carcasses were evaluated for marbling and maturity, using USDA beef quality grade standards (USDA, 1997) as a guide, by 1 trained person from the West Texas A&M University-Beef Carcass Research Center. Carcasses were ribbed between the 5th and 6th thoracic vertebrae prior to grading. Each carcass was measured for neck fat depth (cm) and then marbling and lean maturity scores were assigned for the *M. Longissimus dorsi muscle* using USDA beef marbling cards as standards. During fabrication of the carcass, total fat trim was collected from the right-side carcass half. The quantity of carcass fat was weighed and expressed as a percentage of HCW.

Statistical Analysis

Data were analyzed using Statistical Analysis Systems Institute (SAS, 2012). Agreement between the 3 independent BCS scores of each horse was tested using the Spearman ranked correlation coefficient. Frequency of variables was determined using the FREQ procedure. Differences in variables amongst the BCS scores was evaluated using the MIXED procedure; the model included the fixed effect of BCS score and the random effect of KPH weight, HCW, marbling, neck fat trim, and cold carcass fat trim. The SATTERTH option was used to correct for unequal cell sizes; the LSMEANS option generated means, which were separated when significant ($\alpha = 0.05$) using the PDIFF option.

Chapter IV

RESULTS AND DISCUSSION

In this study, horses (n = 402) were evaluated for BCS and carcass fat measurements. Internal fat measurements were not recorded for horses assigned a BCS of 9 (n = 27), as Bouvy Exports processes carcass with that amount of fat separately as fat is not trimmed from these carcass and that data is unavailable; therefore, the relationship of BCS and various carcass measurements were only reported for horses with a BCS ranging from 3.0 to 8.0 in Table 2. Descriptive statistics of all data collected in the sample equine population are found in Table 1.

Spearman ranked correlation coefficient was used to test the level of agreement between variables measured amongst the equine carcasses reported in Table 3.The Spearman ranked correlation test was also used to test the level of agreement between the 3 independent BCS scores of the three BCS evaluators ($r > 0.92$; $P < 0.01$). The 3 independent BCS scores were entered into a common spreadsheet, and a median score was calculated. Frequencies of BCS for horses evaluated in this study were recorded and reported by median BCS. Median BCS from the 3 independent evaluations of each horse were calculated; frequencies of BCS were: 3.0 (n=9); 4.0 (n=43); 5.0 (n=116); 6.0 (n=86); 7.0 (n=72); 8.0 (n=76).

Mean HCW measurements and the relationship to median BCS are reported in Table 2. As median BCS increased, mean HCW increased ($P < 0.01$; $r = 0.52$). Mean

HCW increased from 274 kg at BCS 3 to 436.7 kg at a BCS 9. The average change in HCW as BCS increased was 222.22 kg. A linear and quadratic trend was observed between mean HCW and median BCS ($P < 0.01$). These data agree with Sanson et al. (1993) who reported BCS in western-range ewes accounted for more variation of percentage of lipid in the empty body ($R^2 = 0.95$) and carcass ($R^2 = 0.90$) than did BW ($R^2 = 0.84$ and 0.80, respectively).

Statistical significance was observed between median BCS and KPH weight ($P < 0.01$). Additionally, a strong correlation(r = 0.74) was also observed between median BCS and KPH weight. A linear trend was reported between KPH weight and median BCS ($P < 0.01$). These data agree with findings of Teixeira et al. (1989) who reported BCS was a better predictor than live weight of the weight of both total body fat and the individual fat depots in Rosa Aragonesa ewes. As BCS increased from 3 to 8, KPH was reported to increase 1.62 to 15.85 kg with an average change of 7.56 kg per 1 unit change in BCS.

Quantity of KPH was also expressed as a percentage of HCW. Similarly, KPH as a percentage of HCW increased as KPH weight increased ($P < 0.01$). The correlation observed between BCS and percentage of KPH was also good (r = 0.65). A linear trend was reported between quantity of KPH expressed as a percentage of HCW and median BCS ($P < 0.01$). The results parallel those of Henneke et al. (1983), who reported that BCS was positively related (r = 0.65) to body fat percentage in horses. As BCS increased from 3 to 8, percentage of KPH fat was observed to increase from 0.605 to 4.53% with an average change of 2.34% per 1 unit change in BCS.

During fabrication of the carcass, marbling scores were assigned using the USDA beef marbling cards as standards. As BCS increased, marbling score increased ($P < 0.01$). As BCS increased from 3 to 8, Marbling score increased from 21.7 to 47.3 with an average change of 33.7 per 1 unit change in BCS. A linear trend was reported between marbling score and BCS ($P < 0.01$). These data agree with Indurain et al. (2009) who reported correlations for visual marbling, ultrasound readings and thoracic depth increases the R^2 – value from 0.24 to 0.57 compared to fatness score.

Neck fat depth was measured and compared across BCS, 3 to 8. The correlation observed between neck fat depth and BCS was also good (r = 0.60). As BCS increased from 3 to 8, neck fat depth increased from 1.14 to 5.25 cm, with an average change of 3.26 cm per 1 unit of change in BCS. Statistical significance was also observed between neck fat depth and median BCS ($P < 0.01$). Gentry et al. (2004) performed correlation coefficients between BCS and subcutaneous fat thickness over the tailhead (r = 0.87), rump (r = 0.84), and 13th rib (r = 0.82), and withers in horses (r = 0.86). Research performed by Westervelt et al. (1976) reported that the rump, shoulder, and average fat thickness were highly correlated with percent of ether extractable fat (r = 0.86) in horses.

Carcass fat and carcass fat as a percentage of HCW were also measured and compared to median BCS. As carcass fat and carcass fat as a percentage of HCW increased, median BCS increased ($P < 0.01$). As BCS increased from 3 to 8, carcass fat increased from 2.21 to 14.63 kg with an average change of 7.05 kg per 1 unit change in BCS. A linear trend was observed between carcass fat and carcass fat as a percentage of HCW and median BCS ($P < 0.01$). In addition, percentage carcass fat increased 1.64 to 9.67% with increasing BCS, with an average change of 4.7% per 1 unit change in BCS.

The correlations observed between carcass fat and percentage carcass fat were good (r = 0.58 and 0.54, respectively) as well.

Table 1

Descriptive statistics of data collected from sample population of equine carcasses

Item	Mean	Std Dev	Min	Max
HCW, kg	328.3	77.9	102.0	645.0
KPH, kg	9.06	7.22	0.11	33.77
KPH, % of HCW	2.75	2.21	0.04	9.93
Marbling Score[1]	33.9	15.1	10	92
Neck fat depth, cm	3.4	1.9	0	12
Trimmed carcass fat, kg	6.08	4.24	0.64	22.28
Trimmed carcass fat, % of HCW	4.04	2.69	0.40	14.04

[1]practically devoid= < 20; traces= 20 to 29; slight= 30 to 39; small=l 40 to 49; modest= 50 to 59; moderate= 60 to 69; slightly abundant= 70 to 79; moderately abundant= 80 to 89; and abundant= 90 to 99

Table 2

Carcass traits of horses by median body condition score (BCS)

	Median BCS									
	3	4	5	6	7	8	SEM	P-Value	Linear	Quadratic
Hot carcass data, n	8	42	115	85	72	75	-	-	-	-
Hot carcass data, % of sample population	2.2	10.7	28.9	21.4	17.9	18.9	-	-	-	-
HCW, kg	274.0[d]	281.0[d]	294.6[d]	310.9[c]	332.3[b]	385.1[a]	7.42	< 0.01	< 0.01	< 0.01
KPH, kg	1.62[d]	2.30[d]	4.04[d]	8.09[c]	13.45[b]	15.85[a]	0.59	< 0.01	< 0.01	0.75
KPH, % of HCW	0.605[c]	0.821[c]	1.36[c]	2.62[b]	4.13[a]	4.53[a]	0.20	< 0.01	< 0.01	0.23
Cold carcass data, n	7	41	103	73	45	29	-	-	-	-
Marbling Score[1]	21.7[c] (Tr^{17})	25.3[c] (Tr^{53})	27.2[c] (Tr^{72})	34.9[b] (Sl^{49})	45.5[a] (Sm^{55})	47.3[a] (Sm^{73})	1.72	< 0.01	< 0.01	0.54
Neck fat depth, cm	1.14[d]	2.07[cd]	2.60[c]	3.79[b]	4.73[a]	5.25[a]	0.21	< 0.01	< 0.01	0.73
Fabrication data, n	2	12	42	25	9	6	-	-	-	-
Trimmed carcass fat, kg	2.21[d]	4.67[d]	4.06[d]	6.60[c]	10.10[b]	14.63[a]	0.72	< 0.01	< 0.01	0.99
Trimmed carcass fat, % of HCW	1.64[d]	3.53[d]	2.74[d]	4.39[c]	6.23[b]	9.67[a]	0.46	< 0.01	< 0.01	0.77
Total removed carcass fat, kg	3.83	6.97	8.1	14.69	23.55	30.48	-	-	-	-

[1]practically devoid= < 20; traces= 20 to 29; slight= 30 to 39; small=l 40 to 49; modest= 50 to 59; moderate= 60 to 69; slightly abundant= 70 to 79; moderately abundant= 80 to 89; and abundant= 90 to 99

Table 3

Spearman correlation coefficients amongst equine carcass variables

Variable	HCW, kg	KPH, kg	KPH, % of HCW	Marbling Score	Neck fat depth, cm	Trimmed carcass fat, kg	Trimmed carcass fat, % of HCW
HCW, kg	1.00	0.41**	0.21**	0.27**	0.33**	0.18	0.01
KPH, kg	0.41**	1.00	0.97**	0.71**	0.63**	0.73**	0.66**
KPH, % of HCW	0.21**	0.97**	1.00	0.72**	0.62**	0.73**	0.70**
Marbling Score	0.27**	0.71**	0.72**	1.00	0.64**	0.68**	0.68**
Neck fat depth, cm	0.33**	0.63**	0.62**	0.64**	1.00	0.52**	0.54**
Trimmed carcass fat, kg	0.18	0.73**	0.73**	0.68**	0.52**	1.00	0.97**
Trimmed carcass fat, % of HCW	0.01	0.66**	0.70**	0.68**	0.54**	0.97**	1.00

*($P < 0.05$)
**($P < 0.01$)

Chapter V

CONCLUSIONS AND IMPLICATIONS

Results from this study provide validation for the use of the current body condition scoring system used in the equine industry as an indicator of internal fat measurements in relation to overall body composition. The data collection in this study was very unique and only a handful of studies with similar research have been reported. This information could be useful to commercial equine processing facilities to formulate maximum return when feeding equine. In addition, this data could also be useful to nutritionists to formulate energy requirement equations, due to the strong correlation reported between BCS and KPH weight. This information could also be useful to producers in the U.S., should the allowance of processing horses be permitted again.

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APPENDIX A

BODY CONDITION SCORING TABLES

Table A-1 Sheep body condition scoring system.

Body Condition Score	**Appearance of Sheep**
Condition 1 (Emaciated)	Spinous processes are sharp and prominent. Loin eye muscle is shallow with no fat cover. Transverse processes are sharp; one can pass fingers under ends. It is possible to feel between each process.
Condition 2 (Thin)	Spinous processes are sharp and prominent. Loin eye muscle has little fat cover but is full. Transverse processes are smooth and slightly rounded. It is possible to pass fingers under the ends of the transverse processes with a little pressure.
Condition 3 (Average)	Spinous processes are smooth and rounded and one can feel individual processes only with pressure. Transverse processes are smooth and well covered, and firm pressure is needed to feel over the ends. Loin eye muscle is full with some fat cover.
Condition 4 (Fat)	Spinous processes can be detected only with pressure as a hard line. Transverse processes cannot be felt. Loin eye muscle is full with a thick fat cover.
Condition 5 (Obese)	Spinous processes cannot be detected. There is a depression between fat where spine would normally be felt. Transverse processes cannot be detected. Loin eye muscle is very full with a very thick fat cover.

Table A-2 Dairy cattle body condition scoring system.

Body Condition Score	Appearance of Dairy Cow
Condition 1 (Emaciated)	Ends of short ribs sharp to the touch, prominent shelf-like appearance to the loin. Individual vertebrae of the backbone are prominent. Hook and pin bones sharply defined. Anal area receded, vulva prominent.
Condition 2 (Thin)	Ends of short ribs can be felt, less visibly prominent. Short ribs do not form as obvious of a shelf effect. Hook, pin bones prominent, but depression of the region less severe. Anal area less sunken, vulva less prominent.
Condition 3 (Average)	Short ribs can be felt by applying slight pressure. Overhanging shelf like appearance gone. Backbone is a rounded ridge. Hook, pin bones are round, smoothed over. Anal area filled out, but no evidence of fat deposit.
Condition 4 (Heavy)	Short ribs can be felt when firm pressure applied, rounded over with no shelf effect. Ridge of the backbone flattening over the loin, rump, chine areas. Hook bones smoothed over, span between hook bones and backbone is flat. Fat deposit around pin bones beginning to show.
Condition 5 (Fat)	Bone structure of topline, hook and pin bones and short ribs not visible. Obvious fat deposits around tailbone and over ribs. Thighs curve out, brisket and flanks heavy.

Table A-3 Beef cattle body condition scoring system.

Body Condition Score	Body Fat, Percent	Appearance of Cow
1	3.77	Emaciated- Bone structure of shoulder, ribs, back, hooks and pins sharp to touch and easily visible. Little evidence of fat deposits or muscling.
2	7.54	Very thin- Little evidence of fat deposits but some muscling in the hind quarters. The spinous processes feel sharp to the touch and are easily seen, with space between them.
3	11.30	Thin- Beginning of fat cover over the loin, back and foreribs. Backbone still highly visible. Processes of spine can be individually by touch and may still be visible. Spaces between the processes are less pronounced.
4	15.07	Borderline- Foreribs not noticeable; 12^{th} and 13^{th} ribs still not noticeable to the eye, particularly in cattle with a big spring of rib and ribs wide apart. The transverse spinous processes can be identifies by palpation to feel rounded rather than sharp. Full but straightness of muscling in the hind-quarters.
5	18.89	Moderate- 12^{th} and 13^{th} ribs not visible to the eye unless animal has been shrunk. The transverse spinous processes can only be felt with firm pressure to feel rounded- not noticeable to the eye. Spaces between process not visible and only distinguishable with firm pressure. Areas on each side of the tail head are fairly well filled but not mounded.
6	22.61	Good- Ribs fully covered, not noticeable to the eye. Hindquarters are plump and full. Noticeable sponginess to covering of foreribs and on each side of the tail head. Firm pressure to now require to feel transverse process.

7	26.38	Very good- Ends of the spinous process can only be felt with firm pressure. Spaces between processes can barely be distinguishable at all. Abundant fat cover on either side of tail head with some patchiness evident.
8	30.15	Fat- Animal taking on smooth, blocky appearance; bone structure disappearing from sight. Fat cover thick and spongy with patchiness likely.
9	33.91	Very Fat- Bone structure not seen or easily felt. Tail head buried in fat. Animal's mobility may actually be impaired by excess amount of fat.