THESIS

DISCOVERING DIMENSIONAL DIFFERENCES AMONG HOLSTEIN AND CONVENTIONAL BEEF MIDDLE MEAT CUTS AND CONSUMER PREFERENCES FOR APPEARANCE

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2014

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ABSTRACT

DISCOVERING DIMENSIONAL DIFFERENCES AMONG HOLSTEIN AND CONVENTIONAL BEEF MIDDLE MEAT CUTS AND CONSUMER PREFERENCES FOR APPEARANCE

Two experiments were conducted to evaluate conformation of middle meat cuts and consumer preference for appearance for size and shape. This study was conducted with beef subprimals from a study conducted by Howard et al. (2014a, 2014b). Calf-fed dairy steers comprise approximately 10% of fed beef harvested annually in the United States (Moore et al., 2012). Dairy steers differ genetically from conventional beef-type cattle and can benefit from the use of growth promotants to meet comparable feedlot and carcass performance. The effect of beta-agonist supplementation on steak conformation of steaks from carcasses of calf-fed Holstein steers was investigated using steers also implanted with a combination trenbolone acetate/estradiol based implant. Beef products evaluated for dimensional differences included beef rib, ribeye (ribeye, lip-on; IMPS 112A), beef loin, short loin (short loin; IMPS 174), and beef loin, strip loin, boneless (strip loin; IMPS 180). Steaks were evaluated for dimensional differences from carcasses of calf-fed Holstein steers that received only the implant (Control), carcasses of steers that received ractopamine hydrochloride (RH) fed at 300 or 400 mg/steer/d for the final 30 d of finishing or fed zilpaterol hydrochloride (ZH) fed at 60 to 90 mg/steer/day for 21 d with a 5 d withdrawal period prior to harvest, as well as steaks from conventional beef-type cattle (CB), the subprimals for this treatment were obtained via boxed beef from a plant located in central Nebraska and a plant located in the panhandle of Texas.

Strip loin steaks were evaluated for 7 or 10 measurements, depending upon *gluteus medius* (GM) presence. These measurements included the length (medial to lateral) of the steak and the depth (dorsal to ventral) at 25, 50, 75, 87.5, and 100% of the length, as well as area of the *longissimus lumborum* (LL). The additional measurements for the strip loin and short loin steaks that contained the *gluteus medius* (GM) were GM length (medial to lateral), GM depth (dorsal to ventral), GM area, and total steak area (combined area of the LL and GM). Short loin steaks (T-Bone and Porterhouse steaks) were evaluated for identical measurements to the strip loins with the addition of length (medial to lateral), depth (dorsal to ventral), and area measurements for the *psoas major* (PM). Ribeye steaks were evaluated for length (medial to lateral) of the entire steak, depth (dorsal to ventral) at 25, 50, 75, 87.5%, and 100% of the length, as well as total steak area, *logissimus thoracis* (LT) length (medial to lateral), LT depth (dorsal-ventral), LT area, *spinalis dorsi* (SD) length (medial to lateral) from medial edge, SD depth (at deepest portion), SD area, *complexus* (C) depth, *complexus* area, and kernal fat area.

For strip loins, significant treatment x location interaction existed ($P < 0.05$) for the 75% depth, 87% depth, LL area, length, total steak area, ratio 25, ratio 50, and ratio 75 measurements. Values for strip loin measurements revealed an increase for the 75% depth, 87% depth, and LL area measurements for steaks from calf-fed Holstein cattle given beta-agonists when compared to controls, making these steaks more similar to CB steaks. When compared to controls, strip loin measurement values for steaks from calf-fed Holstein cattle that received ZH revealed lower values for the ratio 25, 50 and 75 measurements, making these steaks more similar to CB steaks. Differences ($P < 0.05$) were found for the strip loin steak location and treatment main effects for the 25, 50, and 100% depth measurements, as well as the GM area measurement. Differences ($P < 0.05$) were also found for the steak location main effect of GM depth in the strip loin steaks.

When compared to controls, strip loin measurement values for steaks from calf-fed Holstein cattle given beta-agonists revealed an increase for the 25, 50, and 100% depth measurements, making these steaks more similar to CB steaks. Values for the GM area measurement increased for steaks from calf-fed Holstein cattle given beta-agonists when compared to controls.

For short loin steaks, significant treatment x location interaction ($P < 0.05$) existed for the 25, 50, 75, and 87% depth, as well as the LL area, PM area, length, ratio 25, ratio 50, ratio 75, total steak area, and GM depth measurements. When compared to controls, short loin measurement values for steaks from calf-fed Holstein cattle given beta-agonists revealed an increase for the 25, 50, 75, and 87% depth, as well as the LL area, PM area, and total steak area measurements, making these steaks more similar to CB steaks. When compared to controls, short loin measurement values for steaks from calf-fed Holstein cattle given beta-agonists revealed a decrease for the ratio 25, 50, and 75 measurements, making these steaks more similar to CB steaks at many steak locations. For short loin steaks, differences ($P < 0.05$) were found for the steak location and treatment main effects ($P < 0.05$) for the 100% depth, PM depth, GM area, and GM length measurements. Differences ($P < 0.05$) were also found for the steak location main effect for PM length. When compared to controls, short loin measurement values for steaks from calf-fed Holstein cattle that received beta-agonists revealed an increase for the 100% depth and PM depth measurements, making these more similar to CB steaks.

For ribeye steaks, significant treatment x location interactions existed ($P < 0.05$) for the 87% depth, 100% depth, kernal fat area, LT area, SD area, C length, C depth, and C area measurements. When compared to controls, ribeye measurement values for steaks from calf-fed Holstein cattle that received beta-agonists revealed an increase for the 87% depth, 100% depth, LT area, SD area measurements making these more similar to CB steaks. For ribeye steaks, significant differences were found for the steak location and treatment main effects ($P < 0.05$) for the 25, 50, and 75% depth measurements, as well as LT depth, length, SD length, ratio 25, ratio 50, ratio 75, and total steak area measurements. For ribeye steaks, differences ($P < 0.05$) were also found for the steak location for the LT length and SD depth measurements. When compared to controls, ribeye measurement values for steaks from calf-fed Holstein cattle given beta-agonists revealed an increase for the 25 and 75% depth measurements, as well as the LT depth measurement, making these steaks more similar to CB steaks. When compared to controls, ribeye measurement values for steaks from calf-fed Holstein cattle that received ZH revealed an increase for the 50% depth, SD length and total steak area measurements, making these more similar to CB steaks. When compared to controls, ribeye measurement values for steaks from calf-fed Holstein cattle given beta-agonists revealed a decrease for the ratio 25, 50, and 75 measurements, making these more similar to CB steaks.

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CHAPTER I

INTRODUCTION

The beef industry is an $85 billion industry that strives to supply consumers with uniform, high quality products to meet consumer expectations. These products are part of over 25 billion pounds of beef produced annually from a cowherd of just fewer than 90 million head of cattle (USDA-ERS, 2014). Approximately 10% of the beef graded in commercial fed beef processing facilities in the United States is from dairy type cattle (Moore et al., 2012). Although calf-fed Holstein steers have been found to produce carcasses that have high levels of marbling (Nour et al., 1981; Nour et al., 1983; Thonney et al., 1984; Knapp et al., 1989; Perry et al., 1991), there still seems to be some price discrimination against steaks from carcasses of calf-fed Holsteins. When compared to steaks from carcasses of Angus cattle steaks from carcasses of calf-fed Holsteins were similar in sensory profiles (Ramsey et al., 1963; O'Quinn, 2012). Similar taste profiles indicate that flavor should not be a factor contributing to this discrimination. Therefore, price discrimination could be due to the conformation of the steak and its appearance in the retail package.

Carcasses from calf-fed Holsteins and other dairy type cattle have traditionally been discounted, despite a greater amount of marbling deposition (McKenna et al., 2002; Moore et al., 2012) and retail yield (Luzardo, Unpublished). These discounts reflect low consumer acceptance of the size and shape of steaks from dairy type cattle. However, Thonney et.al (1991) found that retail meat managers were unable to consistently identify ribeye steaks from carcasses of Holstein cattle and steaks from carcasses of beef breeds, the correct breed type was identified just over 50%, this indicated that there should be no discrimination against steaks from carcasses of calf-fed Holstein cattle. However, many retail stores insist that consumers would be less likely to accept steaks from calf-fed Holstein cattle, thus the continued discounting of calf-fed Holstein products.

Beta-agonists may be a mechanism to modify size and shape and overall conformation of steaks from dairy type cattle (Lawrence et al., 2011). This could be used to help with the perceived consumer discrimination against calf-fed Holstein steaks. Beta-agonist supplementation has been reported to increase hot carcass weight (HCW) and ribeye area (REA), and reduce marbling score and tenderness in beef breeds (Dikeman, 2007). Howard et al. (2014a) found that while beta-agonists improved productivity, efficiency and carcass yields for calf-fed Holstein steers, beta-agonists were detrimental to the quality of the meat.

Despite the long-standing trend of discounting beef derived from carcasses of calf-fed Holsteins, there has been some success of calf-fed Holstein beef in a retail setting. In 1989, Ralphs, a supermarket chain in southern California, began a research program to develop a superior branded beef program (Tronstad and Unterschultz, 2005). Tronstad and Unterschultz (2005) stated, Ralphs' concluded that properly-managed Holsteins would produce more consistently tender beef than their existing beef products. Sales of "California Beef", the brand under which Ralphs sold their calf-fed Holstein beef, through the first seven months of the program revealed a 3.7% increase of consumer expenditures in their stores. While other supermarkets in the area had flat to negative sales for beef during this time period (Tronstad and Unterschultz, 2005). Ralphs no longer features "California Beef", but the program's success showed that consumers were willing to purchase beef from carcasses of calf-fed Holsteins.

Calf-fed Holsteins are a major contributor to the United States beef supply consisting of approximately 10% of the graded beef (Moore et al., 2012). Although calf-fed Holsteins are a major contributor to the U.S. beef supply, calf-fed Holstein steers still pose potential problems to feedlot producers in terms of efficiency (Duff and McMurphy, 2007) and to beef processors due to muscle to bone ratio and low dressing percentage (Schaefer, 2005). Growth promotants such as hormone based implants and beta-agonists could help address these issues posed by calf-fed Holsteins. Differences exist between the commercially available implants and beta-agonists relative to their effects on beef quality and yield (Avendaño-Reyes et al., 2006; Arp, 2012). Calf-fed Holstein steers are inherently high quality (Schaefer, 2005); therefore they may be able to be treated with more aggressive growth promotants without detectable differences in sensory attributes. Even though, studies have shown that in a retail setting calf-fed Holstein steaks could not be differentiated from each other (Thonney et al., 1991), retailers still discriminate against calf-fed Holstein products, therefore these products must be drastically discounted. Many studies have shown that beta-agonists impact muscle growth and yield and preliminary research has been conducted to identify where this growth occurs, medial-laterally or dorsal-ventrally. However, there has not been a comprehensive study that has addressed the differences in growth in retail steaks for both ZH and RH supplemented cattle.

The objective of this study was to determine if differences existed between growth enhancement treatments for various dimensional measurements of different muscles within beef top loin steaks, short loin steaks, and ribeye steaks and to determine if a consumer preference exists for beef top loin steaks based on visual appearance and the conformation of the steak.

CHAPTER II

REVIEW OF LITERATURE

Calf-Fed Holstein Steers

The nation's 9.2 million dairy cows make up 24% of the cows in the U.S. cowherd. The number of dairy cows in the U.S. has remained relatively constant while beef cattle and overall cattle numbers have declined over time (NASS, 2014). Cheatham and Duff (2004) estimated there are 3 million head of Holstein bull calves available for feeding, from which beef from dairy type cattle comprises 9.9% of beef graded in commercial fed beef processing facilities in the U.S. (Moore et al., 2012). Dairy cattle are selected for the single trait of milk production; this single trait selection has led to much more homogeneous genetics within the Holstein breed. The more uniform genetics of the Holstein breed could also lead to animals that are more uniform in terms of meat yield and quality (Schaefer, 2005). Through this uniformity, calf-fed Holstein beef may provide a more consistent meat product that consumers desire.

In addition to uniformity, beef from carcasses of calf-fed Holsteins also exhibit greater amounts of marbling – on average – than conventional beef-type and *bos indicus* cattle (Nour et al., 1981; Nour et al., 1983; Thonney et al., 1984; McKenna et al., 2002; Moore et al., 2012). Higher marbling scores could lead to a more satisfying eating experience, and therefore, a greater chance of fulfilling the consumer's expectations. Issues arise when the conformation of steaks from carcasses of calf-fed Holsteins is visually evaluated, as steaks from calf-fed Holsteins are criticized for being elongated when compared to steaks from beef breeds. Rather than this being solely related to longer steaks, it could be due to the overall conformation of the steaks from carcasses of calf-fed Holsteins also being narrower with respect to dorsal-ventral measurements, compared with steaks from carcasses of conventional beef breeds. Steaks may also taper such that the steaks from carcasses of calf-fed Holsteins are overall narrower in dorsal-ventral measurements, but particularly in the tail end of the steak, so that the steak appears to taper from the medial end to lateral end.

Feedlot Performance

Calf-fed Holstein steers must be managed differently than beef breeds. A majority of calf-fed Holsteins enter the feed yard weighing less than 136 kg whereas a majority of traditional beef breeds of cattle enter the feedlot weighing between 272 and 362 kg (Duff and McMurphy, 2007). Calf-fed Holsteins are fed a growing ration upon first entering the feedlot and therefore are also fed for longer periods in the feedlot. Holsteins remain in the feedlot for a longer period of time to reach the ideal endpoint as Holsteins have a lower average daily gain when compared to beef breeds (Duff and Anderson, 2007). Holstein calves enter the feedlot at a lower initial weight due to the structure of the dairy industry. In the dairy industry bull calves that will be entering the veal or beef supply are commonly sent to calf ranches a few days after birth (Duff and Anderson, 2007). The lower initial weight of Holstein steers is a main contributor to the extended feeding period required for calf-fed Holstein steers. Holstein steers that enter the feedlot weighing less than 136 kg will remain in the feedlot for approximately 370 days while beef breeds that enter the feedlots weighing between 272 and 362 kg will remain in the feedlot for approximately 159 days (Duff and Anderson, 2007).

In a trial that evaluated feedlot performance in Holstein, Angus and Angus Simmental crosses, Perry et al. (1991) found that Holstein steers had lower average daily gain (ADG) than beef steers. When implanted and non-implanted Holstein steers were compared, the implanted steers had increased ADG (Perry et al., 1991). Scheffler et al. (2003) also found that Holstein steers that were implanted had a greater ADG than steers that were not implanted. Scheffler et al. (2003) also found that the feed to gain ratio was higher for the Holsteins steers, but that among all breeds, the implanted steers required less feed per kg of gain than non-implanted steers (Perry et al., 1991). The need to further improve efficiency and average daily gain encourages adoption of pre-harvest management strategies that use growth promotants.

Abney et al. (2007) found that feeding ractopamine hydrochloride (RH) improved feedlot performance through increased final body weight, ADG and gain-to-feed conversion. These findings were similar to those of Montgomery et al (2009) where final body weight, ADG and gain-to-feed was improved. However, this latter study (Montgomery et al., 2009) found a decrease in dry matter intake (DMI) while Abney et al. (2007) found no differences in intake patterns. In a study specific to calf-fed Holstein steers, Beckett et al. (2009) found that growth performance of dairy cattle was enhanced by revealing an improved feed-to-gain conversion in steers that were fed zilpaterol hydrochloride (ZH). In the same study, Beckett et al. (2009) also found that ADG was not improved from feeding ZH for 20 d with a 3 d withdrawal period before slaughter. In a study that evaluated both ZH and RH supplementation in beef cattle, Arp (2012) found that ADG and F:G ratios were improved for cattle that were provided beta-agonists, while final body weight was not affected. Avendaño-Reyes et al. (2006) concluded that ADG and gain-to-feed were improved in steers treated with ZH and RH compared to controls. Avendaño-Reyes et al. (2006) also found that steers given RH consume less dry matter (DM) than steers in the control group, while steers that were supplemented with ZH did not differ from the control group in terms of dry matter intake.

Carcass Performance

With the differing management practices for calf-fed Holsteins and traditional beef breeds, calf-fed Holsteins enter the feedlot a lighter weight than conventional beef breeds. This means that calf-fed Holsteins must remain in the feedlot for a longer period of time than the conventional beef breeds. This extended period in the feedlot allows calf-fed Holsteins to have higher levels of intramuscular fat, but despite this calf-fed Holsteins maintain lower levels of subcutaneous fat than beef cattle (Nour et al., 1981; Nour et al., 1983; Thonney et al., 1984; McKenna et al., 2002; Moore et al., 2012). Studies that have compared beef products from beef breeds to those from calf-fed dairy steers have found greater tenderness in the products from calf-fed dairy steers (Knapp et al., 1989; Thonney et al., 1991). These findings have been contrasted by other works, which have failed to find a difference in tenderness when beef products from calf-fed Holstein steers were compared to those from beef breeds (Ramsey et al., 1963; Armbruster et al., 1983).

As discussed in the previous section of this review, Holstein cattle have the need for hormonal implants to improve efficiency and increase gains. Use of implants may influence carcass performance. Perry et al. (1991) found no differences between breeds or between implanted and non-implanted cattle in marbling score; however, this study was conducted to reach an endpoint of a small degree of marbling evaluated by ultrasound. It is widely known that the implementation of implant programs improve ADG, feed efficiency, and protein deposition, but there was some concern about eating quality (Montgomery et al., 2009). No differences were found for sensory panel acceptability of implanted steers and non-implanted steers (Perry et al., 1991). Scheffler et al. (2003) found no differences between implanted and non-implanted for percentage of actual kidney, pelvic, and heart fat (KPH), 12^{th} rib fat, or yield grade. This was in line with the findings of Perry et al. (1991) where there were no differences between 12th rib fat thickness.

Beta-agonists have a major impact on carcass characteristics in terms of both lean yield and meat quality. Many studies have evaluated effects of ZH and RH on lean meat yield and meat quality. In a study utilizing RH, Abney et al. (2007) found that hot carcass weight (HCW) was increased as the dosage increased in feedlot cattle that were treated with RH. Montgomery et al. (2009) discovered that, for both steers and heifers fed ZH, HCW, dressing percentage, and LM area increased. Feeding ZH improved calculated yield grade for both steers and heifers but marbling scores and quality grade were decreased (Montgomery et al., 2009), no differences were found in 12th rib fat thickness and KPH. In a study that evaluated both ZH and RH supplementation in beef cattle, Arp (2012) found increases in HCW and percentage of yield grade 1 carcasses for cattle that were fed RH and those that were fed ZH. Cattle receiving ZH had the largest LM area and the highest dressing percentage Marbling and frequency of cattle grading U.S. Choice decreased for both beta-agonist treatments (Arp, 2012). Avendaño-Reyes et al. (2006) concluded that both RH and ZH treated beef cattle saw an increase in HCW and an improvement in carcass yield. The LM area was increased in steers that were given ZH but steers that were supplemented with RH were similar to the control group measurements, color measurements did not differ between beta-agonist supplemented cattle and the control group (Avendaño-Reyes et al., 2006).

Carcass yield can be greatly affected by supplementation with beta-agonists. Hilton et al. (2010) found that the weights of all major subprimals were increased with supplementation of ZH when compared to controls. Increased weight of subprimals also increased percentages of cold carcass weight for the tenderloin, strip loin and top sirloin butt (Hilton et al., 2010). The tenderloin increased by 0.06 %, the strip loin increased by 0.08 % and the top sirloin butt saw the greatest increase with 0.11 % (Hilton et al., 2010). Total saleable carcass yields increased by 1.76 % when ZH was supplemented; fat trim and bone also decreased by 0.58 and 1.10 % respectively (Hilton et al., 2010).

Calf-fed Holsteins tend to have a lower muscle to bone ratio (M:B) than conventional beef-type cattle and steaks from calf-fed Holsteins have poor conformation because of this lighter muscling, so supplementing calf-fed Holsteins with beta-agonists could make calf-fed Holstein products more similar to conventional beef products. Beckett et al. (2009) found that feeding ZH to calf-fed Holsteins for 20 d increased HCW up to 11.6 kg and also increased dressing percentage. However, the percentage of carcasses grading U.S. Choice was reduced in cattle that were fed ZH (Beckett et al., 2009); this study found no difference in the skeletal maturity score, liver integrity, lean color, fat thickness and KPH.

Garmyn et al. (2010) found that calf-fed Holstein steers that had been supplemented with ZH had increased saleable yield. The subprimal yield also increased in the shoulder clod, strip loin, peeled tenderloin, top sirloin butt, bottom sirloin tri-tip, peeled knuckle, inside round, bottom round flat, eye of round, heel and shank (Garmyn, et al., 2010). Results of decreased fat trim and bone percentage from Garmyn et al. (2010) were in agreement with results of Hilton et al. (2010). Howard et al. (2014a) found that calf-fed Holstein steers fed beta-agonists generated increased saleable yields of whole muscle cuts compared to controls. These increases were by 0.61% for RH 300, 0.86% RH 400, and 1.95% for ZH (Howard et al., 2014a). Howard et al. (2014a) also found that percent fat and bone decreased in steers supplemented with ZH; however, there were no differences observed between the RH groups and controls. Trimmings, expressed as a percentage of chilled carcass side weight, did not differ between the treatments

(Howard et al., 2014a). Howard et al. found that while the saleable yield increased for whole muscle cuts, certain cuts that showed a larger impact from ZH supplementation; cattle supplemented with beta-agonists exhibited a shift of salable yield within individual primals, with a greater proportion of yield increase in cuts from the hindquarter.

All of these studies have indicated some form of growth enhancement through feedlot performance as well as carcass performance; however, there has been a limited amount of research conducted on how these differences impact the shape of the muscles. Lawrence et al. (2011) conducted a study on the conformation of strip loins steaks from calf-fed Holsteins supplemented with ZH. The purpose of this particular study was to evaluate the steaks and determine if the growth was more medial-lateral or more dorsal-ventral in nature. Lawrence et al. (2011) found that there were increases in LM area, total muscle area, and depths (dorsal-ventral) measured at 25% and 50% of the length of the steak. Lawrence et al. (2011) failed to find differences in the length (medial-lateral), 75% depth or the GM area measurements.

Tenderness also may be impacted by beta-agonist supplementation. Arp (2012) found that WBSF and SSF values were increased by feeding ZH and RH, resulting in a greater percentage of steaks shearing over 4 kg (WBSF) and 20 kg (SSF). Arp (2012) also reported that trained sensory panelists detected a reduction in tenderness due to beta-agonist treatment; however, the trained sensory panel was unable to find differences in juiciness or beef flavor attributes. Avendaño-Reyes et al. (2006) reported that steaks from both RH and ZH supplemented steers had higher shear force values, for both WBSF and SSF, when compared with steaks from control steers. In a report by Garmyn et al. (2010), shear force values for the LM and inside round steaks were increased by supplementation of ZH. Trained panelists classified the LM steaks from beta-agonist treated animals as slightly to moderately tender, but

WBSF values for the same steaks indicated a classification of intermediately tender (Garmyn et al., 2010). Howard et al. (2014b) found that beta-agonist supplementation increased shear force values by 12-25% in steaks aged 14 d and 9-21% in steaks aged 21 d.

Retail

Even though calf-fed Holstein steaks and steaks from Angus cattle have been found to have similar taste profiles (Ramsey et al., 1963; O'Quinn, 2012) Holstein cuts have traditionally been discounted and are still discounted at a wholesale level to retailers. Retailers believe that consumers will not purchase products from calf-fed Holsteins due to the retail cut shape or the appearance of the steak (Thonney et al., 1991). Thonney et al. (1991) conducted a study to determine the validity of this claim and compared ribeye steaks from calf-fed Holsteins and beef breeds of cattle. That study concluded that retail meat managers were only able to identify the correct breed type when visually appraising steaks approximately 51% of the time, which was no different from being random. Sweeter et al. (2005) found that there was no difference in consumer preference for ribeye steaks that were from carcasses with extremely small to extremely large LM areas (61 to 119 cm^2) at the 12^{th} and 13^{th} rib.

Calf-fed Holstein beef has had some success of in a retail setting as evidenced by Ralphs' "California Beef". In 1989, Ralphs, a supermarket operator in southern California, began a research program to develop a superior branded beef program (Tronstad and Unterschultz, 2005). Tronstad and Unterschultz stated Ralphs' research, showed that properly-managed Holsteins would produce more consistently tender beef than their existing beef products. Sales of "California Beef", the brand that Ralphs sold their calf-fed Holstein beef under, through the first seven months of the program revealed a 3.7% increase of consumer expenditures in their stores. While other supermarkets in the area had flat to negative sales for beef (Tronstad and

Unterschultz, 2005). Ralphs no longer features "California Beef" but the program's success shows that consumers would be willing to purchase a calf-fed Holstein product.

There have been many studies that evaluate consumer preference and willingness to pay for beef strip loin steaks. In a study evaluating both marbling level and steak color Killinger et al. (2004) found that consumers were more likely to prefer bright, cherry-red colored steaks when compared to dark red steaks. However, it should be noted that even though there were statistical differences between the colors, the dark red steaks were preferred by 23.5-32.4% of the consumers in the study (Killinger et al., 2004). This same study showed that consumers preferred steaks lower marbling levels 67-86.7% of the time (Killinger et al., 2004). In contrast to Killinger et al. (2004), Platter et al. (2005) found that consumer would be were more willing to pay for steaks with higher marbling that were evaluated for sensory attributes. This higher willingness to pay was evidenced by steaks in the premium choice and prime categories receiving a lower percentage of bids that were zero (Platter et al., 2005). These studies reveal that there are differences in consumer preferences when marbling and color are evaluated, therefore it is very important to minimize the differences in these attributes when possible.

Summary

Calf-fed Holsteins are a major contributor to the United States beef supply consisting of approximately 10% of beef graded in fed beef processing facilities (Moore et al., 2012). Although calf-fed Holsteins are a major contributor to the U.S. beef supply, calf-fed Holstein steers still pose potential problems to feedlot producers in terms of efficiency (Duff and McMurphy, 2007) and to beef processors due to muscle to bone ratio and low dressing percentage (Schaefer, 2005). Growth promotants such as hormone based implants and beta-agonists could help address these issues posed by calf-fed Holsteins. Differences exist between the commercially available implants and beta-agonists relative to their effects on beef quality and yield (Avendaño-Reyes et al., 2006; Arp, 2012). Beef from carcasses of calf-fed Holstein steers are inherently high quality (Schaefer, 2005); therefore, they may be able to be treated with more aggressive growth promotants without detrimental effects on fresh meat quality characteristics or sensory attributes. Even though, studies have shown that retail steaks from carcasses of calf-fed Holstein steers could not be differentiated from steaks from carcasses of beef type cattle (Thonney et al., 1991), retailers still discriminate against calf-fed Holstein products. Therefore, these products must be drastically discounted. Many studies have shown that beta-agonists impact muscle growth and yield and preliminary research has been conducted to identify where this growth occurs, medial-laterally or dorsal-ventrally. However, there has not been a comprehensive study that has addressed the differences in growth in retail steaks for both ZH and RH supplemented cattle.

CHAPTER III

INTRODUCTION

In the United States beef is an $85 billion industry that strives to produce uniform, high quality products (USDA-ERS, 2014). These products are part of over 25 billion pounds of beef produced annually from a herd of just fewer than 90 million head (USDA-ERS, 2014). According to the National Beef Quality Audit, approximately 10 % of the cattle graded in commercial fed beef processing facilities in the United States are calf-fed Holstein (Moore et al., 2012). Even though calf-fed Holstein steers have been found to produce carcasses that have high levels of marbling (Nour et al., 1981; Nour et al., 1983; Thonney et al., 1984; Knapp et al., 1989; Perry et al., 1991) and steaks that have similar sensory attributes to those produced by Angus cattle (Ramsey et al., 1963; O'Quinn, 2012); strip loin and ribeye steaks are commonly sold at a discounted price, due to conformational differences, in comparison to conventional beef. Therefore, this discrimination seems to be due to the shape of the steak and its appearance in the retail package.

Carcasses from calf-fed Holsteins have traditionally been discounted because of M:B ratio, despite a greater amount of marbling deposition (McKenna et al., 2002; Moore et al., 2012) and retail yield (Luzardo, Unpublished). At retail, Holstein steaks are discounted due to non-conformation of shape; these discounts seems to be due in part to low consumer acceptance of the size and shape of top loin steaks from dairy type cattle. Supplementation with beta-agonists could be used as a mechanism to modify size, shape and therefore overall conformation of steaks from dairy type cattle (Lawrence et al., 2011). There has been some success of calf-fed Holstein beef in retail as evidenced by Ralphs' "California Beef" program. In 1989, Ralphs, a supermarket operator in southern California, began a research program to develop a superior branded beef program (Tronstad and Unterschultz, 2005). Tronstad and Unterschultz stated Ralphs' research, showed that properly-managed Holsteins would produce beef products that were more consistently tender than their existing beef products. During the first seven months of the program, sales of "California Beef", the brand under which Ralphs marketed their calf-fed Holstein beef, resulted in a 3.7% increase of consumer expenditures in their stores. While other supermarkets in the area had flat to negative sales for beef during the same period (Tronstad and Unterschultz, 2005). Ralphs supermarkets no longer feature "California Beef" but the program's success showed that consumers would be willing to purchase a calf-fed Holstein product.

The objectives of this study was to determine if differences existed between treatments for dimensional measurements of muscles within beef top loin, short loin, and ribeye steaks and to determine if a consumer preference exists for beef top loin steaks based on visual appearance focusing on the conformation of the steak.

MATERIALS AND METHODS

Two experiments were conducted to address the objective of this study. Experiment 1 was conducted to determine the effects of beta-agonist treatment, ractopamine hydrochloride (RH) and zilpaterol hydrochloride (ZH), on the conformation of steaks from the ribeye, strip loin and short loin. Experiment 2 was an online survey conducted to better understand consumer preference of steak shape.

Treatment and Sample Preparation

Beef subprimals were obtained from a study (Howard et al., 2014a; Howard et al., 2014b) that evaluated the subprimal cutout value for carcasses of calf-fed Holstein steers, these steers were fed as described by Howard et al. (2014a, 2014b). A second study was conducted on the retail cut out value of the subprimals from the initial study. The steaks from the retail cut out study were the steaks used for this study.

Beef rib, ribeye (ribeye, lip-on; IMPS 112A), beef loin, short loin (short loin; IMPS 174), and beef loin, strip loin, boneless (strip loin IMPS 180) were selected by Colorado State University (CSU) personnel. The product was then kept in the facility until being processed into retail cuts by CSU personnel. Steers for the cutout study were implanted with a progesterone (100mg) plus estradiol benzoate (10 mg) combination implant (Synovex®-C; Zoetis, Florham Park, NJ). These steers were then re-implanted with a terminal trenbolone acetate (200 mg) plus estradiol implant (40 mg; Revalor®-XS; Merck Animal Health, Summit, NJ). The steers were then either received no beta-agonists (control), ractopamine hydrochloride (RH) at 300 mg or 400 mg /steer/day for the last 31 d of finishing, or zilpaterol hydrochloride (ZH) fed at 60 to 90 mg/steer/day for 21 d with a 5 d withdrawal period. Full treatment descriptions are described by Howard et al. (2014a, 2014b). An additional treatment was included in the present study, conventional beef-type cattle (CB), the subprimals for this treatment were obtained via boxed beef from a plant located in central Nebraska and a plant located in the panhandle of Texas.

Each fresh subprimal was fabricated into 2.54 cm thick steaks using a band saw. External fat of each steak was trimmed to 0.3175 cm. Weights on each individual steak were obtained as part of the retail study. Steaks were placed on a gridded background, to allow for the measurement of steak dimensions, (EZ Quilting®, Plastic Gridded Template) and digitally imaged using a digital camera with a fixed zoom lens (Nikon^{TM} D90 camera, AF-S Micro Nikkor 60mm f/2.8G ED lens). The anterior surface of steaks was imaged from directly above using a multi-angle center column tripod (Manfrotto^{TM} 190XPROB) extended to the same height each day. This tripod allowed for the camera to be placed parallel to the surface upon which the steaks were placed. Images were obtained from every steak of each subprimal from the retail study. Steaks are numbered from anterior to posterior within the subprimal.

Image Analysis

Steak dimensions were measured using image analysis software ImageJ 1.46r (National Institutes of Health, Bethesda, MD). ImageJ recorded the measurements as pixels. The pixels were converted into inches based on an average pixels/inch for each day that the steaks were imaged. The pixels were converted into inches because the gridded background units were inches; the measurements were then converted into cm for analysis. Measurements were obtained on a total of 142 strip loins; of the 142 strip loins there were 80 CB, 20 ZH, 20 RH and 22 control strip loins. Measurements were obtained on a total of 116 short loins; of the 116 short loins there were 60 CB, 18 ZH, 18 RH, and 20 control short loins. Measurements were obtained on a total of 119 ribeyes; of the 119 ribeyes there were 60 CB, 19 ZH, 20 RH and 20 control ribeyes. The strip loin images had 7 or 10 measurements depending on GM presence. Steaks that did not contain a *gluteus medius* (GM) had 7 measurements, whereas steaks that possessed a GM had 10 measurements. These measurements included: the length of the steak (medial to lateral), the depth (dorsal to ventral) at 25, 50, 75, 87.5, and 100% of the length, as well as, area of the *longissimus lumborum* (LL). Additional measurements for the steaks that contained the GM were GM length (medial to lateral), GM depth (dorsal to ventral), GM area, and total steak area (area of the LL and area of GM). Percentages of length used to standardize depth measurements were measured from the medial edge of the *longissimus lumborum*. Measurements for short loins were identical to measurements for strip loins with the addition of length (medial to lateral), depth (dorsal to ventral), and area measurements for the *psoas major* (PM). Measurements obtained for ribeye steaks were: length (medial to lateral), depth (dorsal to ventral) at 25, 50, 75, 87.5, and 100% of the length of the entire steak (muscles included: *longissimus thoracis, spinalis dorsi*, and *complexus*) as well as, area, *longissimus thoracis* (LT) length (medial to lateral), LT depth (dorsal to ventral), LT area, *spinalis dorsi* (SD) length (medial to lateral) from medial edge (measured from a line perpendicular to the medial edge of the SD to the lateral end of the SD), SD depth measured at the deepest portion of the SD, SD area, *complexus* (C) length (medial to lateral), C depth (dorsal to ventral), C area, and kernel fat area. For the statistical analysis, ratios were created by dividing the 25, 50 and 75% steak depths by the length of the steak.

Survey Steak Selection

An online consumer survey was developed to better understand consumer preferences for conformation attributes of the steaks. Two rounds of surveys were conducted. The first round consisted of 2 surveys with approximately 225 (N = 458) panelists each and the second round of surveys consisted of 3 surveys with approximately 50 (N = 152) panelist each, for a total of 610 panelists. Each survey consisted of 8 steak images. For the first round of surveys, 6 steaks in each survey did not possess the GM and 2 steaks possessed the GM. The second round of surveys, steaks that possessed a GM were excluded because it was concluded from the first round of surveys that the consumers did not prefer the steaks that contained a GM. This was evidenced by GM steaks consistently being ranked at or near the bottom for the first round of surveys.

To select steaks for inclusion in each survey, steaks were sorted in to quadrants using the ratio of the depth at 75% of the length (75% depth/length). For each survey, 2 steaks were selected from each quadrant for equal representation within the survey. For the selection of these steaks, steaks with similar color and intramuscular fat were chosen for the same survey to reduce variation. Other factors that were considered when choosing steaks were the texture of the meat & fat trim level. Even though the steaks were selected based on these criteria, there were still differences that existed between steaks within the same survey.

To reproduce how consumers would normally view beef in a retail setting the gridded background was removed from the images and the steaks were then placed on an image of a black Styrofoam tray commonly used in retail settings. This tray remained a constant size to maintain the scale of steaks. To even further reduce the variation, the steaks were then subjected to color equalization and individual steaks were identified for specific edits that were needed (texture correction, fat correction). Images included in the surveys were sent to Colorado State University Photography Creative Services for editing, all edits were made using Adobe Photoshop.

Survey Development

Survey Crafter Professional 4.0.14 (Survey Crafter, Inc., Acton, MA) was used to develop the surveys. Surveys were distributed online through a membership driven organization that specializes in surveys; this organization has its members answer basic demographic questions to ensure panelists meet the criteria to participate in the survey. Before accessing the survey, panelists were asked if they consumed beef and if they were the primary shopper in their household. If the panelist failed to meet the criteria of these 2 qualifying questions the individual would be disqualified from participating. If no was answered to either question the panelist was then redirected to a disqualification page and were not able to complete the survey. All of the panelists that were qualified were then asked a series of demographic questions including gender, household size, marital status, age, ethnic origin, annual household income, education level, and how many times per week beef was consumed.

Best-worst (B/W) scaling component of the surveys was designed to rank steaks for consumer preference based on visual appearance. As described by Louviere and Islam (2008), an orthogonal fraction of 2^8 was used to create 9 sets of comparisons; this was based on a 2^k design to construct sets for comparisons (k = number of steaks). Best-worst scaling insured that each steak was presented an equal number of times within each survey. Best/Worst scaling allows the steaks to be ranked in an objective manner by the panelist. The steaks were shown 4 at a time and the panelist was then asked to choose the most desirable steak and the least desirable steak, based on visual appraisal. The panelists were asked to identify the most and least desirable steak of a group of 4 steaks in the first 8 comparisons The last comparison required panelists to identify the most and least desirable of all 8 eight steaks in the survey. Survey Crafter Professional tracked the panelist's answers and tallied the ranking before proceeding to the next set of questions. According to Louviere and Islam (2008) each attribute may be treated as having 2 levels (presence/absence). For the current study, this was used to determine a steak ranking by assigning +1 for the most desirable steak and -1 for the least desirable steak. The steak with the lowest total was the least desirable steak and the steak with the highest total was the most desirable steak for that panelist. By using B/W scaling to rank the steaks, the likelihood of bias occurring was substantially reduced compared to protocols that used a rating scale (Cohen and Neira, 2003).

After the ranking had been determined, the panelist was then asked if a discount was required on the 4 steaks that had been ranked the lowest. If the panelist required a discount to purchase the steaks, the panelist would then be asked if they would purchase the highest ranking steak that they indicated a discount would be required to purchase at a randomly generated discount percentage between 10% and 20%. If the panelist answered yes to the randomly generated discount they would be asked a randomly generated discount that was lower than the original discount. If the panelist answered no to the first randomly generated discount, they would be asked another randomly generated discount that was higher than the first. The second discount question had a range of 5% to 25%. Panelists were asked a final question in which they had to rank what they considered most important when purchasing steaks. Attributes considered for this ranking included: brand name of the product, breed of the animal, marbling level, nutrient content, taste/eating experience, USDA grade of the product, visual appearance, where and how the animal was raised, whether or not the animal received growth promotants and/or antibiotics, or if the animal was raised exclusively on pasture or fed grain in a feedlot for a period of time. Panelists were asked to rank these attributes 1-10, with1 being the most important and 10 being the least important.

Statistical Methods

All statistical analyses were conducted using statistical procedures of SAS 9.3 (SAS Inst. Inc., Cary, NC). Interactions and main effects for treatment means were analyzed using the MIXED procedure, with the fixed effects of treatment and steak location as well as the random effect of ID (subprimal ID). Least squares means were calculated for each measurement across treatments and steak locations, with differences defined at $\alpha = 0.05$. PROC OPTEX was used to determine the comparisons for the B/W scaling. Pearson's correlation coefficients were calculated to show relationships between average rank and the measurements using the CORR procedure.

RESULTS AND DISCUSSION

Regardless of beta-agonist treatment or production system steaks from CB cattle had greater measurement values for many of the measurements, with the exception of the ratio and length measurements, where lower values were more desirable. The steaks from CB cattle revealed greater or more desirable measurements throughout the different subprimal cuts.

Strip Loin

Significant differences were found for the main effect of steak location ($P < 0.05$) for the 25%, 50%, and 100% depth measurements, as well as GM depth, and GM area measurements. Least squares means for the main effect of steak location are displayed in Table 10. Least squares means for GM measurements for the main effect of steak location are displayed in Table 11. For the 25% depth measurement ($P = < 0.0001$), increases in measurement depth were observed from steak 1 to 4 and decreased from steak 4 to 10, the measurement values leveled out at steak locations 9 to 12. Strip loin 50% depth measurement ($P = < 0.0001$) values decreased from steaks 1 to 9 and increased from steak 10 to 12. Strip loin 100% measurement ($P = < 0.0001$) values revealed no differences between steak locations 1 and 2; values increased from steaks 2 to 4 and from steak 4-12 the measurements decreased. For both the GM Depth ($P = < 0.0001$) and GM Area ($P = < 0.0001$) measurements the values increased from steak 9 to12.

Significant differences were also found between the main effect of treatment ($P < 0.05$) for the 25%, 50%, and 100% depth measurements, as well as the GM Area measurement. Least squares means for the main effect of treatment are displayed in Table 12. For the 25% depth measurement (P = < 0.0001) the CB treatment was greater (P < 0.05) than all treatments. Measurements from the ZH treatment were greater (P < 0.05) than the remaining calf-fed Holstein treatments, which statistically did not differ. Measurement values for the 50% depth measurement (P = < 0.0001) revealed the treatment CB was greater (P < 0.05) than all other treatments. The remaining treatments did not differ (P > 0.05) from each other for the 50% depth measurement. For the 100% depth measurement (P = < 0.0001) CB and ZH treatments did not differ (P > 0.05). The ZH treatment also did not differ (P > 0.05) from the RH treatment for the 100% depth measurement. The RH treatment did not differ (P > 0.05) from controls for the 100% depth measurement. For the GM Area measurement (P = 0.0308) ZH has the highest numerical value but did not differ (P > 0.05) from RH and Control. The RH, Control, and CB treatments also did not differ from each other. Strip loins from steers that received some growth promotant, control included, revealed a greater GM Area, with ZH being the largest increase.

For strip loins, significant treatment x steak location interaction existed (P < 0.05) for the 75%, 87% depth, LL area, length, total steak area, ratio 25, ratio 50, and ratio 75 measurements. Least squares means for strip loin treatment x steak location interaction (P = <0.0001) for the LL area measurement are presented in Table 3. Values for the LL area for the CB treatment were always numerically higher but only differed (P < 0.05) from the ZH treatment in the posterior portion of the strip loin at steak locations 9 to 12. The ZH and RH treatments did not differ (P < 0.05) at any steak location; RH also did not differ (P < 0.05) from controls at any steak location. In comparison with results of this study Lawrence et al. (2011) found a 5.5 cm^2 increase in area of LL muscle in animals that were treated with ZH for 20 d over those that did not receive ZH.

Least squares means for strip loin treatment x steak location interaction (P = 0.0043) for the 75% depth measurement are presented in Table 1. The 75% depth measurement values for steaks from ZH supplemented cattle did not statistically differ from the other calf-fed Holstein treatments at many steak locations. However, the values for the ZH treatment were numerically higher than the other treatments, making it more similar to the CB measurement values for the 75% depth measurement. In comparison to results from this study Lawrence et al. (2011) found no differences between calf-fed Holsteins that received ZH for 0 d or 20 d at the maximum dorsal-ventral depth of LL at 75% length of LL from the midline. Least squares means for strip loin treatment x steak location interaction (P = <0.0001) for the 87.5% depth measurement are presented in Table 2. The 87.5% depth measurement values for steaks from ZH supplemented cattle did not statistically differ from values from steaks of RH supplemented cattle at any steak location, RH measurements also did not differ ($P < 0.05$) from controls at any steak location. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the 87.5% measurement. Least squares means for strip loin treatment x steak location interaction (P = 0.0305) for the length measurement are presented in Table 4. The length measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at any steak location. Length measurement values for calf-fed Holstein treatments were statistically greater than CB in the posterior portion of the strip loin and were numerically higher at all steaks locations. Results from Lawrence et al. (2011) found no differences in maximum medial-lateral width of LL.

Least squares means for strip loin treatment x steak location interaction (P = <0.0001) for the ratio 25 measurement are presented in Table 5. Ratio 25 measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at a majority of steak locations. However, the values for the ZH treatment were numerically lower than the other calf-fed

Holstein treatments, making it more similar to the CB measurement values for the ratio 25 measurement. Least squares means for strip loin treatment x steak location interaction (*P* = <0.0001) for the ratio 50 measurement are presented in Table 6. Ratio 50 measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at a majority of steak locations. However, the values for the ZH treatment were numerically lower than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the ratio 50 measurement. Least squares means for strip loin treatment x steak location interaction (*P* = <0.0001) for the ratio 75 measurement are presented in Table 7. The ratio 75 measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at a majority of steak locations. However, the values for the ZH treatment were numerically lower than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the ratio 75 measurement.

Least squares means for strip loin treatment x steak location interaction (*P* = 0.0262) for the total area measurement are presented in Table 8. The total area measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at 3 out of the 4 steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments. Least squares means for strip loin treatment x steak location interaction (*P* = 0.0322) for the GM length measurement are presented in Table 9. The GM length measurement values for steaks from calf-fed Holstein steers did not statistically differ from each other at any steak location. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, distancing it from CB measurements for the GM length measurement.

Short Loin

Differences were found for the main effect of steak location ($P < 0.05$) for the 100% depth, PM depth, GM area and GM length measurements. Least squares means for the short loin main effect of steak location are presented in Table 25. Least squares means for the short loin GM measurements main effect of steak location are presented in Table 26. The 100% measurement ($P = < 0.0001$) revealed an overall increase from 1to 4. The 100% measurement plateaued from steak locations 4 to 6 then decreased to steak 10, the measurement values leveled out from steak location 10 to 14. For the PM Depth measurement ($P = < 0.0001$) values increased from steak 1 to 12 and plateaued at steak locations 12 to 14. The PM Length measurement ($P = < 0.0001$) values increases from steak 1 to 8, the measurement values plateaued at steak locations 8 to 14. The GM Area and GM Length measurements ($P = <0.0001$) both revealed increased measurement values from steak locations 11 to 14.

Significant differences ($P < 0.05$) were also found for the main effect of treatment for the 100% depth, GM Length, and PM Depth measurements. Least squares means for the short loin main effect of treatment are presented in Table 27. For the 100% measurement ($P = < 0.0001$) CB did not differ ($P > 0.05$) from ZH, ZH also did not differ from RH or Control. GM Length measurement (P=0.0205) values revealed that the ZH treatment did not differ ($P > 0.05$) from the other calf-fed Holstein treatments and was greater than the CB treatment; CB measurement values also did not differ ($P > 0.05$) from RH and controls for the GM length measurement. The PM Depth measurement (P=0.0153) revealed that CB did not differ ($P > 0.05$) from RH and ZH and that calf-fed Holstein treatments did not differ ($P > 0.05$) from one another.

Least squares means for short loin treatment x steak location interaction ($P = <0.0001$) for the length measurement are presented in Table 19. The length measurement values for all treatments, including CB, did not differ (*P* > 0.05) from each other a majority of steak locations, with the only differences occurring in the posterior portion of the short loin. Least squares means for short loin treatment x steak location interaction (*P* =0.0091) for the total area measurement are presented in Table 23. The total area measurement values for all treatments, including CB, did not differ (*P* > 0.05) from each other at 2 out of the 4 steak locations. The total area measurement values for ZH were the greatest at all 4 steak locations, values for all of the treatments did not differ (*P* > 0.05) Least squares means for short loin treatment x steak location interaction (*P* =0.0280) for the GM depth measurement are presented in Table 24. Least squares means for short loin treatment x steak location interaction (*P* = <0.0001) for the PM area measurement are presented in Table 18. The PM area measurement values for the beta-agonist treatments and CB measurements did not differ (*P* > 0.05) from each other at a majority of steak locations. Short loin PM area measurements for the control group were significantly lower at many of the steak locations.

Least squares means for short loin treatment x steak location interaction (*P* = <0.0001) for the LL area measurement are presented in Table 17. The LL area measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the short loin LL area measurement. The LL area measurement is one of the measurements where the separation of CB and the calf-fed Holstein treatments is very apparent, CB measurements range from 9.96 – 22.18 cm greater than the next closest measurement.

Least squares means for short loin treatment x steak location interaction (*P* = 0.0290) for the 25% depth measurement are presented in Table 13. The 25% depth measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the short loin 25% depth measurement. Least squares means for short loin treatment x steak location interaction (*P* = 0.0005) for the 50% depth measurement are presented in Table 14. The 50% depth measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments in the posterior portion of the short loins, making it more similar to the CB measurement values for the short loin 50% depth measurement. Least squares means for short loin treatment x steak location interaction (*P* = 0.0057) for the 75% depth measurement are presented in Table 15. The 75% depth measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the short loin 75% depth measurement. Least squares means for short loin treatment x steak location interaction (*P* = <0.0001) for the 87.5% depth measurement are presented in Table 16. The 87.5% depth measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment were numerically higher than the other calf-fed Holstein treatments at a majority of steak locations, making it more similar to the CB measurement values for the short loin 87.5% depth measurement.

Least squares means for short loin treatment x steak location interaction (*P* = <0.0001) for the ratio 25 measurement are presented in Table 20. Least squares means for short loin treatment x steak location interaction (P = <0.0001) for the ratio 50 measurement are presented in Table 21. Least squares means for short loin treatment x steak location interaction (P = <0.0001) for the ratio 75 measurement are presented in Table 22. The ratio 25, 50 and 75 measurements, values for the calf-fed Holstein treatments did not differ ($P > 0.05$) from each other at a majority of steak locations. However, the values for the ZH treatment were numerically higher than the other calf-fed Holstein treatments at a majority of steak locations, making it more similar to the CB measurement values for the short loin ratio 25 measurement.

Ribeye

Differences ($P < 0.05$) were found between the steak locations for the 25, 50, and 75% depth, as well as LT depth, overall Length, SD length, ratio 25, ratio 50, ratio 75, and Total Area measurements. Least squares means for the steak location main effect are presented in Tables 36. The 25% measurement (P = < 0.0001) revealed an increase from steak 1 to steak 4; the measurement plateaued until steak 12 and decrease from steaks 12 to steak 16. For the 50% measurement (P = < 0.0001) an increase was observed from steak 1 to steak 4, the values decreased from steak 4 to steak 16. The ribeye 75% depth measurement (P = < 0.0001) had an increase from steak 1 to 8, where the values then decrease to steak 12, values increased from steak location 12 to 13, plateaued from 13 to 15 and decreased from 15 to 16. Ribeye LT Depth measurement (P = < 0.0001) values revealed an increase from steak locations 1 to 3, measurements plateaued from steak locations 3 to 5, from steak locations 5 to 8 values decreased. Ribeye LT depth measurement values also revealed an increase from steak locations 8 to 15 and from there decreased to steak 16. Ribeye LT Length measurement (P = < 0.0001) values revealed an increase from steak location 1 to 16. Ribeye length measurement (P = < 0.0001) was another measurement that was sporadic. Ribeye length values revealed an increase from steak 1 to 3 where the measurements declined from steak location 3 to 6. Ribeye length measurements also revealed an increase from steak locations 6 to 10, from steak location 10 to 15 values plateaued, from steak 15 to 16 values decreased. The SD Depth measurement (P = < 0.0001) revealed a decrease from steaks 1-16. The SD Length measurement (P = < 0.0001) values increased from steak location 1 to steak location 8 and then decreased from steak locations 8 to 16. The total area measurement (P = < 0.0001) values revealed an increase from steak 1 to steak 8 where values plateaued to steak location 12 and decreased from steak location 12 to steak location 16. Ratio 25 measurement (P = < 0.0001) values revealed a decrease from steaks 1 to 7; values plateaued from steak location 7 to 12 and increased from steak 12 to steak 16. Ratio 50 measurement (P = < 0.0001) values revealed a decrease from steak location 1 to 4, values leveled out from steaks 4 to 7 and increased from steak locations 7 to 16. Ratio 75 measurement (P = < 0.0001) values were level from steak location 1 to 4, values decreased from steak location 4 to 7. Ratio 75 measurement values also revealed an increase from steak 7 to 12, values decreased from steak 12 to 13 and leveled out from steak location 13 to 16.

Differences ($P < 0.05$) were also found between the treatments for the 25% Depth, 50% Depth, 75% Depth, LT Depth, Overall Length, SD Length, Ratio 25, and Total Area measurements. Least squares means for the treatment main effect are presented in Table 37. At the 25% measurement (P = < 0.0001) the CB treatment was greater than all other treatments, while the beta-agonist treatments did not differ ($P > 0.05$). Control also did not differ ($P > 0.05$) from the RH treatment. Ribeye 50% depth measurement (P = < 0.0001) revealed the CB treatment was greater ($P > 0.05$) than all other treatments and ZH was also different ($P > 0.05$) from all other treatments. The RH and Control treatments did not differ ($P > 0.05$). Ribeye 75% depth measurement (P = < 0.0001) revealed measurements for the CB treatment were greater (P

> 0.05) than all other treatments; the beta-agonist treatments were not different ($P > 0.05$) from each other and RH did not differ ($P > 0.05$) from controls. For the LT Depth measurement ($P = < 0.0001$) revealed measurements for the CB treatment were greater ($P > 0.05$) than all other treatments; the beta-agonist treatments were not different ($P > 0.05$) from each other and RH did not differ ($P > 0.05$) from controls. For the length measurement ($P = < 0.0001$) CB was not different ($P > 0.05$) from the ZH treatment, ZH was also did not differ ($P > 0.05$) from RH. The RH treatment was not different ($P > 0.05$) from the Control. Ribeye ratio 25 measurement (P=0.0353) revealed Control was the treatment that had the highest ratio value, and the Control group did not differ ($P > 0.05$) from the beta-agonist treatments. The CB treatment had the lowest value for ratio 25; the CB treatment did not differ ($P > 0.05$) from beta-agonist treatments. Ribeye ratio 50 measurement ($P = < 0.0001$) revealed Control was the treatment that had the highest ratio value and the Control group did not differ ($P > 0.05$) from the RH treatment. Beta-agonist treatments did not differ ($P > 0.05$) from each other and CB values differed ($P < 0.05$) from all other treatments for the ribeye ratio 50 measurement. Ribeye ratio 75 measurement ($P = < 0.0001$) revealed Control was the treatment that had the highest ratio value, and the Control group did not differ ($P > 0.05$) from the beta-agonist treatments. Ribeye ratio 75 values for CB were lower ($P < 0.05$) than all other treatments. Ribeye SD length measurement (P=0.0088) revealed the CB treatment was the treatment that exhibited the longest measurement. The CB treatment did not differ ($P > 0.05$) from the ZH treated steers; the ZH treatment also did not differ ($P > 0.05$) from the RH and Control treatments for the SD length measurement. Ribeye total area measurement ($P = < 0.0001$) revealed the CB treatment had the greatest total area and was greater ($P < 0.05$) than all other treatments. The ZH treatment had the next greatest Total

Area and was significantly different (*P* < 0.05) from all other treatments. The RH, and Control treatments did not differ (*P* > 0.05) for the ribeye total area measurement.

Least squares means for ribeye treatment x steak location interaction (*P* = 0.0004) for the ribeye 87% depth measurement are presented in Table 28. Ribeye 87% depth measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment were numerically higher than the other calf-fed Holstein treatments at every steak location, making it more similar to the CB measurement values for the ribeye 87% depth measurement. Least squares means for ribeye treatment x steak location interaction (*P* = 0.0377) for the ribeye 100% depth measurement are presented in Table 29. Ribeye 100% depth measurement values revealed all treatments, including CB, did not differ (*P* > 0.05) at a majority of steak locations. Treatments did differ (*P* < 0.05) in the posterior portion of the ribeye.

Least squares means for ribeye treatment x steak location interaction (*P* = <0.0001) for the ribeye kernel fat area measurement are presented in Table 31. Ribeye kernel fat area measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at any steak location. Calf-fed Holstein treatments, including controls, reveal significantly lower values for kernel fat area than the CB treatment. Lower values for kernel fat area are more desirable; therefore, calf-fed Holstein treatments were superior for the kernel fat measurement.

Least squares means for ribeye treatment x steak location interaction (*P* = 0.0411) for the SD area measurement are presented in Table 30. Ribeye SD area measurement values for the calf-fed Holstein treatments did not differ (*P* > 0.05) from each other at a majority of steak locations. However, the values for the ZH treatment generally were numerically higher than the other calf-fed Holstein treatments, making it more similar to the CB measurement values for the

SD area measurement. Least squares means for ribeye treatment x steak location interaction (P = 0.0015) for the LT area measurement are presented in Table 32. Ribeye LT area measurement values for the ZH treatment did not differ ($P > 0.05$) from CB values at many of the steak locations. Measurement values for the ZH treatment also did not differ ($P > 0.05$) from the RH treatment at a majority of steak locations. Controls and the RH treatment also did not differ ($P > 0.05$) at a majority of steak locations.

Least squares means for ribeye treatment x steak location interaction (P = 0.0024) for the C depth are presented in Table 33. Least squares means for ribeye treatment x steak location interaction (P = 0.0039) for the C area are presented in Table 34. Least squares means for ribeye treatment x steak location interaction (P = 0.0459) for the C length are presented in Table 35. Measurement values for C length and C area for all treatments did not differ ($P > 0.05$) at a majority of steak locations Measurement values for C depth for calf-fed Holstein treatments did not differ ($P > 0.05$) at all steak locations; however, there were differences from CB measurement values at some locations in the anterior portion of the ribeye.

Survey Correlations

Survey correlations are presented in Table 38. There are no measurements that show a correlation higher than 0.36 to average rank as determined by the five surveys. The ratio 25 measurement was the most highly correlated to the average rank with a correlation of 0.35. Other measurements that revealed a ≥ 0.30 correlation were ratio 25, ratio 50, LL area, 87, 75, and 25% depth. Length measurements only revealed a 0.10 correlation to the average rank. The 100% measurement revealed a 0.16 correlation to the average rank. The 50% measurement only revealed a 0.29 correlation to the average rank. These correlations revealed that there was no measurement that could accurately gauge consumer preference for steaks. All correlations (P = < 0.0001).

Conclusions

Through the extensive measurement of the steaks from middle meat cuts the sample population revealed that for many of the measurements the beta-agonist treatments made the steaks more similar to the CB treatment, as the CB treatment was superior in most measurements evaluated. The location, anterior or posterior, within the strip loin, short loin, or ribeye that was impacted was not consistent for the various measurements. Some of the measurements revealed a larger impact on the anterior portion and some in the posterior portion. There were also differences within the measurements where the cuts were impacted in different areas by the different treatments. The consumer surveys indicated that none of the measurements evaluated in this study were highly correlated to the average rank from the surveys. This low correlation indicates that it would be difficult to predict consumer preference based on any of the measurements from this research.

Table 1. Least squares means for Strip Loin 75% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	6.77^{az}	6.69^{ay}	6.89^{az}	6.75^{azy}	6.40^{ax}	6.15^{aw}	5.77^{av}	5.24^{au}	4.74^{at}	4.38^{as}	4.23^{asr}	4.17^{ar}
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.08)	(0.07)	(0.06)	(0.08)
Control	5.75^{bz}	5.57^{cz}	5.65^{cz}	5.59^{bz}	5.04^{cy}	4.90^{by}	4.40^{bx}	4.00^{bw}	3.62^{bv}	3.42^{bvu}	3.42^{bvu}	3.16^{cu}
	(0.15)	(0.14)	(0.12)	(0.14)	(0.15)	(0.15)	(0.15)	(0.10)	(0.12)	(0.11)	(0.09)	(0.11)
RH	5.74^{bzy}	5.56^{cy}	5.90^{bcz}	5.67^{bzy}	5.10^{bcx}	4.87^{bx}	4.42^{bw}	4.10^{bv}	3.77^{bu}	3.58^{but}	3.48^{but}	3.39^{bct}
	(0.16)	(0.14)	(0.16)	(0.14)	(0.16)	(0.17)	(0.19)	(0.17)	(0.14)	(0.14)	(0.14)	(0.10)
ZH	6.12^{bz}	6.06^{bzy}	6.09^{bzy}	5.82^{by}	5.50^{bx}	5.00^{bw}	4.80^{bw}	4.32^{bv}	3.90^{bu}	3.76^{but}	3.53^{bt}	3.69^{but}
	(0.15)	(0.15)	(0.13)	(0.20)	(0.17)	(0.15)	(0.15)	(0.12)	(0.13)	(0.13)	(0.14)	(0.19)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-r] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum* in cm.

[2] SEM is the standard error of the least squares means.

[3] CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 2. Least squares means for Strip Loin 87.5% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	5.98^{ayx}	5.96^{ax}	6.26^{az}	6.16^{azy}	5.93^{ax}	5.58^{aw}	5.15^{av}	4.61^{au}	4.36^{at}	4.06^{as}	3.86^{ac}	3.72^{ar}
	(0.09)	(0.08)	(0.08)	(0.07)	(0.08)	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)	(0.08)	(0.09)
Control	5.14^{bz}	5.03^{bz}	4.99^{cz}	4.94^{czy}	4.59^{cyx}	4.40^{bxw}	4.14^{bcw}	3.59^{cv}	3.61^{bv}	3.66^{bv}	3.52^{av}	2.99^{bu}
	(0.18)	(0.17)	(0.17)	(0.14)	(0.22)	(0.18)	(0.16)	(0.14)	(0.19)	(0.19)	(0.20)	(0.17)
RH	5.10^{bzy}	5.11^{bzy}	5.45^{bcz}	5.22^{bcz}	4.75^{bcy}	4.34^{bx}	3.89^{cwv}	3.98^{bcxw}	3.51^{bvu}	3.32^{bu}	3.51^{avu}	3.56^{abwvu}
	(0.18)	(0.14)	(0.17)	(0.16)	(0.20)	(0.21)	(0.17)	(0.19)	(0.19)	(0.16)	(0.18)	(0.21)
ZH	5.38^{bzy}	5.5^{bzy}	5.70^{bz}	5.51^{bzy}	5.23^{by}	4.73^{bx}	4.44^{bxw}	4.16^{bwv}	3.98^{abvu}	3.61^{bu}	3.69^{au}	3.54^{abu}
	(0.12)	(0.17)	(0.15)	(0.18)	(0.20)	(0.19)	(0.19)	(0.17)	(0.19)	(0.13)	(0.25)	(0.21)

$^{a\text{-}c}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).

$^{z\text{-}r}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Depth of *longissimus lumborum* (dorsal to ventral) at 87.5% of the length of the *longissimus lumborum* in cm.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 3. Least squares means for Strip Loin LL Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	97.92^{az}	96.83^{az}	98.16^{az}	96.84^{az}	92.82^{ayx}	90.52^{aw}	90.42^{aw}	93.26^{ayx}	94.29^{ay}	92.47^{ax}	88.23^{av}	84.83^{au}
	(1.65)	(1.41)	(1.45)	(1.70)	(1.51)	(1.44)	(1.46)	(1.56)	(1.41)	(1.39)	(1.47)	(1.48)
Control	83.65^{czyx}	86.22^{cz}	83.97^{czy}	83.38^{czyx}	82.63^{cyxw}	80.36^{bxwv}	79.61^{cwv}	79.97^{cwv}	78.02^{cvu}	75.07^{cut}	72.61^{bts}	70.38^{bs}
	(2.11)	(2.19)	(2.21)	(2.21)	(2.27)	(1.85)	(1.91)	(1.87)	(1.71)	(1.95)	(1.82)	(2.46)
RH	88.66^{bczy}	88.38^{bczy}	90.12^{bcz}	86.14^{bcyx}	85.84^{bcyxw}	83.92^{bxw}	83.06^{bcwv}	84.32^{bcxw}	82.53^{bcwv}	80.26^{bcv}	76.50^{bu}	72.42^{bt}
	(2.50)	(1.98)	(1.84)	(2.07)	(2.32)	(2.19)	(2.07)	(2.07)	(2.24)	(1.64)	(1.79)	(1.91)
ZH	92.97^{abzy}	94.36^{abz}	93.58^{abzy}	92.01^{abzy}	90.28^{abyx}	87.28^{abxw}	88.33^{abxw}	87.47^{abxw}	86.42^{bwv}	83.16^{bv}	77.76^{bu}	76.62^{bu}
	(2.74)	(2.31)	(2.56)	(2.77)	(2.71)	(2.16)	(2.51)	(2.15)	(2.14)	(2.56)	(2.23)	(2.73)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Area of *longissimus lumborum* in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 4. Least squares means for Strip Loin Length[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	16.00^{bvu}	15.68^{but}	15.30^{bs}	15.33^{bs}	15.23^{bs}	15.45^{bts}	16.26^{bv}	17.60^{bw}	18.81^{bx}	19.54^{by}	20.03^{bz}	20.39^{bz}
	(0.19)	(0.15)	(0.16)	(0.16)	(0.16)	(0.14)	(0.18)	(0.21)	(0.18)	(0.18)	(0.16)	(0.20)
Control	16.09^{abut}	16.14^{abut}	15.94^{abt}	15.80^{abt}	16.22^{aut}	16.66^{au}	17.69^{av}	18.64^{aw}	19.87^{ax}	20.49^{ayx}	20.99^{ay}	21.90^{az}
	(0.29)	(0.28)	(0.27)	(0.18)	(0.26)	(0.31)	(0.30)	(0.35)	(0.31)	(0.28)	(0.30)	(0.50)
RH	16.91^{avu}	16.41^{auts}	15.89^{abts}	15.76^{abs}	16.46^{avut}	17.11^{av}	18.05^{aw}	19.03^{ax}	19.87^{ay}	20.82^{az}	21.25^{az}	21.45^{az}
	(0.36)	(0.29)	(0.25)	(0.23)	(0.25)	(0.35)	(0.36)	(0.38)	(0.26)	(0.31)	(0.35)	(0.42)
ZH	16.68^{abu}	16.39^{abut}	16.11^{aut}	16.15^{aut}	15.97^{at}	16.49^{aut}	17.87^{av}	18.73^{aw}	20.31^{ax}	20.67^{ayx}	21.22^{azy}	21.96^{az}
	(0.35)	(0.34)	(0.24)	(0.26)	(0.27)	(0.34)	(0.32)	(0.34)	(0.30)	(0.27)	(0.34)	(0.40)

a,b Least squares means within a column lacking a common superscript differ ($P < 0.05$).

z-s Least squares means within a row lacking a common superscript differ ($P < 0.05$).

1 Length of *longissimus lumborum* (medial to lateral) within steaks in cm.

2 SEM is the standard error of the least squares means.

3 CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride

Table 5. Least squares means for Strip Loin Ratio 25[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	2.38^{bvu}	2.27^{but}	2.08^{bs}	2.11^{bs}	2.14^{cs}	2.19^{cts}	2.40^{cv}	2.68^{cw}	3.01^{bx}	3.14^{by}	3.21^{czy}	3.32^{cz}
	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
Control	2.95^{au}	2.60^{asr}	2.63^{atsr}	2.49^{ar}	2.71^{ats}	2.85^{aut}	3.20^{av}	3.44^{aw}	3.69^{ax}	3.91^{ayx}	4.08^{azy}	4.20^{az}
	(0.10)	(0.09)	(0.11)	(0.09)	(0.13)	(0.14)	(0.10)	(0.13)	(0.13)	(0.12)	(0.12)	(0.18)
RH	3.10^{ax}	2.68^{awv}	2.47^{avu}	2.40^{au}	2.54^{abvu}	2.78^{abw}	3.14^{abx}	3.44^{ay}	3.62^{ay}	3.88^{abz}	3.97^{abz}	4.11^{az}
	(0.16)	(0.09)	(0.09)	(0.08)	(0.07)	(0.10)	(0.12)	(0.11)	(0.11)	(0.13)	(0.12)	(0.16)
ZH	2.91^{ay}	2.43^{axw}	2.45^{axw}	2.40^{axw}	2.29^{bcw}	2.54^{bx}	2.89^{by}	3.07^{by}	3.53^{az}	3.68^{bz}	3.73^{bz}	3.78^{bz}
	(0.12)	(0.07)	(0.09)	(0.07)	(0.06)	(0.11)	(0.09)	(0.12)	(0.10)	(0.08)	(0.11)	(0.18)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-r] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum*.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 6. Least squares means for Strip Loin Ratio 50[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	2.40^{bu}	2.35^{but}	2.22^{bt}	2.31^{but}	2.34^{but}	2.54^{bv}	2.71^{bw}	3.02^{bx}	3.32^{cy}	3.48^{cz}	3.29^{cy}	3.05^{cx}
	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
Control	2.74^{at}	2.84^{aut}	2.94^{aut}	2.89^{aut}	3.09^{avu}	3.27^{av}	3.76^{aw}	4.07^{ax}	4.63^{az}	4.54^{azy}	4.35^{ay}	4.34^{ayx}
	(0.09)	(0.08)	(0.10)	(0.08)	(0.11)	(0.09)	(0.13)	(0.16)	(0.13)	(0.15)	(0.16)	(0.24)
RH	2.83^{ats}	2.92^{ats}	2.67^{as}	2.83^{ats}	3.02^{at}	3.30^{au}	3.64^{av}	4.12^{ayx}	4.36^{abzy}	4.53^{az}	4.03^{bxw}	3.77^{bwv}
	(0.10)	(0.11)	(0.09)	(0.10)	(0.07)	(0.09)	(0.12)	(0.16)	(0.17)	(0.17)	(0.17)	(0.19)
ZH	2.69^{au}	2.76^{au}	2.76^{au}	2.88^{avu}	2.81^{au}	3.14^{av}	3.55^{aw}	3.96^{ayx}	4.32^{bz}	4.18^{bzy}	4.04^{byx}	3.74^{bxw}
	(0.08)	(0.09)	(0.10)	(0.10)	(0.07)	(0.12)	(0.10)	(0.16)	(0.20)	(0.18)	(0.29)	(0.29)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum*.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 7. Least squares means for Strip Loin Ratio 75[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location											
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12
CB	2.39^{but}	2.37^{but}	2.24^{bt}	2.90^{bt}	2.40^{but}	2.54^{bu}	2.87^{cv}	3.44^{cw}	4.05^{bx}	4.55^{cy}	4.81^{bz}	4.99^{cz}
	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)	(0.08)	(0.08)	(0.08)	(0.08)	(0.11)
Control	2.85^{at}	2.93^{at}	2.85^{at}	2.86^{at}	3.29^{au}	3.47^{au}	4.12^{abv}	4.73^{abw}	5.65^{ax}	6.15^{ay}	6.21^{ay}	6.96^{az}
	(0.11)	(0.09)	(0.08)	(0.07)	(0.14)	(0.14)	(0.17)	(0.15)	(0.24)	(0.25)	(0.18)	(0.26)
RH	2.99^{aut}	3.00^{aut}	2.74^{at}	2.82^{at}	3.29^{avu}	3.60^{av}	4.27^{aw}	4.83^{ax}	5.45^{ay}	6.03^{abz}	6.35^{az}	6.35^{bz}
	(0.11)	(0.11)	(0.10)	(0.08)	(0.12)	(0.15)	(0.23)	(0.26)	(0.27)	(0.30)	(0.31)	(0.18)
ZH	2.74^{at}	2.73^{at}	2.67^{at}	2.84^{at}	2.94^{at}	3.37^{au}	3.80^{bv}	4.41^{bw}	5.32^{ax}	5.64^{byx}	6.12^{az}	5.98^{bzy}
	(0.06)	(0.08)	(0.06)	(0.12)	(0.08)	(0.14)	(0.14)	(0.14)	(0.20)	(0.22)	(0.30)	(0.34)

$^{a\text{-}c}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).

$^{z\text{-}t}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum*.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 8. Least squares means for Strip Loin Total Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location			
TRT[3]	9	10	11	12
CB	7.29[bw]	38.03[bx]	80.58[aby]	102.83[az]
	(2.89)	(5.43)	(4.54)	(3.51)
Control	29.59[ax]	45.62[abx]	71.73[by]	102.33[az]
	(8.58)	(9.20)	(7.83)	(3.27)
RH	14.46[abx]	60.92[ay]	90.77[abz]	98.51[az]
	(7.96)	(9.40)	(2.78)	(3.88)
ZH	33.63[ax]	57.79[ay]	95.28[az]	114.82[az]
	(9.51)	(9.84)	(6.14)	(4.26)

[a,b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-w] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Area of *longissimus lumborum* + area of the *gluteus medius* in cm^2.

[2] SEM is the standard error of the least squares means.

[3] CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 9. Least squares means for Strip Loin GM Length[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location			
TRT[3]	9	10	11	12
CB	0.39^{bw}	2.25^{bx}	5.62^{by}	8.77^{bz}
	(0.16)	(0.35)	(0.41)	(0.40)
Control	2.12^{aw}	4.01^{ax}	6.87^{aby}	10.71^{az}
	(0.63)	(0.90)	(1.01)	(0.69)
RH	0.78^{abw}	3.92^{ax}	7.72^{ay}	10.97^{az}
	(0.43)	(0.77)	(0.60)	(0.56)
ZH	1.68^{abw}	4.17^{ax}	8.41^{ay}	11.67^{az}
	(0.53)	(0.81)	(0.83)	(0.73)

[a,b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-w] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Length of *gluteus medius* (medial to lateral) in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 10. Least squares means for Strip Loin Steak location Main effects (SEM[1])

	Measurement		
Steak Location	25% Depth[2]	50% Depth[3]	100% Depth[4]
1	5.98^{d}	6.26^{a}	2.64^{bcd}
	(0.08)	(0.08)	(0.11)
2	6.58^{bc}	6.07^{bc}	2.58^{cd}
	(0.08)	(0.08)	(0.11)
3	6.72^{ab}	6.13^{ab}	2.92^{ab}
	(0.08)	(0.08)	(0.11)
4	6.83^{a}	5.91^{cd}	3.13^{a}
	(0.08)	(0.08)	(0.11)
5	6.74^{ab}	5.80^{d}	2.87^{abc}
	(0.08)	(0.08)	(0.11)
6	6.51^{c}	5.47^{e}	2.65^{bcd}
	(0.08)	(0.08)	(0.11)
7	6.15^{d}	5.24^{f}	2.41^{de}
	(0.08)	(0.08)	(0.11)
8	6.01^{d}	5.03^{g}	2.17^{ef}
	(0.08)	(0.08)	(0.11)
9	5.80^{e}	4.90^{g}	1.89^{fg}
	(0.08)	(0.08)	(0.11)
10	5.68^{e}	5.03^{g}	1.84^{g}
	(0.08)	(0.08)	(0.11)
11	5.67^{e}	5.52^{e}	1.59^{gh}
	(0.08)	(0.08)	(0.12)
12	5.69^{e}	5.98^{bcd}	1.44^{h}
	(0.10)	(0.09)	(0.15)

[a-h] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] Depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.

[3] Depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm.

[4] Depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.

Table 11. Least squares means (SEM[1]) for Strip Loin Steak location Main effects for *gluteus medius* measurements

	Measurement	
Steak location	GM Depth[2]	GM Area[3]
9	0.29[d]	1.37[d]
	(0.10)	(0.83)
10	0.94[c]	5.14[c]
	(0.10)	(0.83)
11	2.06[b]	13.31[b]
	(0.10)	(0.85)
12	3.03[a]	22.98[a]
	(0.12)	(1.00)

[a-d] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] Depth of the *gluteus medius* in cm.

[3] Area of the *gluteus medius* in cm^2.

Table 12. Least squares means for Strip Loin Treatment Main effects (SEM[1])

TRT[2]	Measurement			
	25% Depth[3]	50% Depth[4]	100% Depth[5]	GM Area[6]
CB	6.80[a]	6.36[a]	2.67[a]	8.38[b]
	(0.06)	(0.06)	(0.06)	(0.76)
Control	5.77[c]	5.15[b]	1.97[c]	10.34[ab]
	(0.11)	(0.11)	(0.10)	(1.48)
RH	5.92[c]	5.40[b]	2.26[bc]	10.66[ab]
	(0.11)	(0.12)	(0.10)	(1.53)
ZH	6.29[b]	5.54[b]	2.47[ab]	13.42[a]
	(0.11)	(0.12)	(0.11)	(1.55)

[a-d] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

[3]Depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.

[4] Depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm.

[5] Depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.

[6] Area of the *gluteus medius* in cm^2.

Table 13. Least squares means for Short Loin 25% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	8.22^{awvu}	8.59^{ayx}	8.94^{az}	8.8^{azy}	8.83^{azy}	8.61^{ayx}	8.50^{ax}	8.36^{axwv}	8.03^{au}	8.11^{avu}	8.15^{awvu}	8.39^{axw}	8.41^{axw}	8.61^{ayx}
	(0.17)	(0.15)	(0.15)	(0.13)	(0.14)	(0.14)	(0.13)	(0.15)	(0.16)	(0.14)	(0.15)	(0.12)	(0.19)	(0.22)
Control	7.03^{byxwv}	7.39^{bzy}	7.58^{bz}	7.29^{bzyx}	7.37^{bzyx}	7.00^{byxwv}	6.91^{bxwv}	6.67^{bwvu}	6.23^{bu}	6.22^{bu}	6.30^{bu}	6.61^{cvu}	7.13^{bzyxw}	7.50^{bzy}
	(0.24)	(0.27)	(0.21)	(0.14)	(0.17)	(0.16)	(0.15)	(0.20)	(0.15)	(0.16)	(0.16)	(0.18)	(0.27)	(0.30)
RH	7.44^{bzy}	7.56^{bzy}	7.84^{bz}	7.38^{bzy}	7.15^{byx}	7.08^{byxw}	6.85^{bxwv}	6.64^{bwvu}	6.49^{bvu}	6.28^{bu}	6.49^{bvu}	6.84^{bcxwv}	7.25^{byx}	7.91^{bz}
	(0.24)	(0.21)	(0.16)	(0.12)	(0.14)	(0.14)	(0.16)	(0.15)	(0.24)	(0.22)	(0.17)	(0.20)	(0.18)	(0.20)
ZH	7.33^{bzyxwv}	7.63^{bzy}	7.81^{bz}	7.57^{bzyx}	7.51^{bzyxw}	7.10^{bxwvut}	7.04^{bwvut}	6.85^{bvut}	6.67^{bt}	6.76^{but}	6.91^{bvut}	7.33^{bzyxwv}	7.24^{byxwvu}	7.77^{bzy}
	(0.17)	(0.23)	(0.15)	(0.16)	(0.24)	(0.18)	(0.25)	(0.15)	(0.17)	(0.18)	(0.17)	(0.23)	(0.33)	(0.38)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-t] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.
[2] SEM is the standard error of the least squares means.
[3]CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 14. Least squares means for Short Loin 50% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	7.44^{ayx}	7.60^{ay}	7.71^{ay}	7.24^{ax}	6.81^{aw}	6.36^{av}	6.20^{av}	5.92^{au}	5.72^{au}	5.80^{au}	5.93^{au}	6.77^{aw}	7.70^{ay}	8.74^{az}
	(0.12)	(0.11)	(0.14)	(0.13)	(0.15)	(0.13)	(0.13)	(0.12)	(0.12)	(0.14)	(0.14)	(0.17)	(0.19)	(0.24)
Control	6.28^{by}	6.19^{by}	5.85^{by}	5.25^{bx}	5.01^{bxw}	4.62^{bwv}	4.58^{bwvw}	4.36^{bvu}	3.99^{bu}	4.04^{bu}	4.28^{cvu}	5.11^{cx}	6.27^{by}	6.87^{bz}
	(0.18)	(0.15)	(0.17)	(0.16)	(0.13)	(0.11)	(0.12)	(0.13)	(0.11)	(0.14)	(0.21)	(0.23)	(0.32)	(0.31)
RH	6.18^{byx}	5.97^{bxw}	5.73^{bxw}	5.50^{bwv}	5.05^{bvu}	4.73^{buts}	4.60^{but}	4.26^{bsr}	4.11^{br}	4.20^{br}	4.40^{ctsr}	5.77^{bxw}	6.61^{by}	7.19^{bz}
	(0.19)	(0.16)	(0.20)	(0.19)	(0.14)	(0.12)	(0.12)	(0.11)	(0.16)	(0.15)	(0.21)	(0.29)	(0.32)	(0.26)
ZH	6.10^{by}	6.12^{by}	5.72^{byx}	5.40^{bxw}	4.98^{bwv}	4.79^{bvu}	4.69^{bvu}	4.41^{bu}	4.38^{bu}	4.65^{bvu}	5.12^{bwv}	6.12^{by}	6.86^{bz}	7.40^{bz}
	(0.21)	(0.20)	(0.18)	(0.16)	(0.15)	(0.12)	(0.15)	(0.11)	(0.11)	(0.16)	(0.28)	(0.30)	(0.31)	(0.51)

$^{a\text{-}c}$ Least squares means within a column lacking a common superscript differ (*P* < 0.05).

$^{z\text{-}r}$ Least squares means within a row lacking a common superscript differ (*P* < 0.05).

[1] Depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm.

[2] SEM is the standard error of the least squares means.

[3]CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 15. Least squares means for Short Loin 75% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	6.43^{ayx}	6.57^{ay}	6.86^{az}	6.60^{azy}	6.25^{axw}	6.02^{aw}	5.53^{av}	5.13^{au}	4.76^{at}	4.41^{asr}	4.33^{asr}	4.15^{ar}	4.43^{as}	5.58^{av}
	(0.11)	(0.11)	(0.13)	(0.13)	(0.13)	(0.11)	(0.12)	(0.12)	(0.14)	(0.12)	(0.11)	(0.11)	(0.18)	(0.34)
Control	5.06^{bzy}	5.04^{bzy}	5.29^{bz}	4.82^{by}	4.10^{bx}	4.15^{bx}	3.84^{bxw}	3.43^{bwv}	3.20^{bvu}	3.10^{bvu}	2.91^{bu}	2.96^{bu}	3.03^{bvu}	3.47^{cwv}
	(0.19)	(0.14)	(0.15)	(0.14)	(0.13)	(0.14)	(0.15)	(0.14)	(0.14)	(0.12)	(0.13)	(0.16)	(0.13)	(0.30)
RH	5.25^{bz}	5.13^{bz}	5.30^{bz}	4.85^{bz}	4.36^{by}	4.32^{by}	3.96^{by}	3.44^{bx}	3.43^{bx}	3.00^{bxw}	2.89^{bw}	3.09^{bxw}	3.45^{bx}	4.15^{bcy}
	(0.17)	(0.19)	(0.20)	(0.16)	(0.20)	(0.16)	(0.15)	(0.13)	(0.14)	(0.15)	(0.12)	(0.15)	(0.23)	(0.31)
ZH	4.97^{bzy}	5.18^{bz}	5.29^{bz}	4.52^{byx}	4.27^{bx}	4.18^{bxw}	3.77^{bwv}	3.63^{bvu}	3.43^{bvut}	3.33^{bvut}	3.07^{bt}	3.28^{but}	3.44^{bvut}	4.19^{bxw}
	(0.19)	(0.19)	(0.13)	(0.19)	(0.13)	(0.15)	(0.16)	(0.10)	(0.14)	(0.12)	(0.10)	(0.29)	(0.27)	(0.53)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-r] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum* in cm.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 16. Least squares means for Short Loin 87% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	5.12^{ax}	5.19^{ax}	5.72^{az}	5.80^{az}	5.73^{az}	5.48^{ay}	5.16^{ax}	4.74^{aw}	4.56^{awv}	4.45^{av}	4.15^{au}	4.09^{au}	4.01^{au}	3.94^{au}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.10)	(0.11)	(0.13)	(0.11)	(0.11)	(0.11)	(0.11)	(0.13)
Control	4.30^{bzyx}	4.05^{byxw}	4.65^{bz}	4.39^{bzy}	3.86^{bw}	3.96^{bxw}	3.39^{bv}	3.20^{bvu}	3.14^{bvu}	2.98^{bu}	2.89^{bu}	2.98^{bu}	3.02^{bu}	3.06^{cvu}
	(0.18)	(0.17)	(0.16)	(0.16)	(0.14)	(0.13)	(0.15)	(0.13)	(0.14)	(0.15)	(0.10)	(0.13)	(0.08)	(0.13)
RH	4.38^{bzy}	4.32^{bzy}	4.59^{bz}	4.31^{bzy}	4.18^{by}	4.05^{byx}	3.48^{bwv}	3.27^{bwvu}	3.35^{bwvu}	3.15^{bu}	2.98^{bu}	3.32^{bwvu}	3.23^{bvu}	3.67^{abxw}
	(0.18)	(0.16)	(0.18)	(0.15)	(0.21)	(0.18)	(0.19)	(0.15)	(0.19)	(0.15)	(0.14)	(0.13)	(0.17)	(0.21)
ZH	4.08^{byx}	4.38^{bzy}	4.51^{bz}	4.26^{bzyx}	4.19^{bzyx}	3.88^{bxw}	3.54^{bwv}	3.40^{bvu}	3.27^{bvu}	3.26^{bvu}	3.12^{bu}	3.39^{bvu}	3.42^{bvu}	3.44^{bcwvu}
	(0.20)	(0.14)	(0.14)	(0.15)	(0.14)	(0.18)	(0.13)	(0.09)	(0.12)	(0.10)	(0.12)	(0.17)	(0.18)	(0.27)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-u] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of *longissimus lumborum* (dorsal to ventral) at 87% of the length of the *longissimus lumborum* in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table17. Least squares means for Short Loin LL Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	99.54^{ayx}	100.84^{ay}	103.91^{az}	101.16^{ay}	97.82^{axw}	95.56^{avu}	95.02^{avu}	96.44^{awv}	96.67^{awv}	96.75^{awv}	93.78^{au}	90.33^{at}	84.85^{as}	83.17^{as}
	(2.22)	(2.11)	(2.42)	(2.51)	(2.41)	(2.15)	(2.05)	(2.09)	(2.01)	(2.04)	(1.97)	(2.05)	(1.70)	(1.85)
Control	80.70^{bz}	79.04^{bzy}	79.98^{bz}	75.55^{byx}	73.41^{bxw}	71.05^{bwv}	71.02^{bwv}	72.26^{bxwv}	72.25^{bxwv}	73.33^{bxw}	72.78^{bxw}	68.61^{bvu}	67.06^{bu}	65.07^{bu}
	(2.51)	(2.47)	(2.28)	(2.06)	(1.96)	(1.54)	(1.49)	(2.01)	(1.64)	(2.30)	(1.77)	(1.61)	(1.83)	(2.00)
RH	85.68^{bz}	82.87^{bz}	83.07^{bz}	78.98^{by}	75.16^{byx}	74.58^{bx}	73.86^{bx}	73.15^{bx}	75.48^{byx}	75.88^{byx}	73.23^{bx}	73.37^{bx}	72.93^{bx}	73.21^{bx}
	(2.54)	(2.57)	(2.52)	(2.36)	(2.25)	(2.23)	(2.00)	(1.89)	(2.22)	(2.07)	(1.85)	(2.03)	(2.58)	(2.93)
ZH	82.60^{bz}	83.64^{bz}	81.98^{bzy}	78.62^{byx}	76.98^{bxw}	75.65^{bxw}	74.26^{bw}	75.43^{bxw}	76.74^{bxw}	76.48^{bxw}	73.84^{bwv}	73.46^{bwv}	69.90^{bvu}	67.21^{bu}
	(3.34)	(2.96)	(2.70)	(2.62)	(2.33)	(1.99)	(1.94)	(1.88)	(2.19)	(1.87)	(1.48)	(1.87)	(2.38)	(2.84)

[a,b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Area of the *longissimus lumborum* in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 18. Least squares means for Short Loin PM Area[1] (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	4.83^{ao}	8.38^{ap}	14.17^{aq}	17.68^{abr}	22.33^{abs}	28.63^{at}	34.59^{au}	40.90^{av}	47.19^{aw}	52.88^{ax}	55.86^{ay}	59.35^{az}	58.88^{az}	59.38^{az}
	(0.55)	(0.74)	(0.82)	(0.85)	(0.91)	(1.14)	(1.36)	(1.28)	(1.46)	(1.44)	(1.33)	(1.31)	(1.27)	(1.38)
Control	2.84^{aq}	6.18^{ar}	12.43^{as}	16.32^{bt}	19.42^{bt}	24.42^{bu}	30.26^{bv}	35.58^{bw}	40.54^{bx}	47.53^{by}	49.80^{bzy}	52.64^{bz}	51.98^{bz}	52.86^{bz}
	(0.95)	(1.06)	(1.27)	(0.87)	(1.17)	(1.03)	(1.02)	(1.13)	(1.37)	(1.33)	(1.29)	(1.54)	(1.20)	(1.61)
RH	6.30^{ao}	10.48^{ap}	15.74^{aq}	19.67^{abr}	23.74^{abs}	29.63^{at}	34.30^{abu}	40.13^{abv}	46.57^{aw}	51.38^{abx}	51.80^{byx}	56.20^{abz}	53.34^{bzyx}	55.38^{abzy}
	(1.50)	(1.55)	(1.40)	(1.27)	(1.48)	(1.38)	(1.46)	(1.37)	(1.71)	(1.28)	(1.45)	(1.29)	(1.26)	(1.56)
ZH	6.41^{aq}	10.35^{ar}	16.25^{as}	21.18^{at}	26.03^{au}	31.90^{av}	38.26^{aw}	42.81^{ax}	47.35^{ay}	52.48^{az}	53.34^{abz}	54.88^{bz}	55.90^{abz}	55.18^{abz}
	(1.36)	(1.70)	(1.46)	(1.25)	(1.59)	(1.64)	(1.56)	(1.48)	(1.45)	(1.16)	(1.58)	(1.43)	(1.40)	(2.11)

$^{a-c}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).

$^{z-o}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Area of the *psoas major* in cm^2.

[2] SEM is the standard error of the least squares means.

[3] CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 19. Least squares means for Short Loin Length[1] (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	15.08^{ar}	15.21^{asr}	15.21^{asr}	15.37^{asr}	15.46^{as}	15.84^{at}	16.53^{au}	17.65^{av}	18.63^{aw}	19.21^{ax}	19.75^{by}	20.01^{bzy}	20.05^{bzy}	20.14^{bz}
	(0.17)	(0.17)	(0.18)	(0.19)	(0.19)	(0.20)	(0.21)	(0.23)	(0.20)	(0.20)	(0.21)	(0.20)	(0.22)	(0.22)
Control	15.00^{ar}	14.93^{ar}	14.89^{ar}	15.00^{ar}	15.29^{asr}	15.74^{as}	16.75^{at}	17.82^{au}	18.72^{av}	19.74^{aw}	20.22^{abxw}	20.75^{ayx}	21.26^{azy}	21.55^{az}
	(0.19)	(0.23)	(0.16)	(0.18)	(0.12)	(0.16)	(0.27)	(0.32)	(0.34)	(0.23)	(0.23)	(0.22)	(0.20)	(0.28)
RH	15.79^{auts}	15.60^{ats}	15.21^{as}	15.54^{ats}	15.85^{aut}	16.26^{au}	17.04^{av}	18.07^{aw}	19.09^{ax}	19.83^{ay}	20.81^{az}	21.25^{az}	21.23^{az}	20.94^{abz}
	(0.27)	(0.27)	(0.24)	(0.26)	(0.35)	(0.32)	(0.36)	(0.43)	(0.29)	(0.30)	(0.32)	(0.31)	(0.31)	(0.34)
ZH	15.34^{as}	15.37^{as}	15.26^{as}	15.62^{as}	15.67^{as}	16.57^{at}	17.27^{au}	17.92^{av}	19.02^{aw}	19.87^{ax}	20.49^{ay}	20.83^{azy}	21.31^{az}	21.35^{az}
	(0.25)	(0.26)	(0.27)	(0.31)	(0.28)	(0.35)	(0.36)	(0.34)	(0.32)	(0.23)	(0.30)	(0.36)	(0.27)	(0.15)

^{a,b} Least squares means within a column lacking a common superscript differ ($P < 0.05$).

$^{z\text{-}r}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Length of *longissimus lumborum* (medial to lateral) within steaks in cm.

[2] SEM is the standard error of the least squares means.

[3]CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 20. Least squares means for Short Loin Ratio 25[1] (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	1.88^{bxw}	1.80^{bwvu}	1.72^{bu}	1.76^{bvu}	1.77^{bwvu}	1.86^{bxwv}	1.97^{bx}	2.16^{by}	2.38^{bz}	2.41^{cz}	2.48^{cz}	2.42^{cz}	2.49^{bz}	2.42^{cz}
	(0.05)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.05)	(0.06)	(0.05)	(0.06)	(0.04)	(0.09)	(0.07)
Control	2.18^{avu}	2.08^{avu}	1.99^{au}	2.07^{avu}	2.09^{avu}	2.27^{awv}	2.45^{aw}	2.72^{ax}	3.04^{azy}	3.21^{az}	3.25^{az}	3.18^{az}	3.07^{azy}	2.94^{ayx}
	(0.08)	(0.10)	(0.05)	(0.05)	(0.04)	(0.06)	(0.08)	(0.09)	(0.11)	(0.07)	(0.09)	(0.09)	(0.14)	(0.11)
RH	2.16^{asr}	2.09^{asr}	1.95^{ar}	2.11^{asr}	2.23^{as}	2.31^{ats}	2.50^{aut}	2.75^{awv}	3.01^{ayx}	3.21^{azy}	3.23^{az}	3.14^{azyx}	2.95^{axw}	2.66^{bvu}
	(0.08)	(0.07)	(0.04)	(0.04)	(0.07)	(0.06)	(0.07)	(0.10)	(0.12)	(0.10)	(0.07)	(0.07)	(0.07)	(0.06)
ZH	2.11^{aw}	2.04^{aw}	1.96^{aw}	2.08^{aw}	2.13^{aw}	2.37^{ax}	2.53^{ayx}	2.65^{azy}	2.88^{az}	2.97^{bz}	2.99^{bz}	2.88^{bz}	3.01^{az}	2.80^{abz}
	(0.05)	(0.06)	(0.04)	(0.06)	(0.09)	(0.10)	(0.14)	(0.09)	(0.08)	(0.07)	(0.07)	(0.09)	(0.11)	(0.13)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-r] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum*.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 21. Least squares means for Short Loin Ratio 50[1] (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	2.05^{bt}	2.02^{bt}	2.00^{bt}	2.15^{but}	2.31^{bvu}	2.54^{bw}	2.73^{bx}	3.05^{by}	3.35^{cz}	3.44^{cz}	3.44^{cz}	3.09^{cy}	2.75^{cx}	2.42^{bwv}
	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.05)	(0.06)	(0.07)	(0.09)	(0.10)	(0.09)	(0.10)	(0.13)	(0.11)
Control	2.43^{au}	2.43^{au}	2.58^{au}	2.90^{av}	3.09^{av}	3.45^{axw}	3.70^{ax}	4.17^{ay}	4.79^{az}	4.99^{az}	4.98^{az}	4.22^{ay}	3.56^{axw}	3.22^{awv}
	(0.08)	(0.06)	(0.06)	(0.09)	(0.08)	(0.09)	(0.10)	(0.17)	(0.19)	(0.17)	(0.29)	(0.20)	(0.19)	(0.16)
RH	2.60^{at}	2.64^{at}	2.71^{at}	2.89^{aut}	3.17^{avu}	3.47^{awv}	3.62^{axw}	4.31^{ay}	4.76^{abz}	4.81^{az}	4.88^{az}	3.84^{abx}	3.32^{abwv}	2.95^{aut}
	(0.09)	(0.07)	(0.10)	(0.11)	(0.11)	(0.10)	(0.13)	(0.19)	(0.21)	(0.17)	(0.21)	(0.20)	(0.15)	(0.12)
ZH	2.55^{au}	2.55^{au}	2.70^{avu}	2.93^{awv}	3.19^{axw}	3.50^{ayx}	3.77^{ay}	4.12^{az}	4.38^{bz}	4.35^{bz}	4.18^{bz}	3.56^{by}	3.19^{bxw}	3.01^{awv}
	(0.08)	(0.07)	(0.08)	(0.09)	(0.11)	(0.12)	(0.20)	(0.16)	(0.11)	(0.14)	(0.20)	(0.19)	(0.14)	(0.22)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-t] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum*.
[2] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 22. Least squares means for Short Loin Ratio 75[1] (SEM[2]) interaction for treatment and steak location

	Steak Location													
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CB	2.38^{but}	2.34^{bt}	2.25^{bt}	2.37^{but}	2.51^{but}	2.68^{bu}	3.06^{bv}	3.56^{bw}	4.15^{bx}	4.54^{cy}	4.74^{bzy}	5.03^{bz}	4.95^{bz}	4.18^{cx}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.07)	(0.10)	(0.15)	(0.13)	(0.13)	(0.14)	(0.20)	(0.23)
Control	3.05^{at}	3.01^{at}	2.86^{at}	3.17^{at}	3.82^{au}	3.88^{au}	4.51^{av}	5.38^{aw}	6.07^{ax}	6.59^{abyx}	7.21^{az}	7.33^{az}	7.18^{az}	6.81^{azy}
	(0.12)	(0.10)	(0.08)	(0.11)	(0.15)	(0.15)	(0.23)	(0.26)	(0.30)	(0.30)	(0.33)	(0.33)	(0.26)	(0.55)
RH	3.07^{au}	3.11^{au}	2.94^{au}	3.27^{avu}	3.75^{av}	3.86^{awv}	4.43^{aw}	5.40^{ax}	5.74^{ax}	6.90^{azy}	7.41^{az}	7.08^{azy}	6.61^{ay}	5.36^{bx}
	(0.12)	(0.13)	(0.12)	(0.13)	(0.17)	(0.18)	(0.22)	(0.27)	(0.28)	(0.40)	(0.31)	(0.29)	(0.43)	(0.40)
ZH	3.16^{auts}	3.03^{ats}	2.91^{as}	3.55^{avut}	3.74^{avu}	4.08^{av}	4.77^{aw}	5.02^{aw}	5.72^{ax}	6.10^{byx}	6.79^{az}	7.02^{az}	6.70^{azy}	5.81^{bx}
	(0.13)	(0.12)	(0.08)	(0.15)	(0.15)	(0.21)	(0.28)	(0.21)	(0.29)	(0.24)	(0.25)	(0.49)	(0.51)	(0.67)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum*.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 23. Least squares means for Short Loin Total Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location			
TRT[3]	11	12	13	14
CB	53.24^{bw}	92.56^{ax}	110.24^{ay}	122.80^{az}
	(6.58)	(4.86)	(2.05)	(2.66)
Control	60.85^{abx}	80.73^{ay}	95.38^{az}	103.77^{bz}
	(8.21)	(4.75)	(3.11)	(3.66)
RH	68.47^{abx}	87.36^{ay}	100.64^{azy}	110.26^{abz}
	(7.78)	(6.16)	(3.93)	(3.50)
ZH	74.24^{ax}	95.29^{ay}	103.52^{azy}	113.97^{abz}
	(8.30)	(3.11)	(3.80)	(6.42)

^{a,b} Least squares means within a column lacking a common superscript differ ($P < 0.05$).
$^{z\text{-}w}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Area of *longissimus lumborum* + area of the *gluteus medius* in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 24. Least squares means for Short Loin GM Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location			
TRT[3]	11	12	13	14
CB	1.14^{bz}	2.35^{by}	3.83^{ax}	4.86^{aw}
	(0.17)	(0.19)	(0.16)	(0.18)
Control	1.51^{abz}	2.28^{by}	3.55^{ax}	4.48^{aw}
	(0.46)	(0.26)	(0.26)	(0.29)
RH	1.33^{abz}	2.79^{aby}	3.61^{ax}	4.33^{aw}
	(0.24)	(0.30)	(0.25)	(0.20)
ZH	2.15^{az}	3.14^{ay}	4.29^{ax}	4.97^{aw}
	(0.37)	(0.26)	(0.23)	(0.35)

[a,b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-w] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of the *gluteus medius* in cm.
[2] SEM is the standard error of the least squares means.
[3] CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 25. Least squares means for Short Loin Steak locations Main effects (SEM[1])

	Measurement		
Steak location	100% Depth[2]	PM Depth[3]	PM Length[4]
1	1.38^{cde}	0.83^{l}	3.04^{h}
	(0.09)	(0.10)	(0.18)
2	1.22^{ef}	1.26^{k}	5.10^{g}
	(0.09)	(0.10)	(0.18)
3	1.60^{bc}	1.65^{j}	6.98^{f}
	(0.09)	(0.10)	(0.18)
4	1.90^{a}	2.02^{i}	7.93^{e}
	(0.09)	(0.10)	(0.18)
5	1.80^{ab}	2.41^{h}	8.42^{d}
	(0.09)	(0.10)	(0.18)
6	1.99^{a}	2.98^{g}	9.24^{c}
	(0.09)	(0.10)	(0.18)
7	1.61^{bc}	3.66^{f}	9.53^{bc}
	(0.09)	(0.10)	(0.18)
8	1.54^{cd}	4.26^{e}	9.97^{a}
	(0.09)	(0.10)	(0.18)
9	1.32^{de}	4.89^{d}	9.92^{ab}
	(0.09)	(0.10)	(0.18)
10	1.03^{fg}	5.51^{c}	10.11^{a}
	(0.09)	(0.10)	(0.18)
11	1.07^{fg}	5.82^{b}	9.97^{a}
	(0.09)	(0.10)	(0.18)
12	1.03^{fg}	6.44^{a}	9.78^{ab}
	(0.09)	(0.10)	(0.18)
13	0.90^{g}	6.47^{a}	9.87^{ab}
	(0.09)	(0.10)	(0.18)
14	1.07^{fg}	6.62^{a}	9.95^{ab}
	(0.11)	(0.12)	(0.21)

$^{a\text{-}l}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] Depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.

[3] Depth of *psoas major* (dorsal to ventral) at 50% of the length of the *psoas major* in cm.

[4] Length of *psoas major* (medial to lateral) in cm.

Table 26. Least squares means (SEM[1]) for Short Loin Steak location Main effects for *gluteus medius* measurements

Steak location	Measurement	
	GM Area[2]	GM Length[3]
11	7.93[d]	4.47[d]
	(1.12)	(0.31)
12	17.37[c]	7.52[c]
	(1.12)	(0.31)
13	28.24[b]	10.01[b]
	(1.14)	(0.31)
14	39.39[a]	12.11[a]
	(1.20)	(0.33)

[a-d] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] Area of the *gluteus medius* in cm^2.

[3] Length (medial to lateral) of the *gluteus medius*.

Table 27. Least squares means for Short Loin Treatment Main effects (SEM[1])

TRT[2]	Measurements		
	100% Depth[3]	GM Length[4]	PM Depth[5]
CB	1.57[a] (0.04)	7.44[b] (0.34)	4.15[a] (0.09)
Control	1.26[b] (0.06)	8.57[ab] (0.60)	3.58[b] (0.15)
RH	1.29[b] (0.07)	8.48[ab] (0.63)	3.93[ab] (0.16)
ZH	1.44[ab] (0.07)	9.60[a] (0.63)	3.99[ab] (0.16)

[a-b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] CB – conventionally managed beef; Control – implanted with Revalor®-XS; Natural – calf-fed Holstein managed without growth promotants; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

[3] Depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.

[4] Length (medial to lateral) of the *gluteus medius* in cm.

[5] Depth of *psoas major* (dorsal to ventral) at 50% of the length of the *psoas major* in cm.

Table 28. Least squares means for Ribeye 87% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location															
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CB	5.66^{aw}	5.60^{awv}	5.71^{aw}	5.45^{awv}	5.30^{av}	5.28^{av}	5.33^{av}	5.65^{aw}	5.77^{axw}	6.25^{ay}	6.44^{azy}	6.42^{azy}	6.69^{az}	6.75^{az}	6.61^{az}	6.10^{ayx}
	(0.13)	(0.10)	(0.10)	(0.10)	(0.10)	(0.13)	(0.11)	(0.09)	(0.11)	(0.12)	(0.12)	(0.09)	(0.09)	(0.09)	(0.10)	(0.10)
Control	4.73^{bw}	4.58^{bw}	4.71^{bw}	4.76^{bw}	4.85^{bxw}	4.61^{bw}	4.59^{bw}	5.30^{ay}	5.37^{azy}	5.33^{czy}	5.61^{bzy}	5.64^{bzy}	5.73^{bz}	5.44^{bczy}	5.57^{bzy}	5.25^{byx}
	(0.25)	(0.18)	(0.15)	(0.18)	(0.25)	(0.16)	(0.14)	(0.20)	(0.12)	(0.16)	(0.16)	(0.19)	(0.10)	(0.18)	(0.19)	(0.16)
RH	4.51^{bt}	4.79^{but}	4.93^{bvut}	4.70^{but}	4.82^{but}	5.11^{axwvu}	5.06^{abwvu}	5.50^{azyx}	5.44^{azyxw}	5.64^{bczy}	5.78^{bz}	5.63^{bzy}	5.74^{bz}	5.39^{czyxw}	5.41^{bzyxw}	5.26^{byxwv}
	(0.25)	(0.10)	(0.15)	(0.18)	(0.17)	(0.19)	(0.19)	(0.21)	(0.21)	(0.19)	(0.18)	(0.19)	(0.20)	(0.18)	(0.32)	(0.15)
ZH	4.72^{bt}	4.97^{but}	5.11^{bvut}	4.98^{but}	5.25^{abwvu}	5.58^{ayxw}	5.39^{axwvu}	5.63^{azyxw}	5.76^{azyx}	5.91^{abzy}	5.88^{bzy}	5.84^{bzy}	6.02^{bz}	5.88^{bzy}	5.86^{bzy}	5.52^{byxwv}
	(0.26)	(0.13)	(0.14)	(0.13)	(0.17)	(0.21)	(0.16)	(0.14)	(0.16)	(0.12)	(0.14)	(0.14)	(0.16)	(0.19)	(0.19)	(0.15)

$^{a-c}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).
$^{z-t}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of *longissimus lumborum* (dorsal to ventral) at 87% of the length of the whole steak in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 29. Least squares means for Ribeye 100% Depth[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location															
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CB	1.65^{awvu}	1.42^{au}	1.68^{awvu}	1.70^{awvu}	1.67^{awvu}	1.60^{avu}	1.58^{avu}	1.99^{axwv}	2.08^{ayxw}	2.47^{abzy}	2.53^{bzy}	2.65^{az}	2.73^{az}	2.45^{abzyx}	2.62^{az}	2.44^{azyx}
	(0.10)	(0.09)	(0.10)	(0.08)	(0.08)	(0.09)	(0.09)	(0.11)	(0.11)	(0.14)	(0.13)	(0.14)	(0.14)	(0.14)	(0.14)	(0.15)
Control	1.13^{at}	1.07^{at}	1.46^{avut}	1.36^{aut}	1.95^{axwvu}	1.66^{awvut}	1.36^{aut}	2.05^{axwv}	2.20^{ayxw}	2.31^{bzyx}	2.14^{bxw}	2.40^{azyx}	2.75^{azy}	2.90^{az}	2.26^{abyx}	2.33^{abzyx}
	(0.19)	(0.09)	(0.23)	(0.13)	(0.33)	(0.21)	(0.20)	(0.17)	(0.26)	(0.27)	(0.25)	(0.20)	(0.32)	(0.17)	(0.25)	(0.30)
RH	1.78^{azyxwv}	1.39^{awv}	1.43^{axwv}	1.36^{av}	1.70^{ayxwv}	1.75^{ayxwv}	1.75^{ayxwv}	1.99^{azyxw}	1.86^{azyxwv}	1.95^{bzyxw}	2.19^{bzy}	2.37^{az}	1.85^{bzyxwv}	2.00^{bzyx}	2.04^{bzy}	1.70^{byxwv}
	(0.61)	(0.13)	(0.19)	(0.15)	(0.19)	(0.22)	(0.20)	(0.24)	(0.19)	(0.22)	(0.24)	(0.30)	(0.15)	(0.28)	(0.26)	(0.19)
ZH	1.40^{as}	1.64^{auts}	1.55^{ats}	1.53^{ats}	1.78^{avuts}	2.11^{axwvut}	1.73^{auts}	1.94^{awvuts}	1.95^{awvuts}	2.94^{azy}	3.20^{az}	2.57^{ayx}	2.50^{ayxw}	2.20^{bxwvu}	2.33^{abxwv}	2.08^{bxwvut}
	(0.20)	(0.16)	(0.17)	(0.20)	(0.23)	(0.21)	(0.16)	(0.19)	(0.21)	(0.28)	(0.22)	(0.17)	(0.31)	(0.22)	(0.27)	(0.29)

[a,b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-r] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the whole steak in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 30. Least squares means for Ribeye SD Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location															
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CB	37.35^{azyx}	38.88^{azy}	38.46^{azy}	39.42^{az}	37.90^{azyx}	37.31^{ayx}	38.09^{azy}	35.93^{axw}	34.69^{aw}	32.31^{av}	28.11^{au}	24.24^{at}	19.21^{as}	13.91^{ar}	10.70^{aq}	5.37^{ap}
	(1.36)	(0.95)	(0.79)	(0.86)	(0.65)	(0.65)	(0.80)	(0.70)	(0.67)	(0.84)	(0.79)	(0.87)	(0.67)	(0.69)	(0.87)	(0.52)
Control	32.06^{bzy}	32.41^{bcz}	32.86^{bz}	33.15^{bz}	32.06^{bz}	32.75^{bz}	30.61^{czy}	29.34^{cyx}	27.12^{bx}	27.79^{bx}	23.44^{bw}	18.51^{bv}	14.21^{bu}	11.31^{at}	8.43^{as}	4.95^{ar}
	(1.52)	(1.47)	(0.93)	(1.02)	(0.83)	(1.21)	(0.81)	(0.69)	(0.76)	(2.19)	(1.06)	(0.93)	(1.04)	(0.97)	(0.78)	(0.79)
RH	33.41^{bzy}	31.16^{czyx}	33.15^{bzy}	33.61^{bz}	32.11^{bzy}	33.75^{bz}	30.44^{cyx}	30.39^{bcyx}	28.73^{bx}	25.85^{bw}	23.59^{bw}	19.55^{bv}	15.85^{bu}	11.22^{at}	7.79^{as}	4.17^{ar}
	(0.92)	(1.22)	(1.25)	(0.94)	(0.84)	(1.71)	(0.93)	(0.71)	(0.93)	(0.90)	(0.89)	(1.08)	(0.87)	(0.53)	(0.71)	(0.63)
ZH	32.26^{bwv}	35.48^{bzyx}	36.95^{az}	36.27^{abzy}	35.21^{abzyx}	34.86^{abzyxw}	33.89^{byxwv}	33.31^{bxwv}	32.03^{av}	27.64^{bu}	26.26^{abu}	20.97^{bt}	16.39^{bs}	13.83^{as}	10.04^{ar}	6.56^{aq}
	(1.05)	(0.97)	(1.33)	(1.02)	(1.05)	(1.18)	(1.07)	(1.25)	(1.35)	(1.07)	(1.20)	(1.18)	(0.75)	(0.98)	(1.02)	(0.83)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-p] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Area of the *spinalis dorsi* in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 31. Least squares means for Ribeye K Fat Area[1] measurements (SEM[2]) interaction for treatment and steak location

	Steak Location															
TRT[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CB	7.17^{as}	9.03^{au}	9.12^{au}	12.76^{ax}	14.68^{azy}	15.14^{az}	13.57^{ayx}	13.59^{ayx}	12.46^{axw}	11.08^{awv}	10.56^{av}	8.94^{aut}	7.61^{ats}	5.37^{ar}	4.31^{arq}	3.04^{aq}
	(0.72)	(0.51)	(0.57)	(0.62)	(0.44)	(0.51)	(0.66)	(0.57)	(0.47)	(0.49)	(0.39)	(0.48)	(0.40)	(0.42)	(0.37)	(0.31)
Control	6.32^{avu}	7.04^{bwvu}	9.67^{ayx}	10.32^{bzyx}	10.88^{bzy}	11.64^{bz}	10.81^{bzy}	9.93^{bzyx}	8.63^{bxw}	7.35^{bwv}	6.78^{bvu}	6.30^{bvu}	5.61^{but}	4.53^{ats}	4.31^{ats}	2.82^{as}
	(1.31)	(0.84)	(0.80)	(0.99)	(0.61)	(0.70)	(0.53)	(0.74)	(0.43)	(0.58)	(0.54)	(0.43)	(0.35)	(0.42)	(0.43)	(0.36)
RH	6.97^{axwvu}	6.99^{bxwvu}	8.51^{ayx}	10.39^{bz}	11.48^{bz}	11.13^{bz}	11.25^{bz}	9.89^{bzy}	8.26^{byxw}	7.90^{bxwv}	6.69^{bwvu}	6.54^{bvu}	5.57^{but}	5.54^{aut}	4.72^{ats}	2.87^{as}
	(1.18)	(0.89)	(0.91)	(0.68)	(0.60)	(0.65)	(0.89)	(0.74)	(0.58)	(0.57)	(0.56)	(0.39)	(0.56)	(0.42)	(0.36)	(0.41)
ZH	7.80^{axwv}	7.75^{abxwv}	9.33^{ayx}	10.88^{bzy}	11.39^{bz}	11.06^{bz}	10.84^{bzy}	8.91^{bxw}	8.39^{bxwv}	8.06^{bxwv}	7.42^{bwvu}	6.70^{bvut}	6.06^{abut}	5.22^{ats}	4.35^{asr}	3.02^{ar}
	(0.80)	(0.86)	(0.76)	(0.66)	(0.58)	(0.75)	(0.68)	(0.55)	(0.61)	(0.68)	(0.44)	(0.52)	(0.47)	(0.61)	(0.35)	(0.33)

[a-b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-q] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1]Area of the Kernel Fat in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 32. Least squares means for Ribeye LT Area[1] measurements (SEM[2]) interaction for treatment and steak location

TRT[3]	Steak Location 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CB	44.39^{am}	47.85^{an}	50.96^{ao}	54.44^{ap}	57.41^{aq}	61.22^{ar}	64.83^{as}	71.42^{at}	75.85^{au}	80.35^{av}	84.89^{aw}	89.75^{ayx}	92.15^{ay}	96.61^{az}	96.29^{ay}	87.77^{ax}
	(1.61)	(0.88)	(0.98)	(0.89)	(0.91)	(1.04)	(1.26)	(1.35)	(1.37)	(1.52)	(1.40)	(1.23)	(1.36)	(1.47)	(1.49)	(1.80)
Control	33.76^{bp}	34.43^{cqp}	40.22^{brq}	40.62^{cr}	46.00^{cs}	46.45^{ct}	54.55^{cu}	60.23^{cv}	63.96^{bw}	65.29^{cx}	69.14^{cx}	74.63^{cy}	76.58^{cy}	76.77^{cz}	79.22^{cz}	72.41^{by}
	(1.77)	(1.09)	(1.53)	(1.63)	(1.75)	(1.90)	(1.77)	(1.99)	(2.42)	(2.96)	(2.16)	(2.21)	(2.35)	(2.06)	(2.48)	(1.99)
RH	38.94^{abr}	39.30^{bcr}	42.44^{bsr}	44.20^{bcs}	48.69^{bct}	52.93^{bt}	58.94^{bcu}	64.78^{bcv}	68.24^{bv}	72.97^{bw}	75.65^{bw}	77.72^{cx}	80.44^{bcyx}	81.61^{czy}	82.79^{bcz}	75.64^{byx}
	(1.31)	(1.19)	(1.23)	(1.17)	(1.04)	(1.50)	(1.29)	(1.33)	(1.70)	(1.42)	(1.51)	(1.57)	(1.62)	(1.97)	(1.65)	(2.09)
ZH	39.51^{abq}	42.53^{bq}	45.55^{br}	48.36^{br}	52.80^{abs}	57.87^{abs}	63.82^{abt}	69.07^{abu}	73.62^{av}	78.79^{av}	78.85^{bw}	83.30^{byx}	83.71^{bzy}	89.53^{bzy}	87.74^{bz}	82.98^{axw}
	(1.76)	(1.42)	(1.34)	(1.87)	(1.78)	(1.59)	(1.73)	(1.69)	(1.70)	(1.78)	(1.85)	(1.85)	(1.74)	(2.21)	(2.12)	(2.50)

$^{a-c}$ Least squares means within a column lacking a common superscript differ ($P < 0.05$).
$^{z-m}$ Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1]Area of the *longissimus thoracis* in cm^2.
[2] SEM is the standard error of the least squares means.
[3] CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 33. Least squares means for Ribeye C Depth[1] measurement (SEM[2]) interaction for treatment and steak location

	Measurements							
TRT[3]	1	2	3	4	5	6	7	8
CB	3.87^{ay}	3.63^{azy}	3.51^{ay}	2.67^{ax}	2.17^{aw}	1.41^{at}	0.72^{au}	0.22^{as}
	(0.17)	(0.11)	(0.12)	(0.10)	(0.10)	(0.12)	(0.12)	(0.08)
Control	3.26^{bz}	2.89^{bzy}	2.66^{byx}	2.44^{abx}	1.67^{bw}	1.47^{aw}	0.56^{avu}	0.24^{au}
	(0.14)	(0.13)	(0.18)	(0.20)	(0.17)	(0.20)	(0.17)	(0.14)
RH	3.45^{abz}	2.99^{by}	2.71^{by}	2.26^{bx}	1.78^{abw}	1.06^{av}	0.59^{au}	0.09^{at}
	(0.22)	(0.13)	(0.11)	(0.15)	(0.18)	(0.17)	(0.16)	(0.05)
ZH	3.42^{abz}	3.30^{abz}	2.92^{by}	2.53^{abx}	1.82^{abw}	1.18^{av}	0.37^{au}	0.02^{at}
	(0.12)	(0.14)	(0.16)	(0.11)	(0.11)	(0.13)	(0.11)	(0.02)

[a-b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Depth of the *complexus* at 50% of the length (medial to lateral) in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 34. Least squares means for Ribeye C Area[1] measurement (SEM[2]) interaction for treatment and steak location

	Measurements							
TRT[3]	1	2	3	4	5	6	7	8
CB	18.16[az]	15.82[ay]	14.07[ax]	8.98[aw]	5.35[av]	2.86[au]	2.05[au]	0.20[at]
	(0.81)	(0.50)	(0.58)	(0.51)	(0.48)	(0.37)	(0.39)	(0.12)
Control	15.56[bz]	13.99[az]	10.62[by]	9.47[ay]	5.60[ax]	4.01[aw]	1.29[av]	0.41[av]
	(1.01)	(0.95)	(0.89)	(0.95)	(0.75)	(0.67)	(0.48)	(0.29)
RH	17.00[abz]	14.58[ay]	12.36[abx]	8.70[aw]	5.78[av]	3.20[au]	1.72[au]	0.12[at]
	(0.85)	(0.79)	(1.39)	(0.88)	(0.80)	(0.65)	(0.50)	(0.06)
ZH	18.40[az]	15.51[ay]	12.31[abx]	10.03[aw]	6.21[av]	2.97[au]	0.73[at]	0.05[at]
	(1.41)	(0.77)	(0.75)	(0.75)	(0.55)	(0.46)	(0.24)	(0.05)

[a-b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[z-t] Least squares means within a row lacking a common superscript differ ($P < 0.05$).

[1] Area of the *complexus* in cm^2.

[2] SEM is the standard error of the least squares means.

[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 35. Least squares means for Ribeye C Length[1] measurement (SEM[2]) interaction for treatment and steak location

	Measurements							
TRT[3]	1	2	3	4	5	6	7	8
CB	6.16^{az}	5.92^{az}	5.32^{ay}	4.23^{abx}	3.22^{bw}	2.14^{av}	1.04^{au}	0.25^{at}
	(0.21)	(0.13)	(0.15)	(0.15)	(0.18)	(0.17)	(0.17)	(0.12)
Control	6.49^{az}	6.16^{az}	5.19^{ay}	4.83^{by}	3.66^{abx}	3.08^{aw}	1.14^{av}	0.30^{au}
	(0.29)	(0.26)	(0.21)	(0.35)	(0.31)	(0.33)	(0.31)	(0.20)
RH	6.90^{az}	6.20^{ay}	5.52^{ax}	4.88^{abw}	3.72^{abv}	2.65^{au}	1.59^{at}	0.25^{as}
	(0.13)	(0.18)	(0.20)	(0.27)	(0.33)	(0.42)	(0.38)	(0.14)
ZH	6.46^{az}	5.99^{azy}	5.48^{ayx}	5.15^{ax}	4.10^{aw}	2.66^{v}	1.02^{au}	0.10^{at}
	(0.19)	(0.21)	(0.18)	(0.21)	(0.17)	(0.27)	(0.30)	(0.10)

[a-b] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[z-s] Least squares means within a row lacking a common superscript differ ($P < 0.05$).
[1] Length of the *complexus* in cm.
[2] SEM is the standard error of the least squares means.
[3] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Table 36. Least squares means for Ribeye Steak location Main effects (SEM[1])

	Measurements											
Steak location	25% Depth[2]	50% Depth[3]	75% Depth[4]	LT Depth[5]	LT Length[6]	Length[7]	SD Depth[8]	SD Length[9]	Total Area[10]	Ratio 25[11]	Ratio 50[12]	Ratio 75[13]
1	7.14^{g}	7.88^{e}	6.22^{f}	5.50^{ef}	8.94^{k}	15.93^{cd}	4.95^{a}	7.76^{ij}	98.46^{i}	2.26^{b}	2.06^{ef}	2.62^{ab}
	(0.14)	(0.13)	(0.12)	(0.12)	(0.15)	(0.15)	(0.08)	(0.21)	(1.45)	(0.05)	(0.04)	(0.05)
2	7.31^{fg}	7.96^{e}	6.24^{f}	5.66^{def}	9.15^{k}	15.97^{cd}	4.82^{a}	8.24^{i}	100.40^{hi}	2.24^{b}	2.04^{efg}	2.63^{ab}
	(0.11)	(0.11)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.28)	(0.04)	(0.04)	(0.04)
3	7.53^{ef}	8.27^{bc}	6.32^{ef}	6.09^{b}	9.54^{j}	16.20^{bc}	4.55^{b}	9.14^{g}	104.14^{fg}	2.18^{bc}	1.99^{fgh}	2.61^{ab}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.26)	(0.04)	(0.04)	(0.04)
4	7.76^{e}	8.52^{a}	6.30^{ef}	6.11^{b}	9.93^{i}	16.13^{c}	4.12^{c}	10.35^{e}	105.41^{ef}	2.12^{cd}	1.92^{hij}	2.62^{ab}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
5	8.27^{bcd}	8.55^{a}	6.41^{cdef}	6.14^{b}	10.60^{h}	15.80^{d}	3.71^{d}	11.09^{cd}	106.79^{de}	1.95^{gh}	1.87^{j}	2.53^{bcd}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
6	8.28^{bcd}	8.51^{a}	6.65^{ab}	6.00^{bc}	11.38^{g}	15.73^{d}	3.54^{e}	11.68^{ab}	108.03^{cd}	1.94^{gh}	1.87^{j}	2.42^{e}
	(0.11)	0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
7	8.56^{a}	8.49^{ab}	6.75^{a}	5.67^{de}	12.44^{f}	15.96^{cd}	3.16^{f}	11.98^{a}	110.14^{bc}	1.90^{h}	1.91^{ij}	2.41^{e}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
8	8.29^{abcd}	8.39^{abc}	6.77^{a}	5.45^{f}	13.26^{e}	16.20^{bc}	3.09^{fg}	12.00^{a}	112.58^{a}	1.99^{fgh}	1.96^{ghi}	2.47^{de}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
9	8.41^{abc}	8.24^{cd}	6.71^{a}	5.50^{ef}	13.77^{d}	16.43^{ab}	2.89^{g}	11.83^{a}	113.65^{a}	2.00^{fg}	2.03^{fg}	2.50^{cde}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
10	8.35^{abcd}	8.22^{cd}	6.59^{abc}	5.67^{de}	14.30^{c}	16.56^{a}	2.71^{h}	11.37^{bc}	114.42^{a}	2.02^{efg}	2.05^{ef}	2.57^{bc}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
11	8.48^{ab}	8.01^{de}	6.47^{bcde}	5.85^{cd}	14.47^{c}	16.55^{a}	2.61^{h}	10.72^{de}	113.75^{a}	1.99^{fg}	2.11^{de}	2.62^{ab}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
12	8.46^{ab}	7.84^{e}	6.35^{def}	6.01^{bc}	14.88^{b}	16.64^{a}	2.40^{i}	9.86^{f}	112.32^{ab}	1.99^{fg}	2.16^{d}	2.68^{a}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
13	8.14^{cd}	7.28^{f}	6.57^{abc}	6.15^{b}	14.99^{ab}	16.55^{a}	2.27^{i}	8.71^{h}	108.33^{cd}	2.07^{def}	2.33^{c}	2.56^{cbd}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
14	8.10^{d}	6.81^{g}	6.56^{abcd}	6.38^{a}	15.19^{a}	16.63^{a}	1.91^{j}	7.57^{j}	106.47^{de}	2.09^{de}	2.52^{b}	2.59^{abc}
	(0.11)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
15	7.67^{e}	6.56^{h}	6.58^{abc}	6.48^{a}	15.17^{a}	16.53^{a}	1.71^{k}	6.25^{k}	102.34^{gh}	2.20^{bc}	2.57^{b}	2.57^{bc}
	(0.12)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)
16	6.61^{h}	6.12^{i}	6.26^{ef}	6.16^{b}	14.88^{b}	15.97^{cd}	1.40^{l}	4.12^{l}	89.84^{j}	2.50^{a}	2.68^{a}	2.60^{ab}
	(0.14)	(0.10)	(0.10)	(0.10)	(0.13)	(0.13)	(0.07)	(0.18)	(1.25)	(0.04)	(0.03)	(0.04)

[a-l] Least squares means within a column lacking a common superscript differ ($P < 0.05$).
[1] SEM is the standard error of the least squares means.
[2] Depth at 25% of the length (medial to lateral) of the whole steak in cm.
[3] Depth at 50% of the length (medial to lateral) of the whole steak in cm.
[4] Depth at 75% of the length (medial to lateral) of the whole steak in cm.
[5] Depth of the *longissimus thoracis* (medial to lateral) at 50% of the length of the *longissimus thoracis* in cm.
[6] Length of the *longissimus thoracis* (medial to lateral) in cm.
[7] Length of the whole steak (medial to lateral) in cm.
[8] Depth of the *spinalis dorsi* at the greatest depth in cm.
[9] Length of the *spinalis dorsi* (medial to lateral) in cm.
[10] Area of the whole steak including LT area, SD area, K Fat area, and C area in cm^2.
[11] Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the whole steak (dorsal to ventral) at 25% of the length of the whole steak.
[12] Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the whole steak (dorsal to ventral) at 50% of the length of the whole steak.
[13] Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the whole steak (dorsal to ventral) at 75% of the length of the whole steak.

Table 37. Least squares means for Ribeye Treatment Main effects (SEM[1])

TRT[2]	Measurements									
	25% Depth[3]	50% Depth[4]	75% Depth[5]	LT Depth[6]	Length[7]	Ratio 25[8]	Ratio 50[9]	Ratio 75[10]	SD Length[11]	Total Area[12]
CB	8.47[a]	8.62[a]	7.37[a]	6.67[a]	16.68[a]	2.01[b]	1.98[c]	2.30[b]	10.00[a]	118.92[a]
	(0.11)	(0.11)	(0.10)	(0.10)	(0.16)	(0.04)	(0.04)	(0.04)	(0.18)	(1.64)
Control	7.46[c]	7.23[c]	5.96[c]	5.43[c]	15.82[c]	2.17[a]	2.25[a]	2.71[a]	9.21[b]	96.98[c]
	(0.13)	(0.14)	(0.12)	(0.13)	(0.20)	(0.04)	(0.04)	(0.05)	(0.22)	(2.06)
RH	7.78[bc]	7.56[c]	6.17[bc]	5.71[bc]	16.06[bc]	2.11[ab]	2.18[ab]	2.65[a]	9.20[b]	101.96[c]
	(0.13)	(0.13)	(0.12)	(0.13)	(0.19)	(0.04)	(0.04)	(0.05)	(0.21)	(2.00)
ZH	8.14[b]	8.00[b]	6.44[b]	5.89[b]	16.38[ab]	2.06[ab]	2.11[b]	2.59[a]	9.76[ab]	109.24[b]
	(0.13)	(0.13)	(0.12)	(0.13)	(0.19)	(0.04)	(0.04)	(0.05)	(0.21)	(2.00)

[a-c] Least squares means within a column lacking a common superscript differ ($P < 0.05$).

[1] SEM is the standard error of the least squares means.

[2] CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

[3] Depth at 25% of the length (medial to lateral) of the whole steak in cm.

[4] Depth at 50% of the length (medial to lateral) of the whole steak in cm.

[5] Depth at 75% of the length (medial to lateral) of the whole steak in cm.

[6] Depth of the *longissimus thoracis* (medial to lateral) at 50% of the length of the *longissimus thoracis* in cm.

[7] Length of the whole steak (medial to lateral) in cm.

[8] Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the whole steak (dorsal-ventral) at 25% of the length of the whole steak.

[9] Ratio of the Length of the whole steak (medial to lateral) divided by the depth of the whole steak (dorsal-ventral) at 50% of the length of the entire steak.

[10] Ratio of the Length of the whole steak (medial to lateral) divided by the depth of the whole steak (dorsal-ventral) at 75% of the length of the whole steak

[11] Length of the *spinalis dorsi* (medial to lateral) in cm.

[12] Area of the whole steak including LT area, SD area, K Fat area, and C area in cm^2.

Table 38. Measurement correlations to Rank

	Measurement									
	Length[1]	25% Depth[2]	50% Depth[3]	75% Depth[4]	87% Depth[5]	100% Depth[6]	LL Area[7]	Ratio 25[8]	Ratio 50[9]	Ratio 75[10]
Correlation to Rank	0.10	-0.32	-0.29	-0.30	-0.32	-0.16	-0.30	0.30	0.35	0.30

[1] Length of *longissimus lumborum* (medial to lateral) within steaks in cm.
[2] Depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.
[3] Depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm.
[4] Depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum* in cm.
[5] Depth of *longissimus lumborum* (dorsal to ventral) at 87.5% of the length of the *longissimus lumborum* in cm.
[6] Depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.
[7] Area of *longissimus lumborum* in cm^2
[8] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum*
[9] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum*
[10] Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum*

LITERATURE CITED

Abney, C. S., J. T. Vasconcelos, J. P. McMeniman, S. A. Keyser, K. R. Wilson, G. J. Vogel, and M. L. Galyean. 2007. Effects of ractopamine hydrochloride on performance, rate and variation in feed intake, and acid-base balance in feedlot cattle. J. Anim. Sci. 85: 3090-3098.

Armbruster, G., A. Y. M. Nour, M. L. Thonney, and J. R. Stouffer. 1983. Changes in cooking losses and sensory attributes of Angus and Holstein beef with increasing carcass weight, marbling score or longissimus ether extract. J. Food Sci. 48: 835-840.

Arp, T. S. 2012. EFFECT OF DIETARY BETA-AGONIST SUPPLEMENTATION ON LIVE PERFORMANCE, CARCASS CHARACTERISTICS, CARCASS FABRICATION YIELDS, AND STRIP LOIN TENDERNESS AND SENSORY TRAITS. PhD Diss. Colorado State Univ, Fort Collins.

Avendaño-Reyes, L., V. Torres-Rodríguez, F. J. Meraz-Murillo, C. Pérez-Linares, F. Figueroa-Saavedra, and P. H. Robinson. 2006. Effects of two β-adrenergic agonists on finishing performance, carcass characteristics, and meat quality of feedlot steers. J. Anim. Sci. 84: 3259-3265.

Beckett, J. L., R. J. Delmore, G. C. Duff, D. A. Yates, D. M. Allen, T. E. Lawrence, and N. Elam. 2009. Effects of zilpaterol hydrochloride on growth rates, feed conversion, and carcass traits in calf-fed Holstein steers. J. Anim. Sci. 87: 4092-4100.

Cheatham, R. C., and G. C. Duff. Implant Programs for Long-fed Holstein Steers. 2004. In Proc. 19th Annual Southwest Nutr. Manage. Conf., Univ. of Arizona, Tucson. Univ. Arizona, Tucson. p. 83-94.

Cohen, S.H., and L. Neira. 2003. Measuring preference for product benefits across countries: Overcoming scale usage bias with maximum difference scaling. Paper presented at the ESOMAR 2003 Latin America Conference, Punta del Este, Uraguay.

Dikeman, M. E. 2007. Effects of metabolic modifiers on carcass traits and meat quality. Meat Science: 77: 121-135.

Duff, G. C., and P. T. Anderson. 2007. Comparative performance of Holstein vs. beef breeds in the feedlot. In Proc. 22nd Annual Southwest Nutr. Manage. Conf., Univ. of Arizona, Tucson. Univ. Arizona, Tucson, pp. 27-36.

Duff, G. C., and C. P. McMurphy. 2007. Feeding Holstein steers from start to finish. Veterinary Clinics of North America: Food Animal Practice 23: 281-297.

Garmyn, A. J., J. N. Shook, D. L. VanOverbeke, J. L. Beckett, R. J. Delmore, D. A. Yates, D. M. Allen, and G. G. Hilton. 2010. The effects of zilpaterol hydrochloride on carcass cutability and tenderness of calf-fed Holstein steers. J. Anim. Sci. 88: 2476-2485.

Hilton, G. G., A. J. Garmyn, T. E. Lawrence, M. F. Miller, J. C. Brooks, T. H. Montgomery, D. B. Griffin, D. L. VanOverbeke, N. A. Elam, W. T. Nichols, M. N. Streeter, J. P. Hutcheson, D. M. Allen, and D. A. Yates. 2010. Effect of zilpaterol hydrochloride supplementation on cutability and subprimal yield of beef steer carcasses. J. Anim. Sci. 88: 1817-1822.

Howard, S.T., 2013. BEEF TENDERNESS AND THE MANAGEMENT OF CALF-FED HOLSTEIN STEERS TO MEET MARKET STANDARDS. PhD Diss. Colorado State Univ, Fort Collins.

Howard, S.T., D.R. Woerner, D.J. Vote, J.A. Scanga, R.J. Acheson, P.L. Chapman, T.C. Bryant, J.D. Tatum and K.E. Belk. 2014a. Effects of ractopamine hydrochloride and zilpaterol hydrochloride supplementation on carcass cutability of calf-fed Holstein steers. J. Anim. Sci. 92: 369-375.

Howard, S.T., D.R. Woerner, D.J. Vote, J.A. Scanga, P.L. Chapman, T.C. Bryant, R.J. Acheson, J.D. Tatum and K.E. Belk. 2014b.Effects of ractopamine hydrochloride and zilpaterol hydrochloride supplementation on longissimus muscle shear force and sensory attributes of calf-fed Holstein steers. J. Anim. Sci. 92: 376-383.

Killinger, K.M., C.R. Calkins, W.J. Umberger, D.M. Feus and K.M. Eskridge. 2004. Consumer visual preference and value for beef steaks differing in marbling level and color. J. Anim. Sci. 82: 3288-3293.

Knapp, R. H., C. A. Terry, J. W. Savell, H. R. Cross, W. L. Mies and J. W. Edwards. 1989. Characterization of Cattle Types to Meet Specific Beef Targets. J. Anim. Sci. 67: 2294-2308.

Lawrence, T. E., D. M. Allen, R. J. Delmore, J. L. Beckett, W. T. Nichols, M. N. Streeter, D. A. Yates, and J. P. Hutcheson. 2011. Technical note: Feeding zilpaterol hydrochloride to calf-fed Holstein steers improves muscle conformation of top loin steaks. Meat Science 88: 209-211.

Louviere, J.J., and T. Islam. 2008. A comparison of importance weights and willingness-to-pay measures derived from choice-based conjoint, constant sum scales and best-worst scaling. J. Bus. Res. 61:903-911.

McKenna, D. R., D. L. Roebert, P. K. Bates, T. B. Schmidt, D. S. Hale, D. B. Griffin, J. W. Savell, J. C. Brooks, J. B. Morgan, T. H. Montgomery, K. E. Belk, and G. C. Smith. 2002. National Beef Quality Audit-2000: survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. 80: 1212-1222.

Montgomery, J. L., C. R. Krehbiel, J. J. Cranston, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, D. T. Bechtol, E. Johnson, T. TerHune, and T. H. Montgomery. 2009. Dietary zilpaterol hydrochloride. I. Feedlot performance and carcass traits of steers and heifers. J. Anim. Sci. 87: 1374-1383.

Moore, M. C., G. D. Gray, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, K. E. Belk, D. R. Woerner, J. D. Tatum, J. L. Igo, D. L. VanOverbeke, G. G. Mafi, T. E. Lawrence, R. J. Delmore Jr., L. M. Christensen, S. D. Shackelford, D. A. King, T. L., Wheeler, L. R. Meadows, and M. E. O'Connor. 2012. National Beef Quality Audit– 2011: In-plant survey of targeted carcass characteristics related to quality, quantity, value, and marketing of fed steers and heifers. J. Anim. Sci. 90: 5143-5151.

National Agriculture Statistics Service (NASS). 2013. Statistics by Subject. Accessed May, 2014. http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=ANIMALS%20&%20PRODUCTS.

Nour, A. Y. M., M. L. Thonney, J. R. Stouffer and W. R. C. White. 1981. Muscle, fat and bone in serially slaughtered large dairy or small beef cattle fed corn or corn silage diets in one of two locations. J. Anim. Sci. 52: 512-521.

Nour, A. Y. M., M. L. Thonney, J. R. Stouffer, and W. R. C. White. 1983. Changes in carcass weight and characteristics with increasing weight of large and small cattle. J. Anim. Sci. 57: 1154-1165.

O'Quinn, T.G., 2012. IDENTIFYING PREFERENCES FOR SPECIFIC BEEF FLAVOR CHARACTERISTICS. PhD Diss. Colorado State Univ, Fort Collins.

Perry, T. C., D. G. Fox, and D. H. Beermann. 1991. Effect of an implant of trenbolone acetate and estradiol on growth, feed efficiency, and carcass composition of Holstein and beef steers. J. Anim. Sci. 69: 4696-4702.

Platter, W. J., J. D. Tatum, K. E. Belk, S. R. Koontz, P. L. Chapman and G. C. Smith. 2005. Effects of marbling and shear force on consumers' willingness to pay for beef strip loin steaks. J. Anim. Sci. 83:890-899.

Ramsey, C. B., J. W. Cole, Bernadine H. Meyer, and R. S. Temple. 1963. Effects of type and breed of British, Zebu and dairy cattle on production, palatability and composition. II. Palatability differences and cooking losses as determined by laboratory and family panels. J. Anim. Sci. 22: 1001-1008.

Schaefer, D. M. 2005. Yield And Quality of Holstein Beef. Schaefer, Daniel M. Managing & Marketing Quality Holstein Steers Proceedings. University of Minnesota Dairy Extension, Rochester, MN. Accessed May, 2014. www.extension.umn.edu/dairy/holsteinsteers/pdfs/papers/YieldAndQuality_Schaefer.pdf.

Scheffler, J. M., D. D. Buskirk, S. R. Rust, J. D. Cowley, and M. E. Doumit. 2003. Effect of repeated administration of combination trenbolone acetate and estradiol implants on growth, carcass traits, and beef quality of long-fed Holstein steers. J. Anim. Sci. 81: 2395-2400.

Sweeter, K.K., D.M. Wulf, and R.J. Maddock. 2005. Determining the optimum beef longissimus muscle size for retail consumers. J. Anim. Sci. 83: 2598-2604.

Thonney, M. L., A. Y. M. Nour, J. R. Stouffer, and W. R. C. White Jr. 1984. Changes in primal cuts with increasing carcass weight in large and small cattle. Canadian J. of Anim. Sci. 64: 29-38.

Thonney, M. L., T. C. Perry, G. Armbruster, D. H. Beermann, and D. G. Fox. 1991. Comparison of steaks from Holstein and Simmental x Angus steers. J. Anim. Sci. 69: 4866-4870.

Tronstad, R., and J. Unterschultz. 2005. Looking beyond value-based pricing of beef in North America. Supply Chain Mgmt.: an Intl. J. 10:214-222.

UDSA-ERS. 2014. Livestock and Meat Domestic Data. Accessed May, 2014. http://www.ers.usda.gov/topics/animal-products/cattle-beef/statistics-information.aspx#.U7nZ7nmy5eU

APPENDIX A

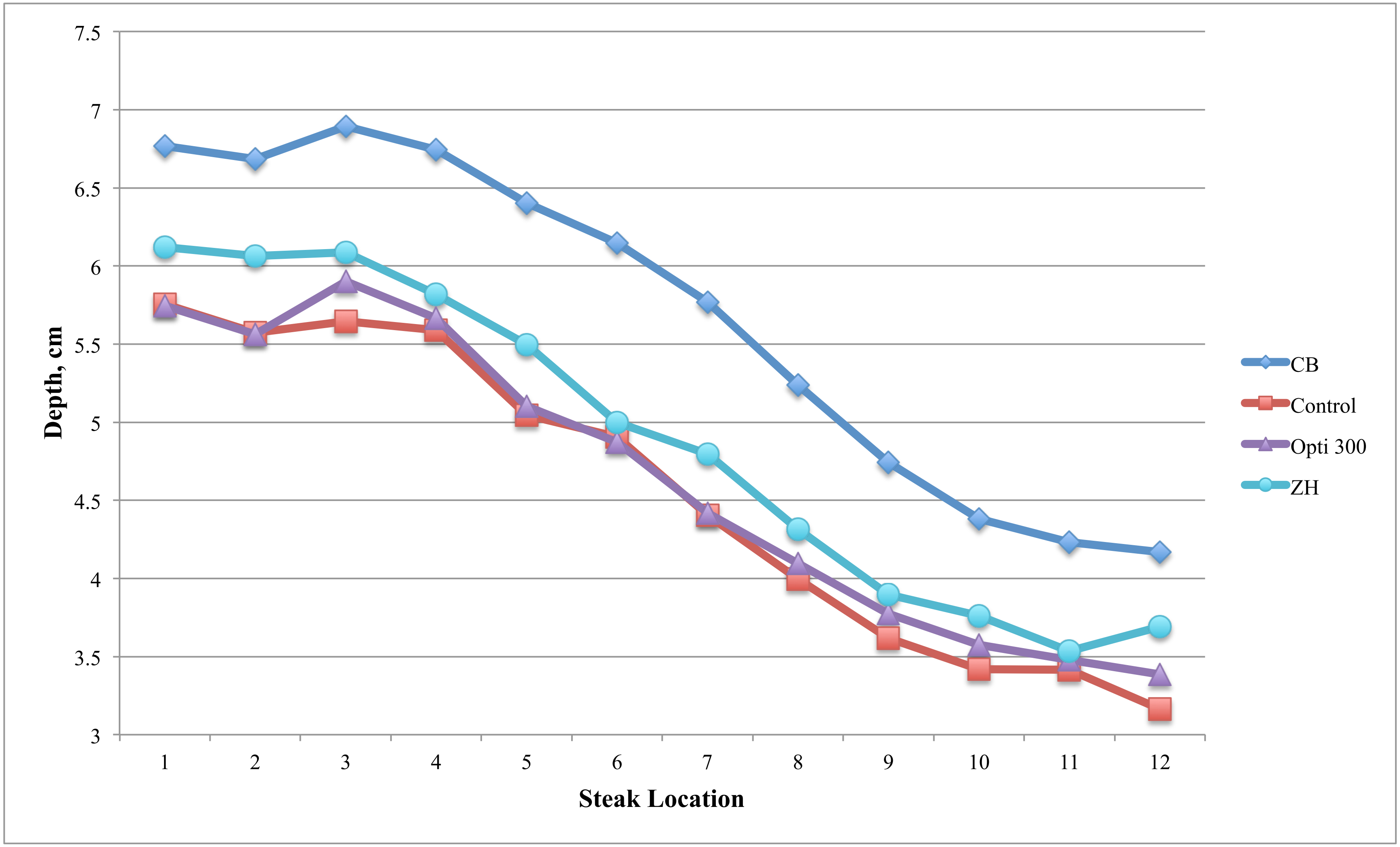

Figure A.1. Least squares means for Strip Loin 75% Depth measurements interaction for treatment and steak location. 75% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

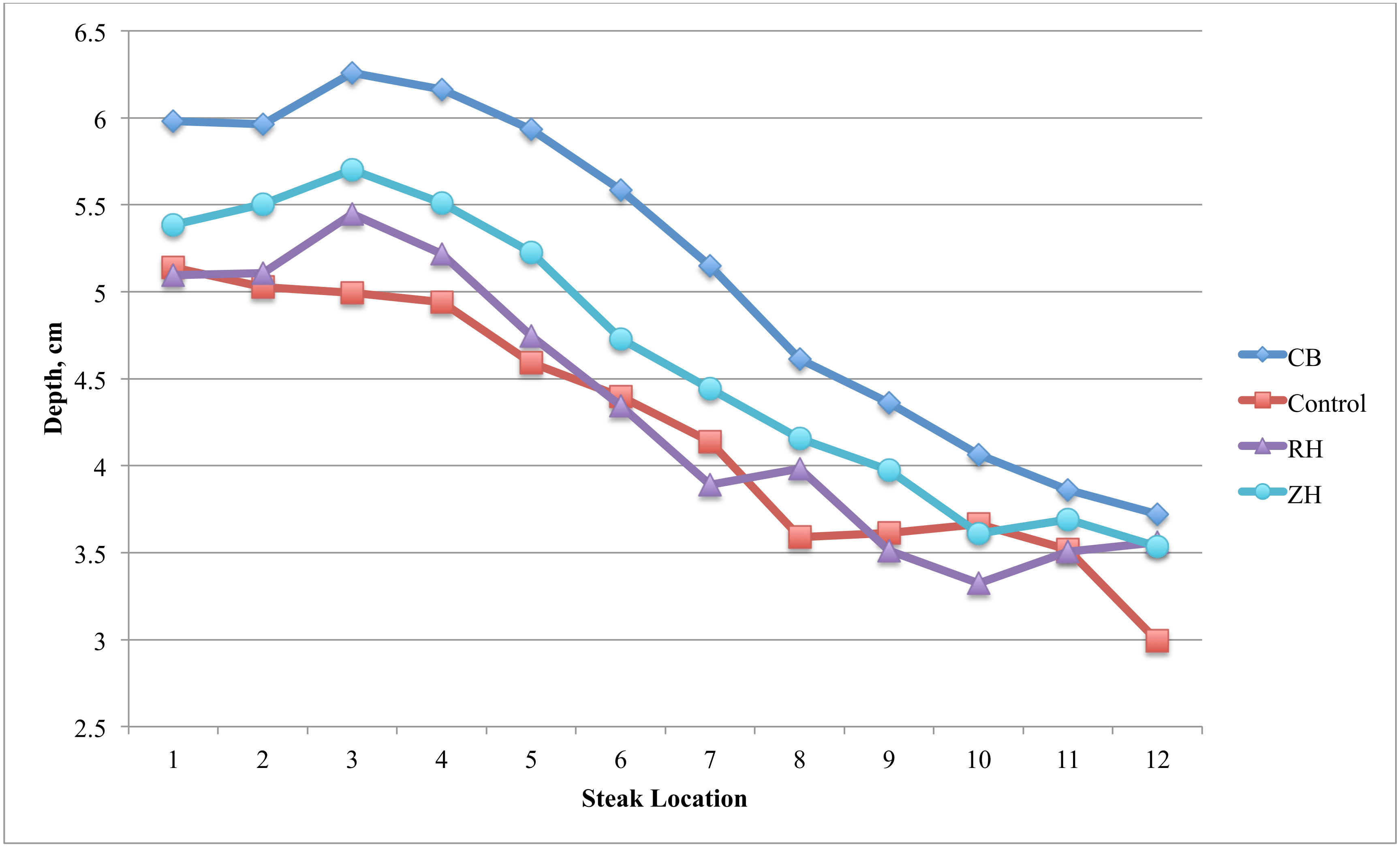

Figure A.2. Least squares means for Strip Loin 87.5% Depth measurements interaction for treatment and steak location. 87.5% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 87.5% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

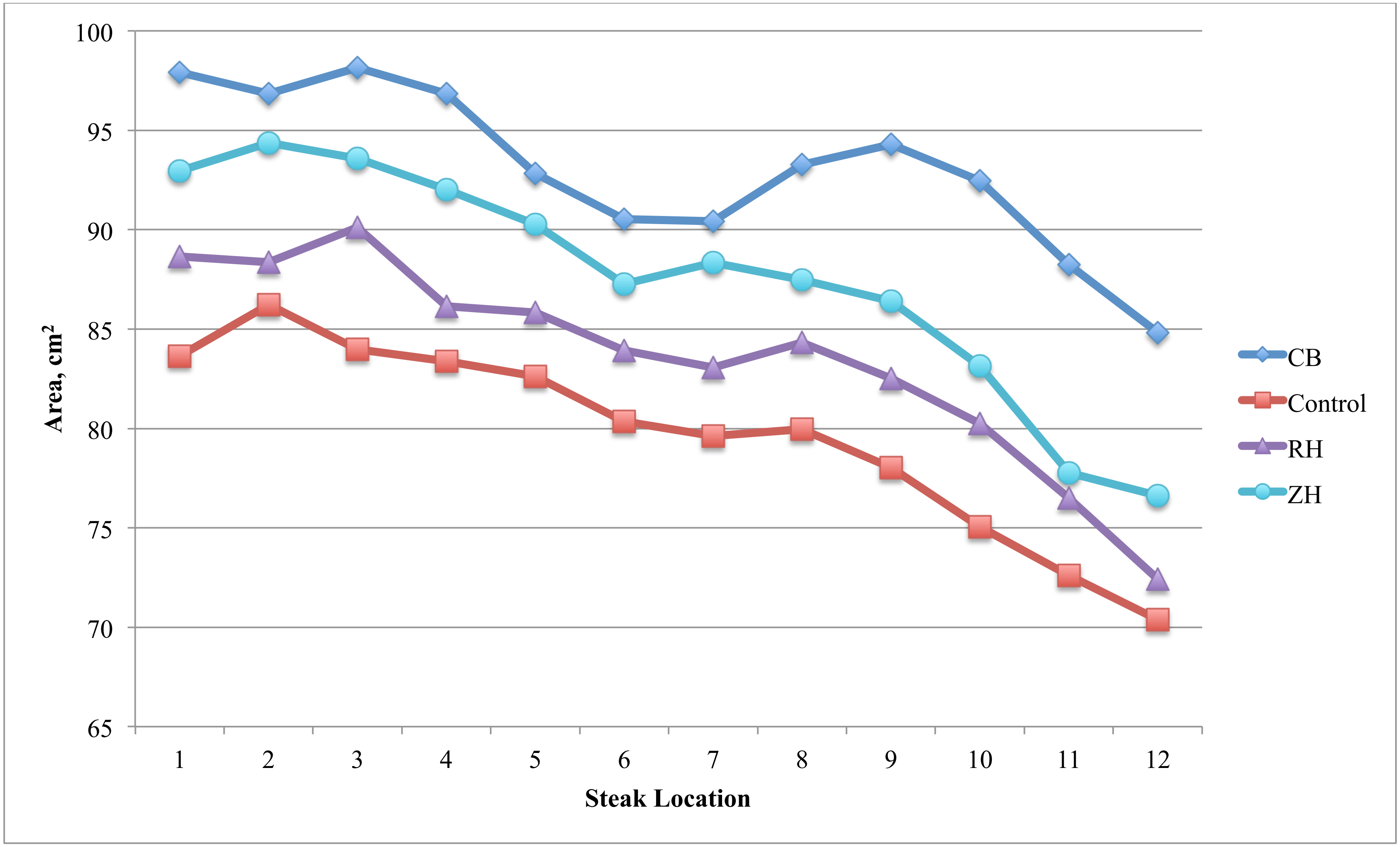

Figure A.3. Least squares means for Strip Loin LL Area measurements interaction for treatment and steak location. Area- Area of *longissimus lumborum* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

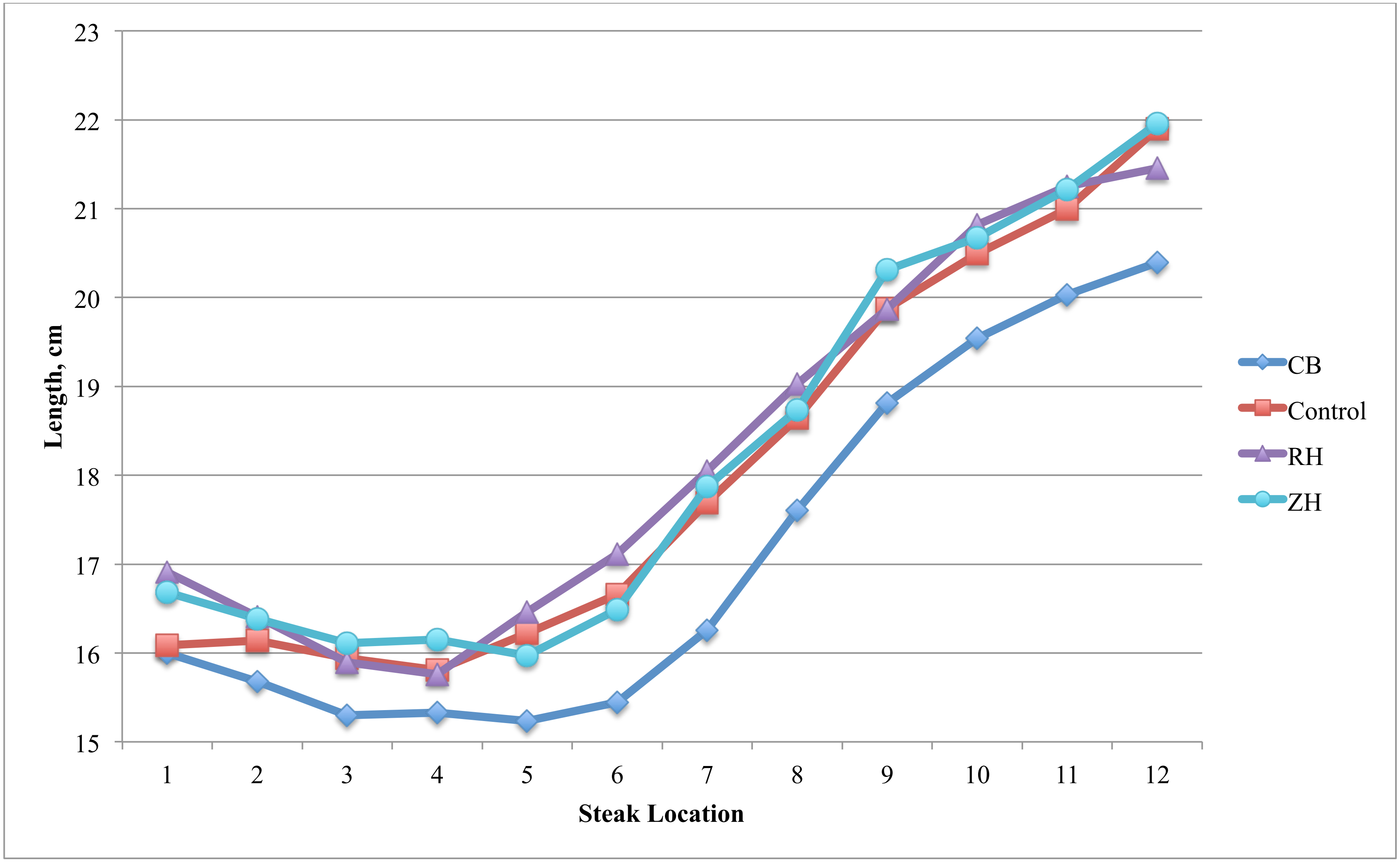

Figure A.4. Least squares means for Strip Loin Length measurements interaction for treatment and steak location. Length- Length of *longissimus lumborum* (medial to lateral) within steaks in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

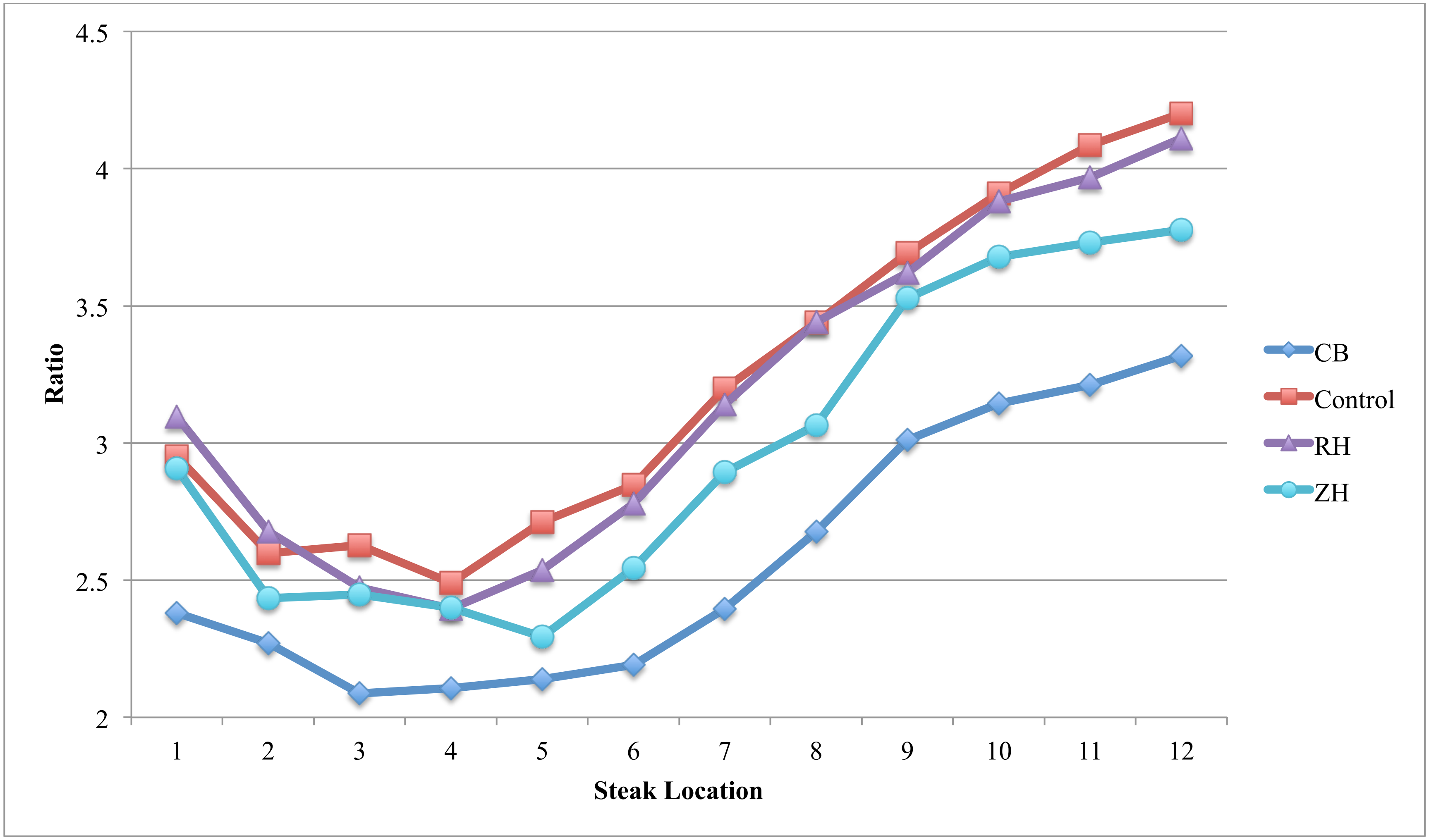

Figure A.5. Least squares means for Strip Loin Ratio 25 measurements interaction for treatment and steak location. Ratio 25- Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum***.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Figure A.6. Least squares means for Strip Loin Ratio 50 measurements interaction for treatment and steak location. Ratio 50- Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum***.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

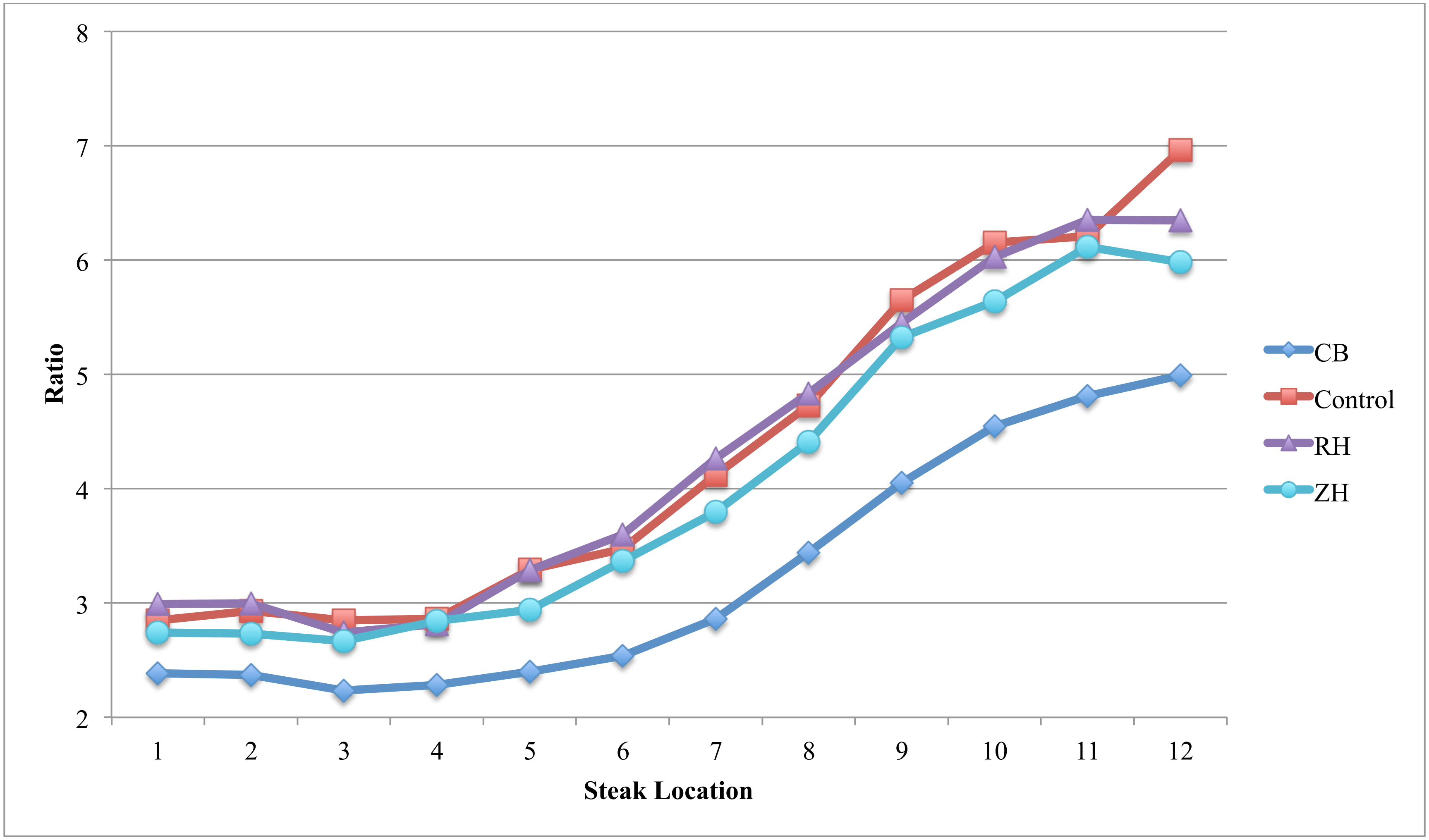

Figure A.7. Least squares means for Strip Loin Ratio 75 measurements interaction for treatment and steak location. Ratio 75- Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum*. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

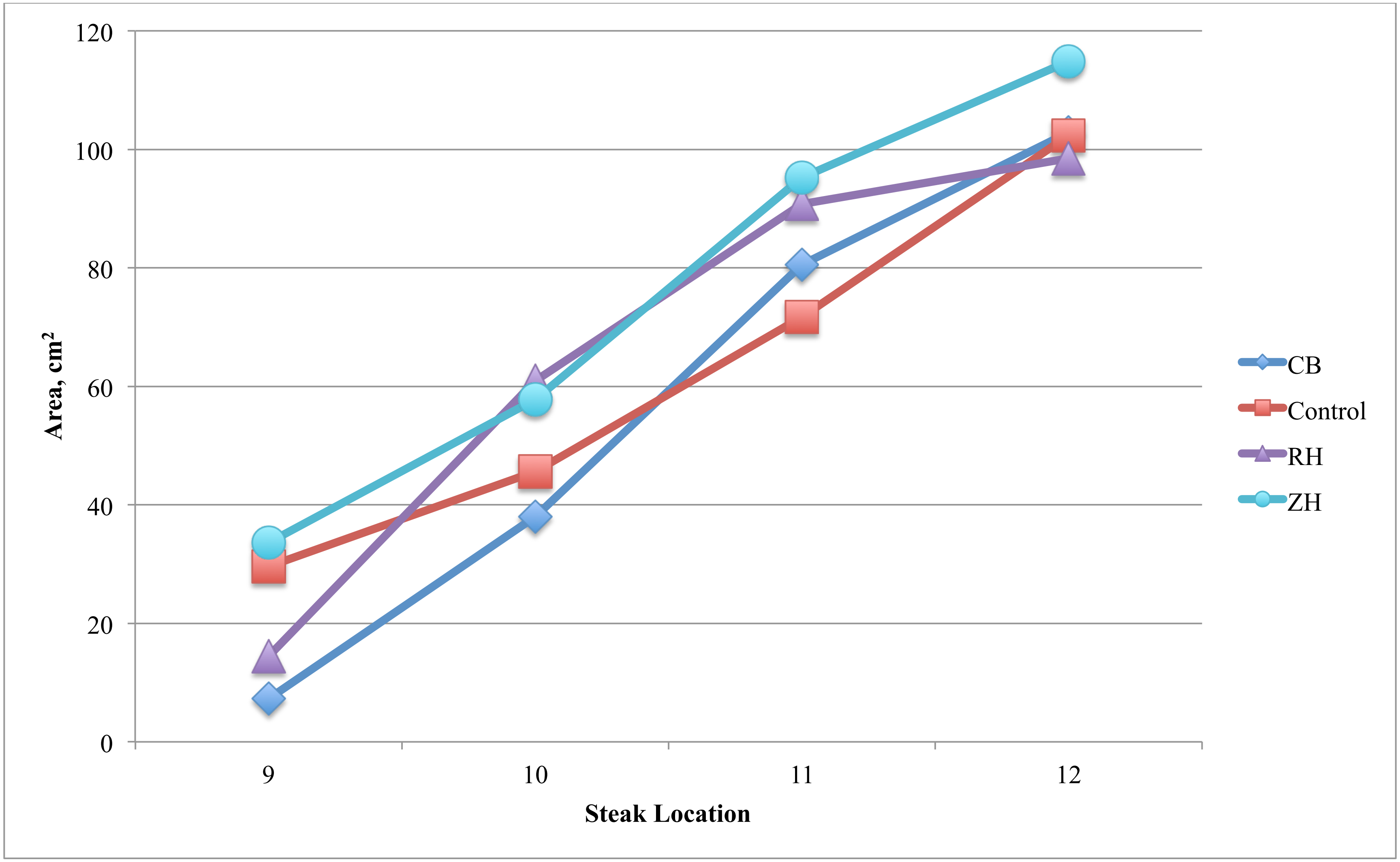

Figure A.8. Least squares means for Strip Loin Total Area measurements interaction for treatment and steak location. Total Area- Area of *longissimus lumborum* + area of the *glutues medius* in cm^2**.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

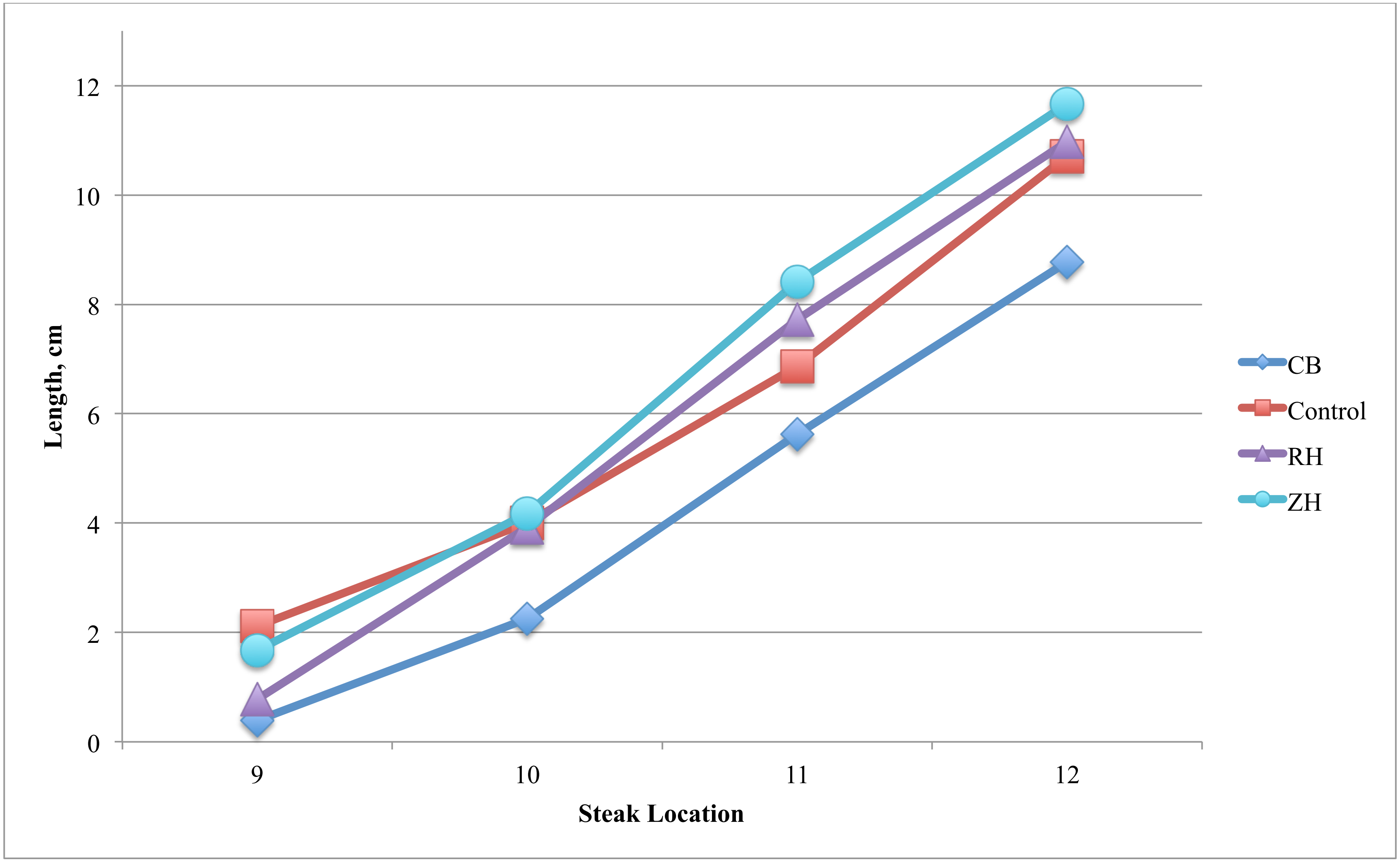

Figure A.9. Least squares means for Strip Loin GM Length measurements interaction for treatment and steak location. GM Length- Length of *gluteus medius* (medial to lateral) in cm**.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

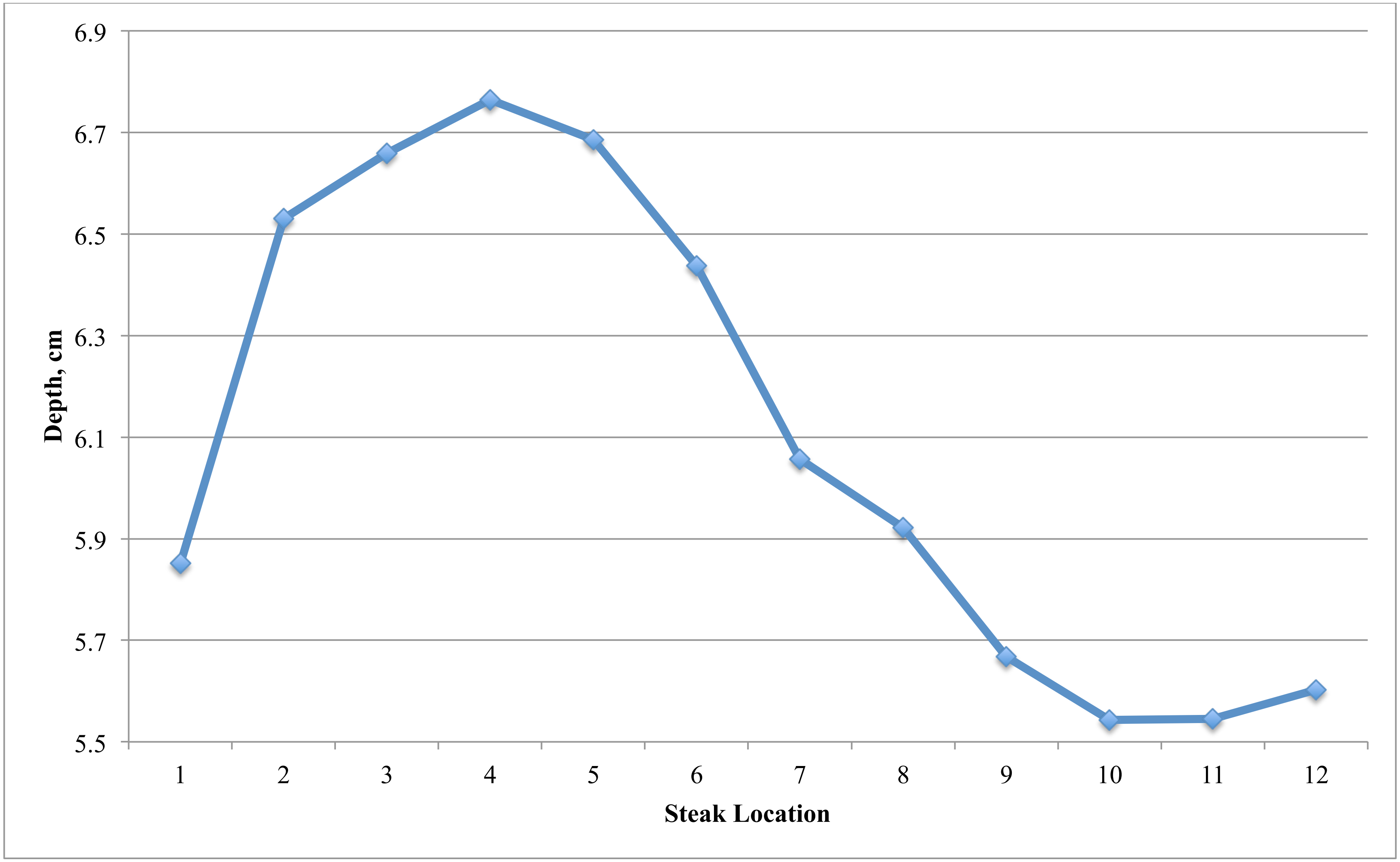

Figure A.10. Least squares means for Strip Loin 25% Depth measurements Steak location Main effect. 25% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm.

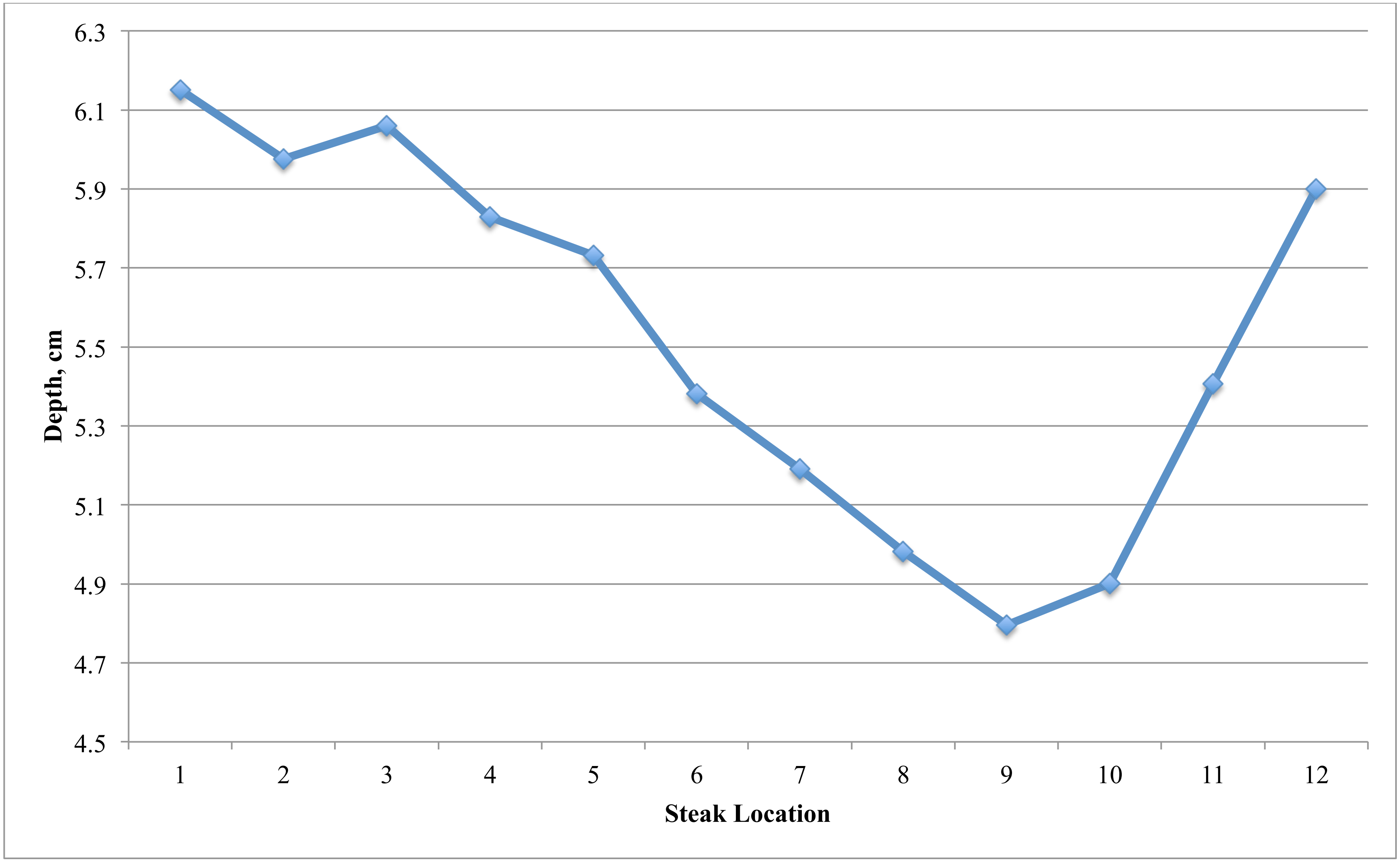

Figure A.11 Least squares means for Strip Loin 50% Depth measurements Steak location Main effect. 50% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm.

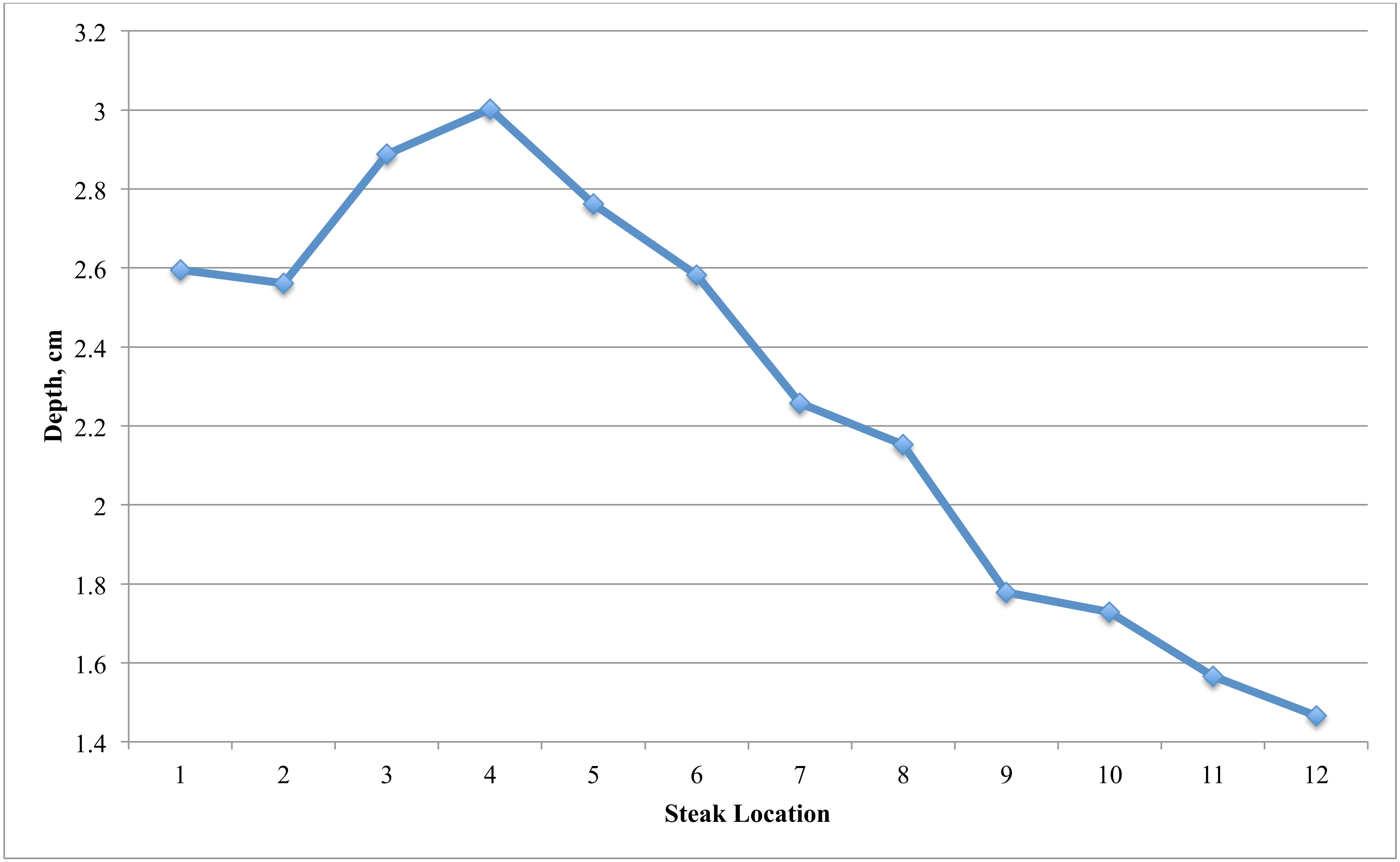

Figure A.12 Least squares means for Strip Loin 100% Depth measurements Steak location Main effect. 100% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.

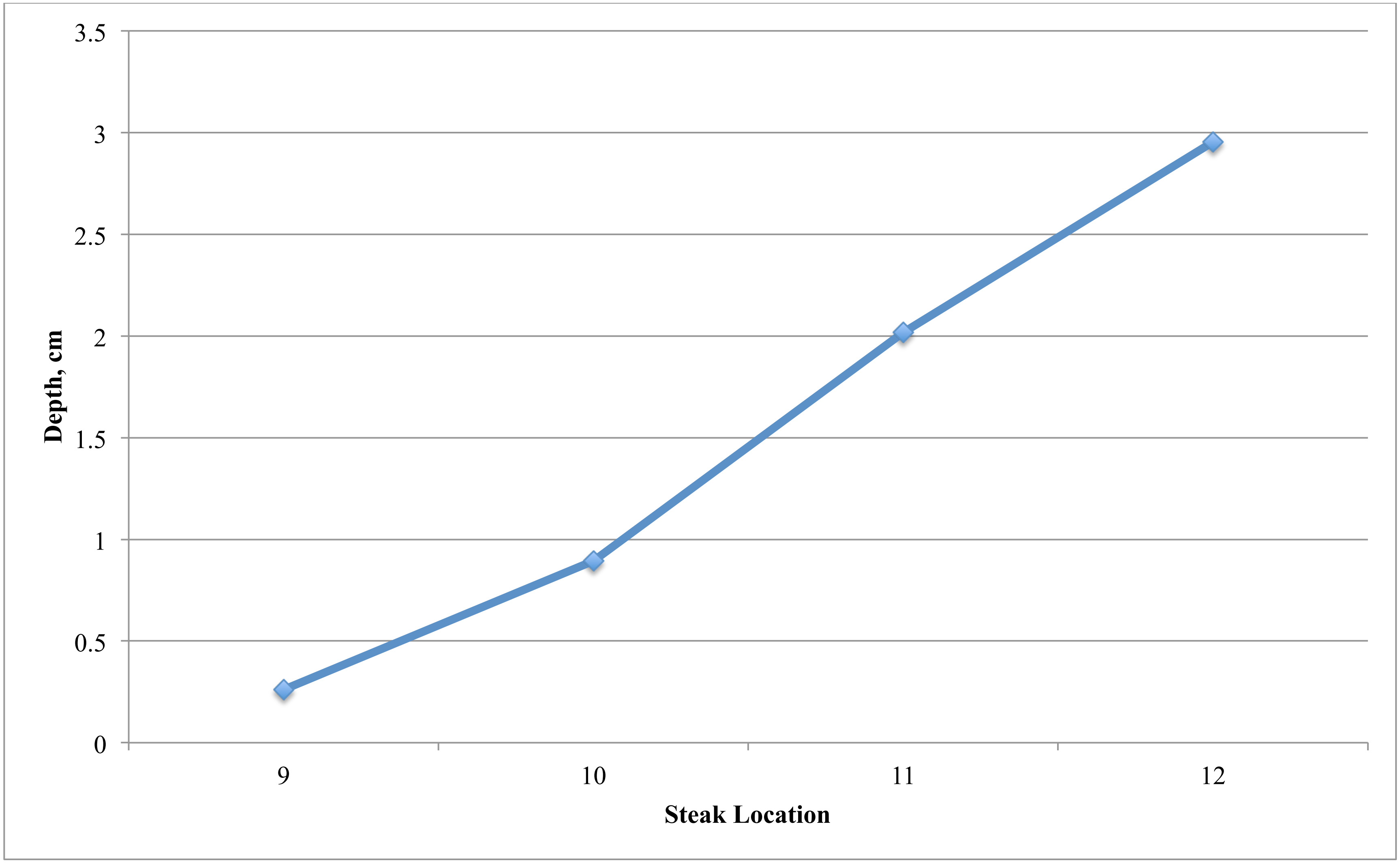

Figure A.13 Least squares means for Strip Loin GM Depth measurements Steak location Main effect. GM Depth- Depth of the *gluteus medius* in cm.

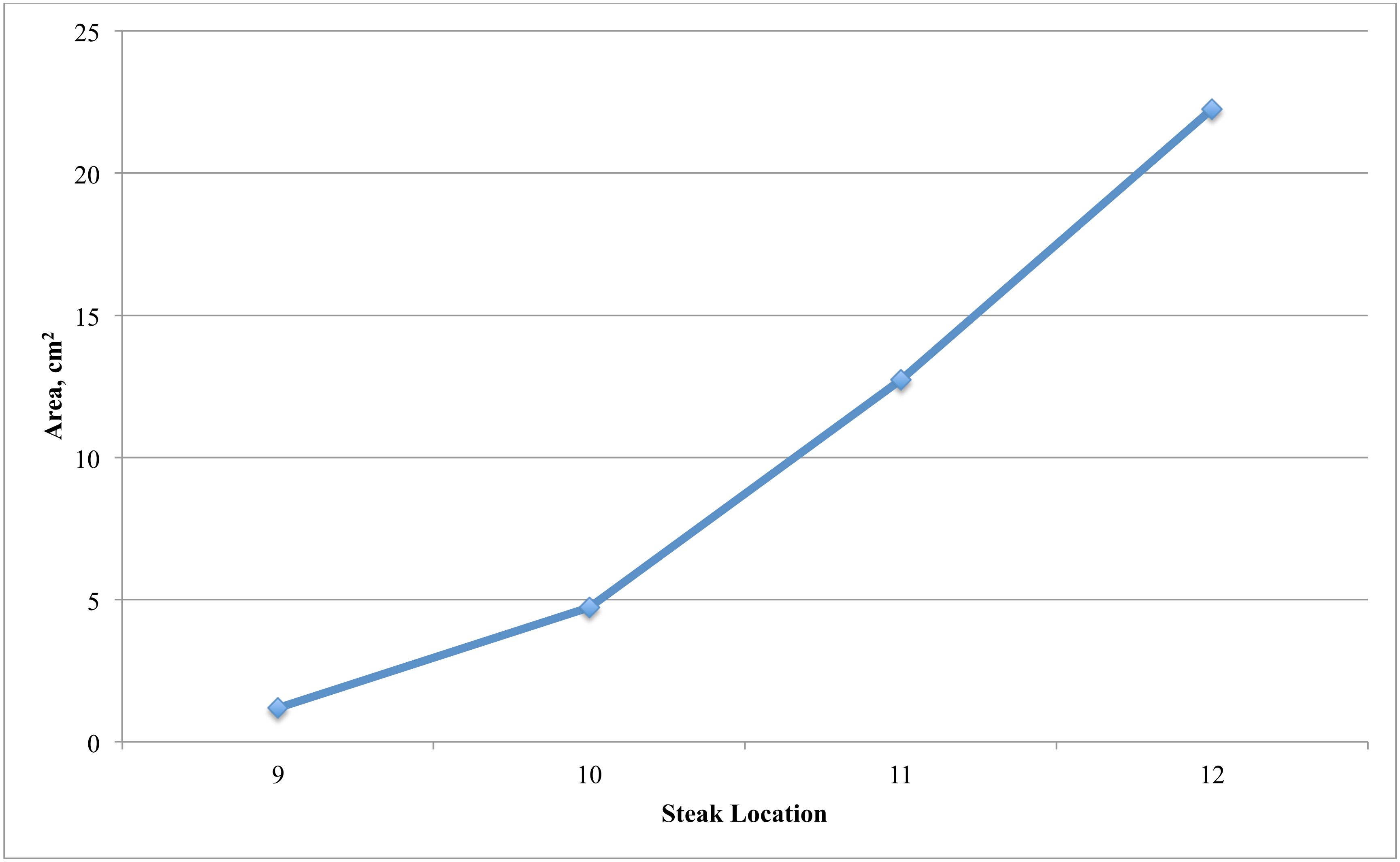

Figure A.14 Least squares means for Strip Loin GM Area measurements Steak location Main effect. GM Area- Area of the *gluteus medius* in cm^2.

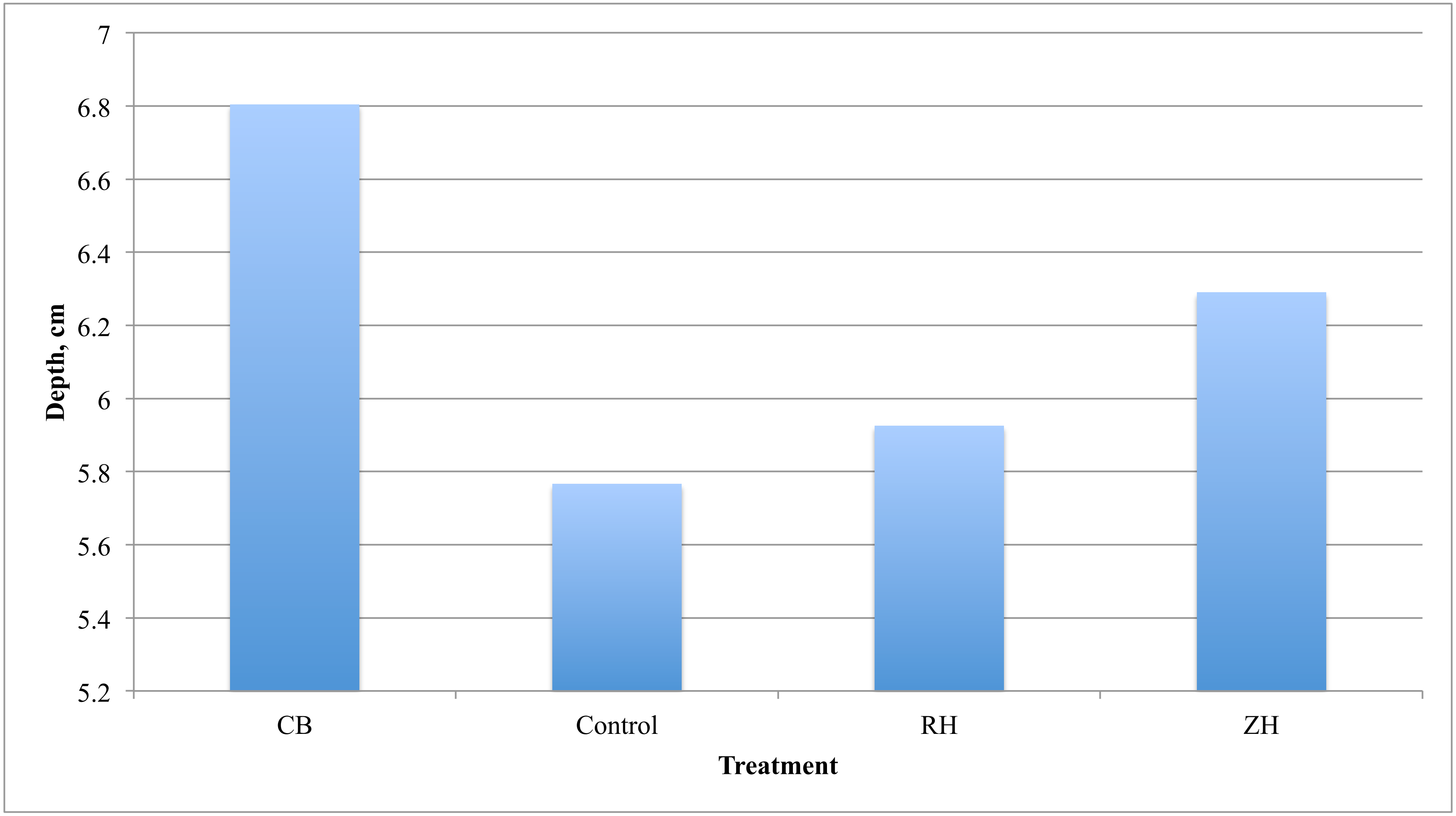

Figure A.15. Least squares means for Strip Loin 25% Depth measurements Treatment Main effect. 25% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

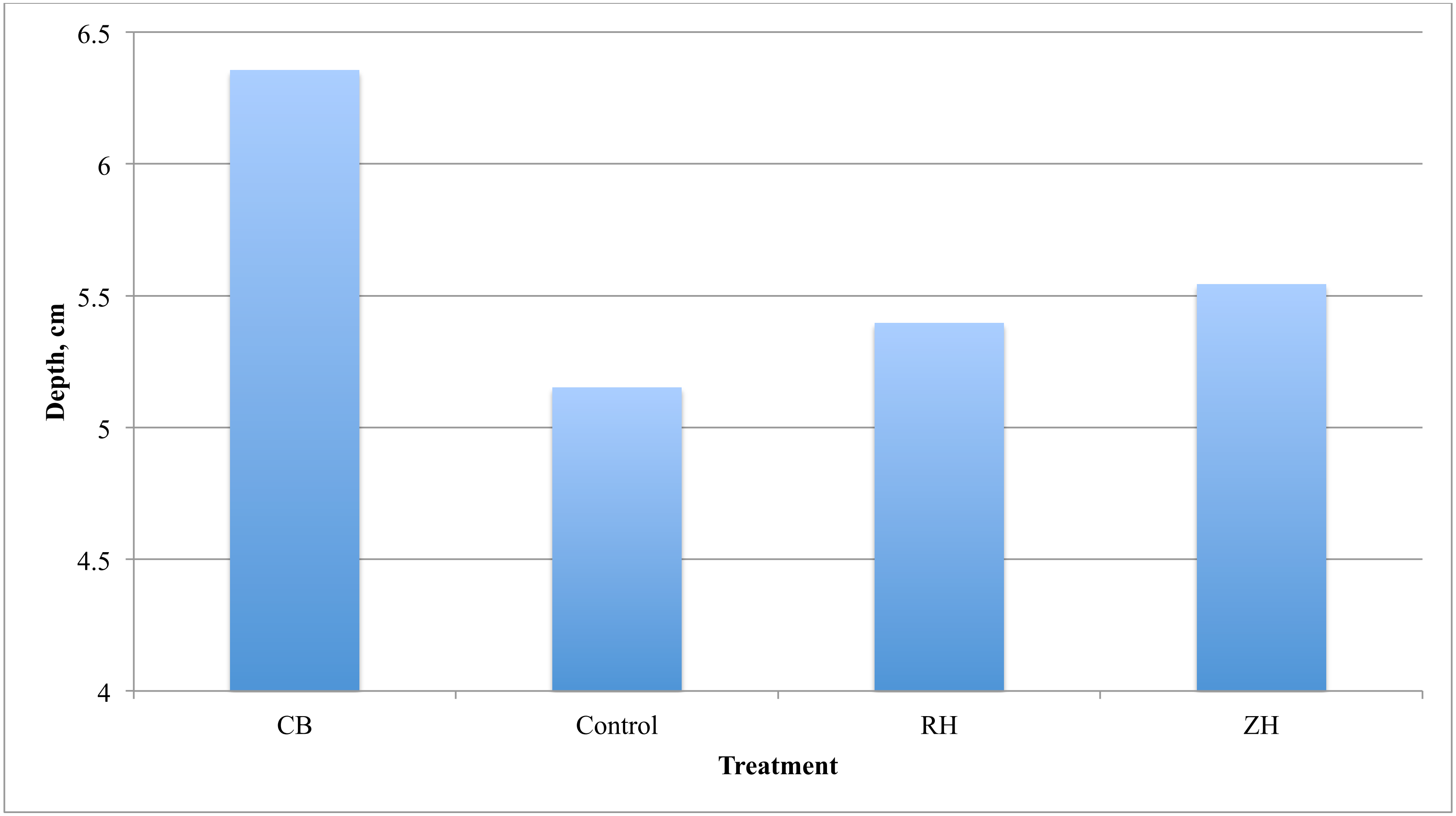

Figure A.16 Least squares means for Strip Loin 50% Depth measurements Treatment Main effect. 50% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

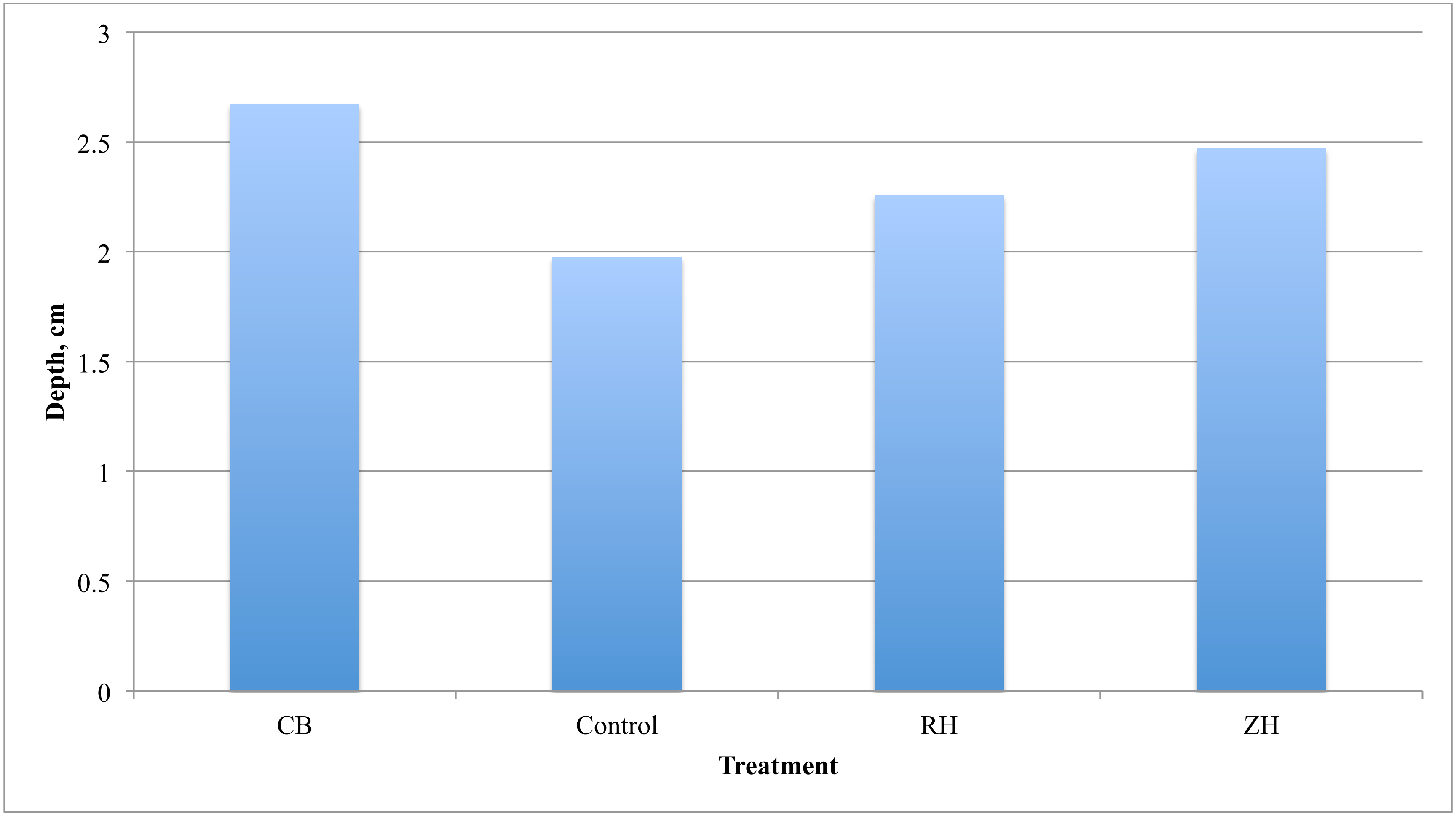

Figure A.17 Least squares means for Strip Loin 100% Depth measurements Treatment Main effect. 100% Depth measurement is the depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

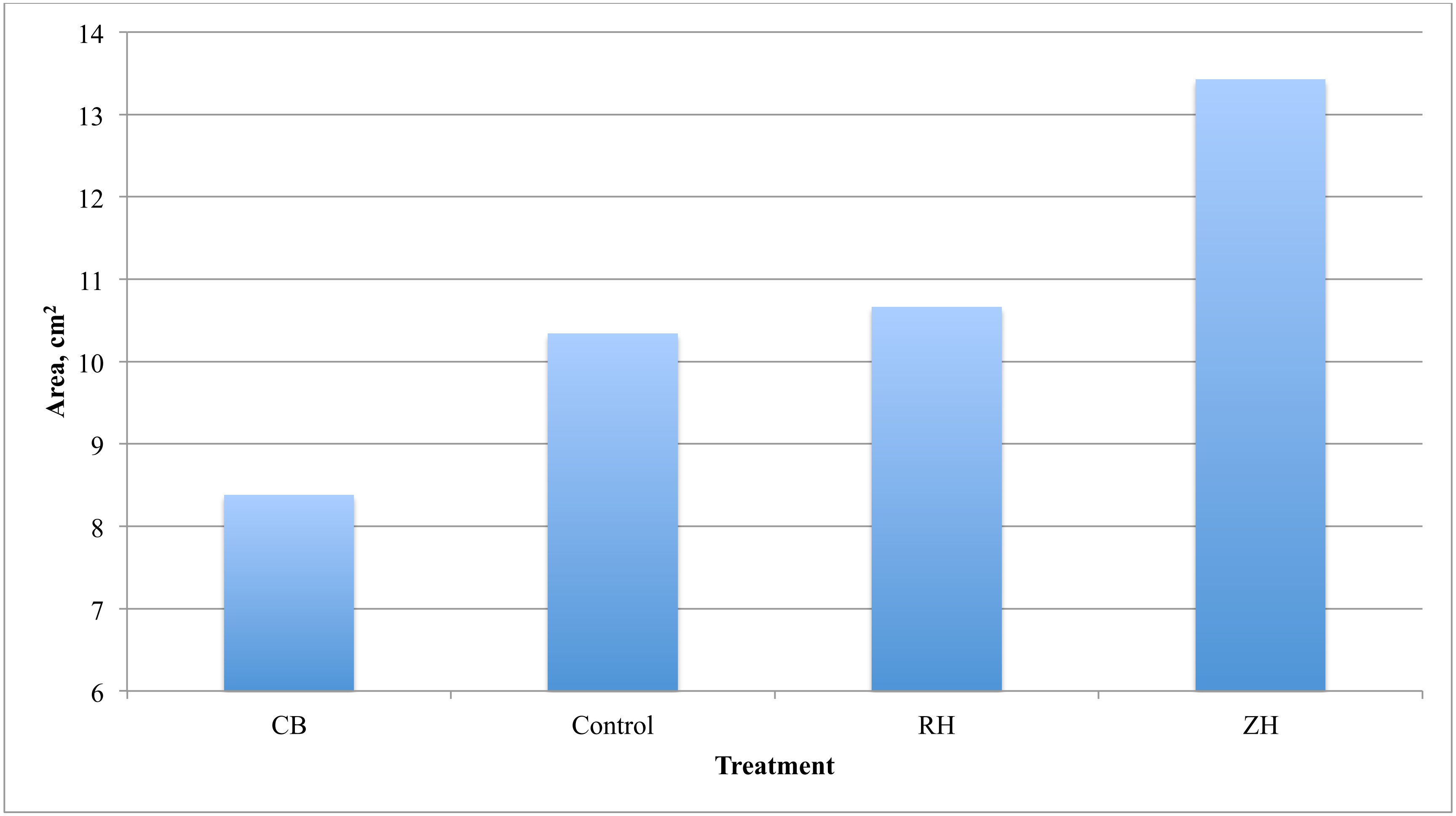

Figure A.18 Least squares means for Strip Loin GM Area measurements Treatment Main effect. GM Area- Area of the *gluteus medius* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

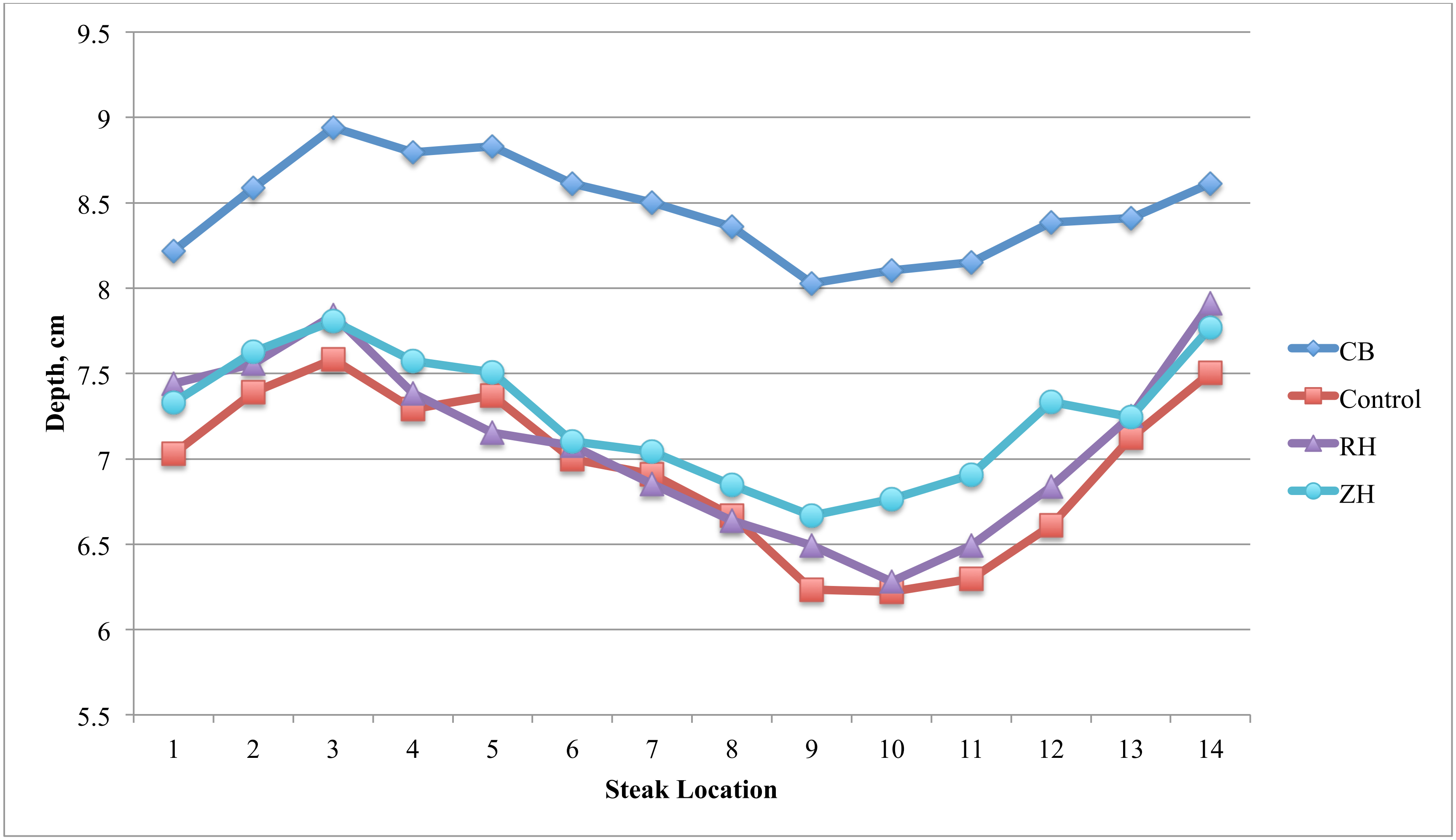

Figure A.19. Least squares means for Short Loin 25% Depth measurements interaction for treatment and steak location. 25% Depth- depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Figure A.20. Least squares means for Short Loin 50% Depth measurements interaction for treatment and steak location. 50% Depth- depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

Figure A.21. Least squares means for Short Loin 75% Depth measurements interaction for treatment and steak location. 75% Depth- depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

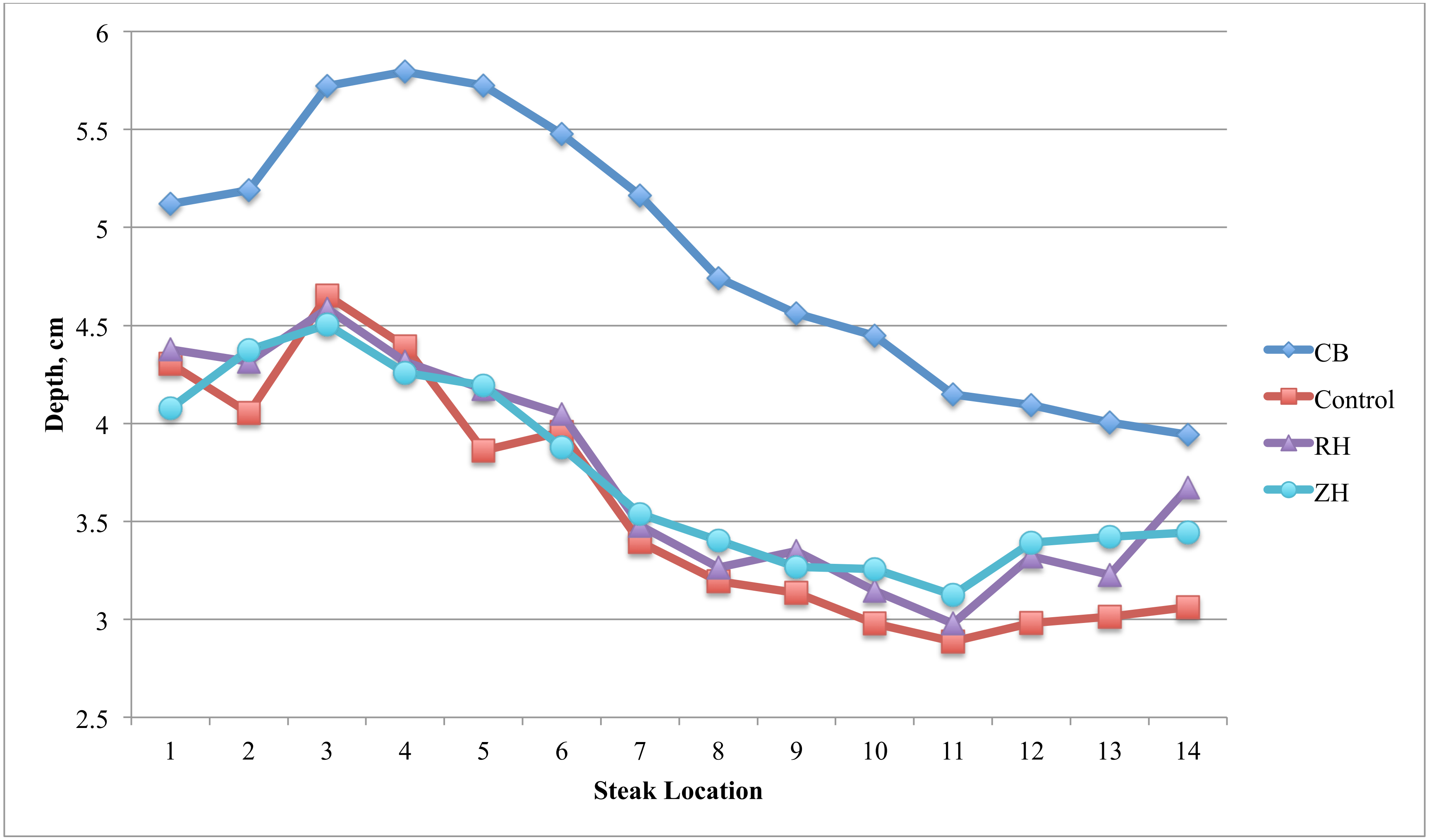

Figure A.22. Least squares means for Short Loin 87.5% Depth measurements interaction for treatment and steak location. 87.5% Depth- depth of *longissimus lumborum* (dorsal to ventral) at 87.5% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

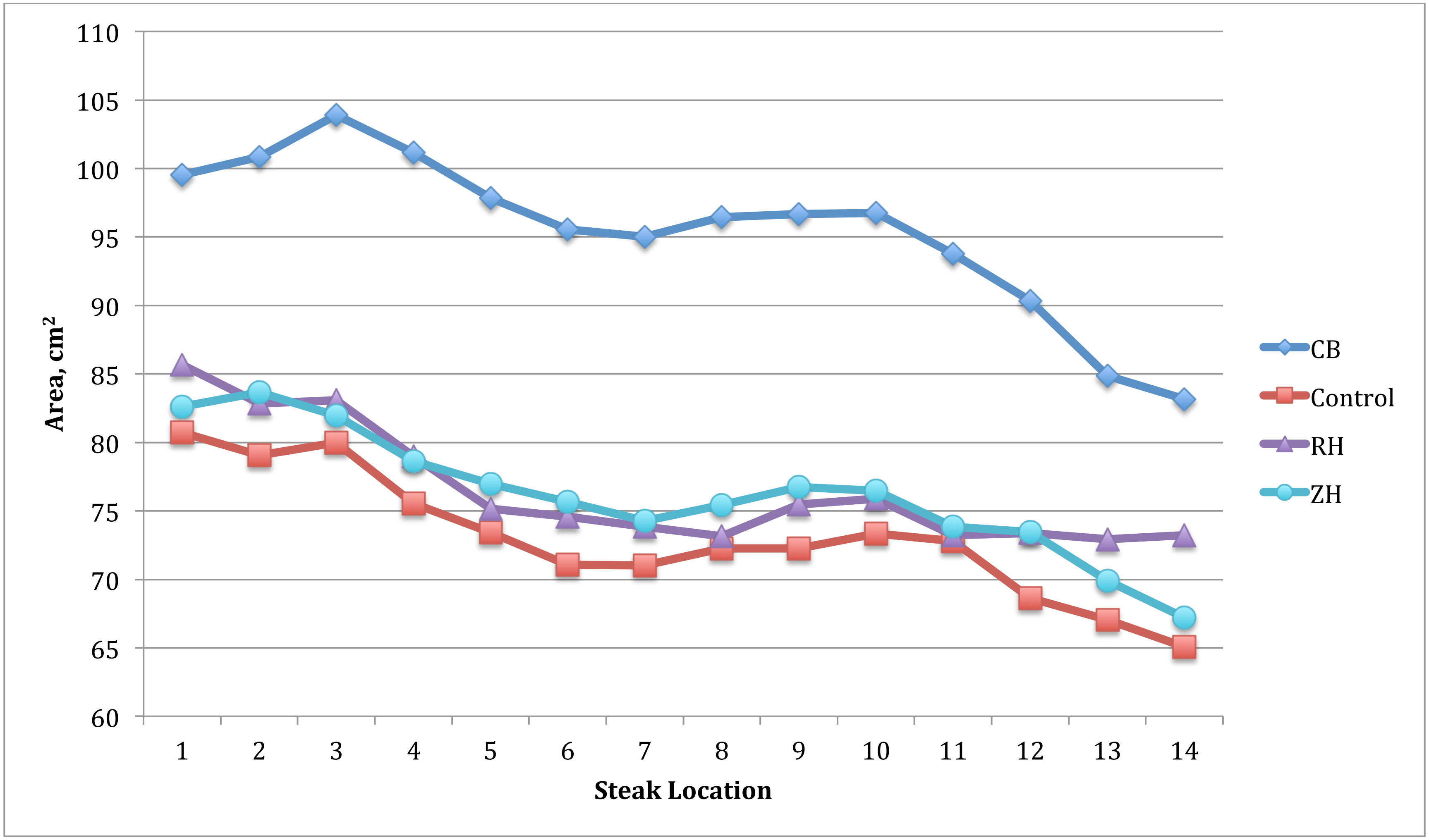

Figure A.23. Least squares means for Short Loin LL Area measurements interaction for treatment and steak location. Area- Area of *longissimus lumborum* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

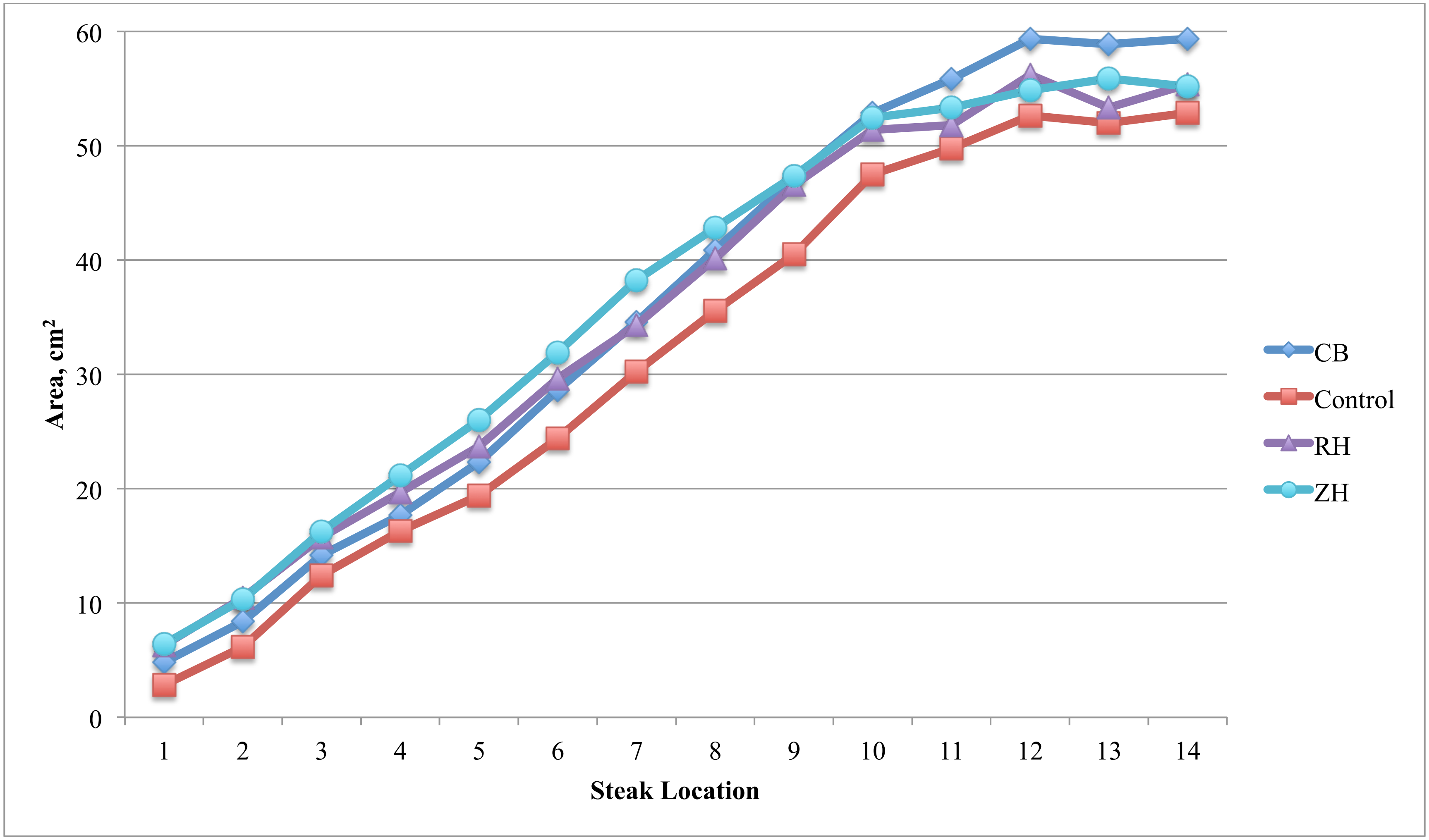

Figure A.24. Least squares means for Short Loin PM Area measurements interaction for treatment and steak location. PM Area- Area of *psoas major* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

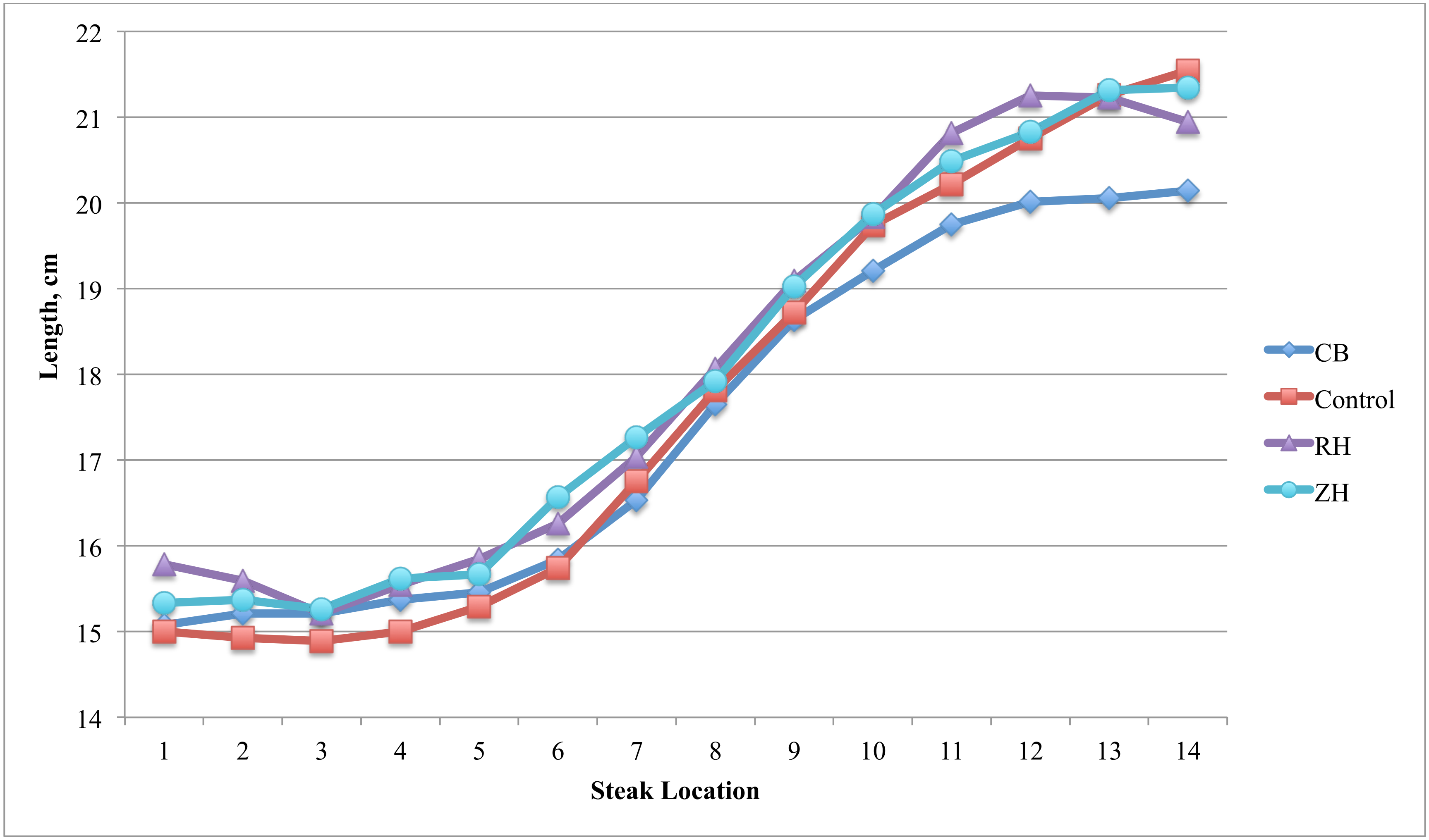

Figure A.25. Least squares means for Short Loin Length measurements interaction for treatment and steak location. Length- Length of *longissimus lumborum* (medial to lateral) within steaks in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

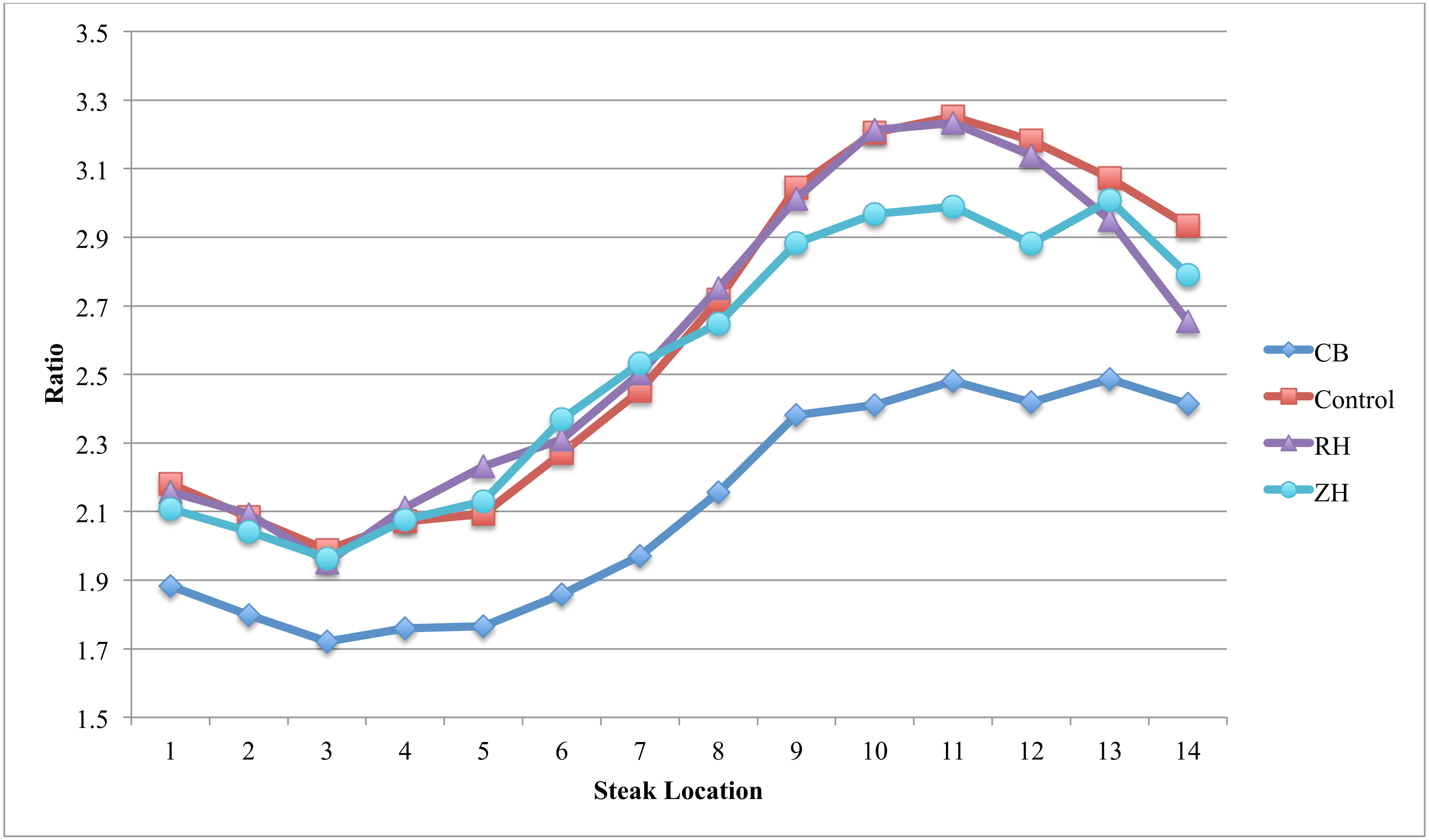

Figure A.26. Least squares means for Short Loin Ratio 25 measurements interaction for treatment and steak location. Ratio 25- Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 25% of the length of the *longissimus lumborum***.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

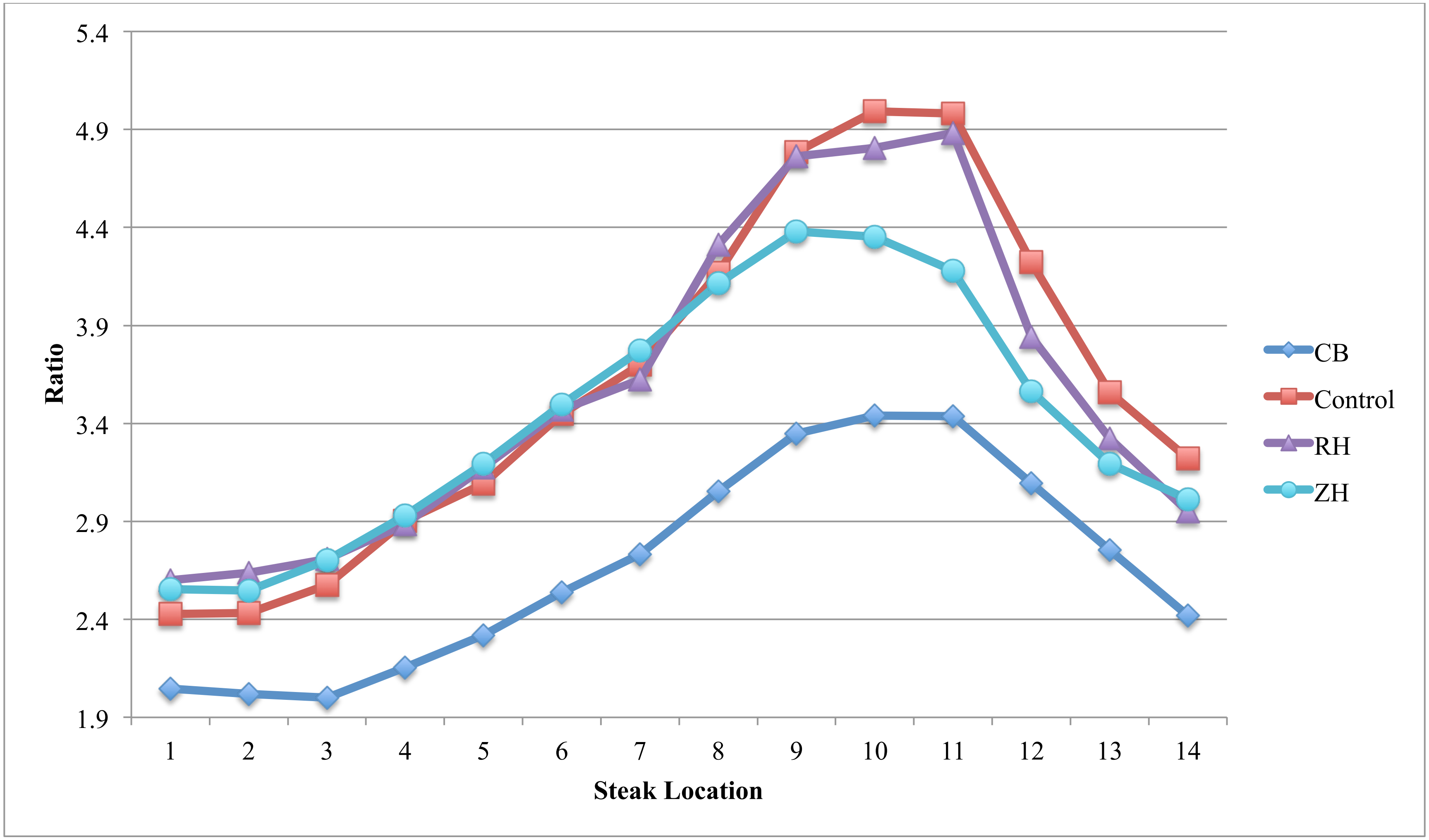

Figure A.27. Least squares means for Short Loin Ratio 50 measurements interaction for treatment and steak location. Ratio 50-Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 50% of the length of the *longissimus lumborum*. CB – conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

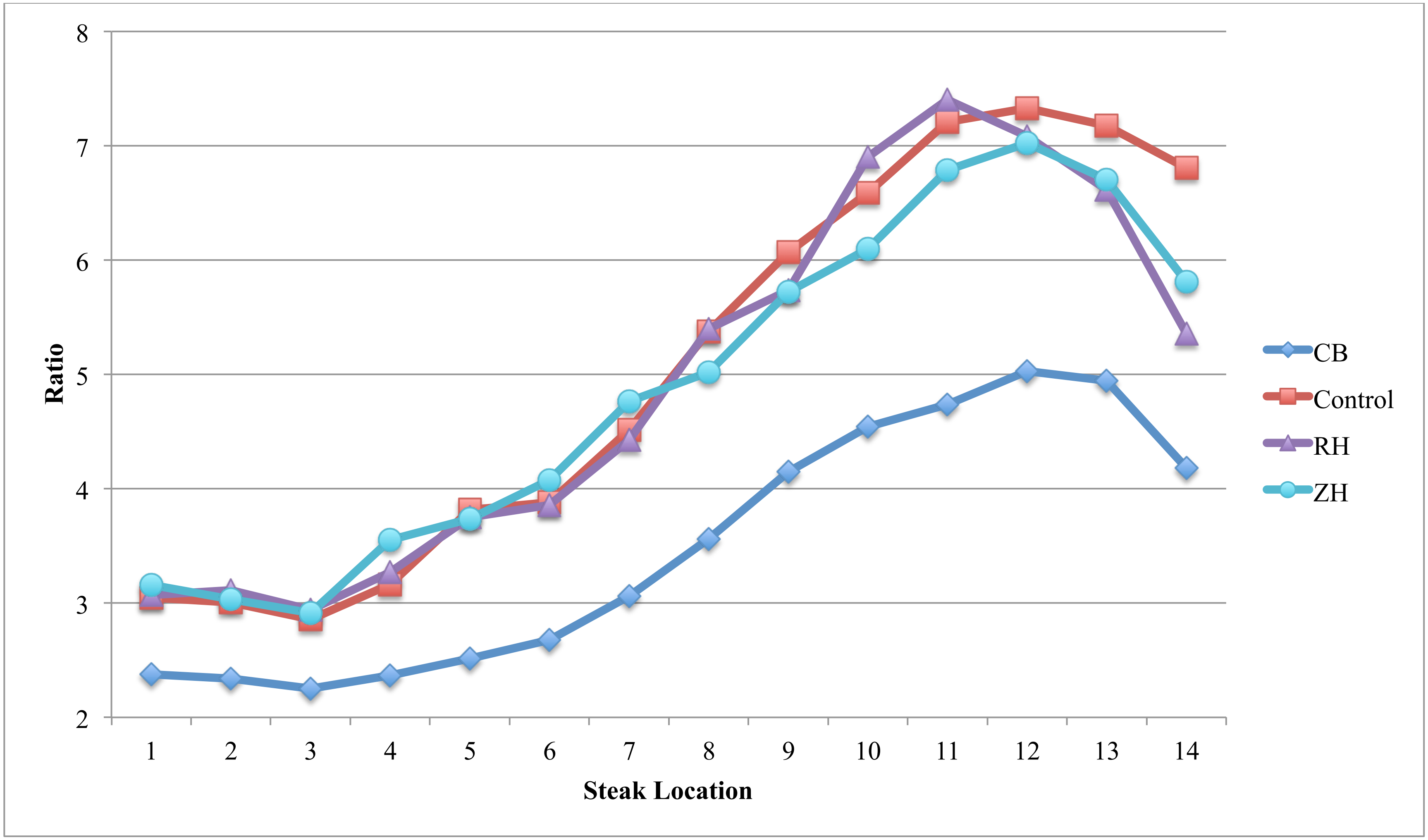

Figure A.28. Least squares means for Short Loin Ratio 75 measurements interaction for treatment and steak location. Ratio 75- Ratio of the Length of *longissimus lumborum* (medial to lateral) divided by the depth of *longissimus lumborum* (dorsal to ventral) at 75% of the length of the *longissimus lumborum*. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

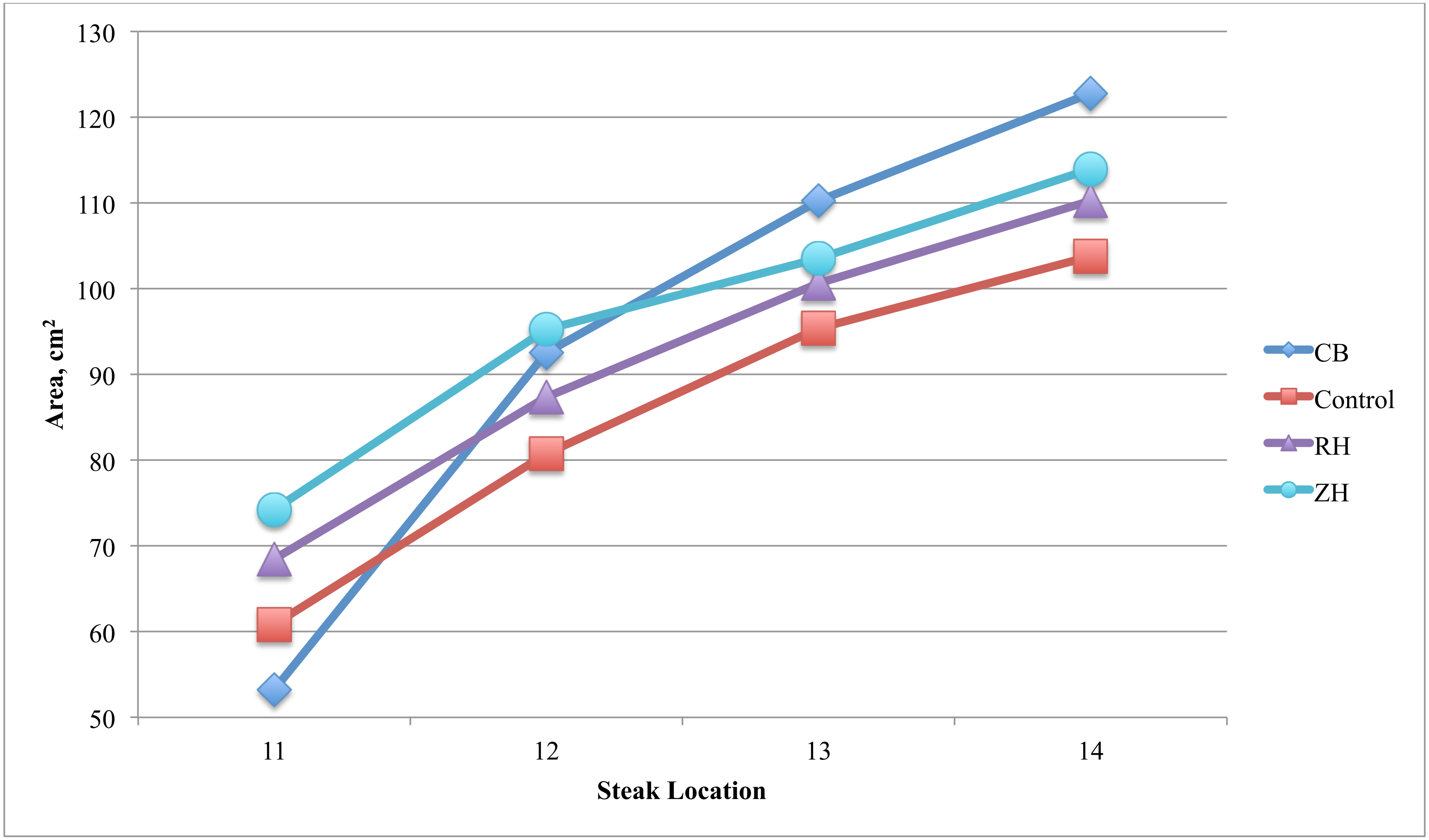

Figure A.29. Least squares means for Short Loin Total Area measurements interaction for treatment and steak location. Total Area- Area of *longissimus lumborum* + area of the *gluteus medius* in cm^2**.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

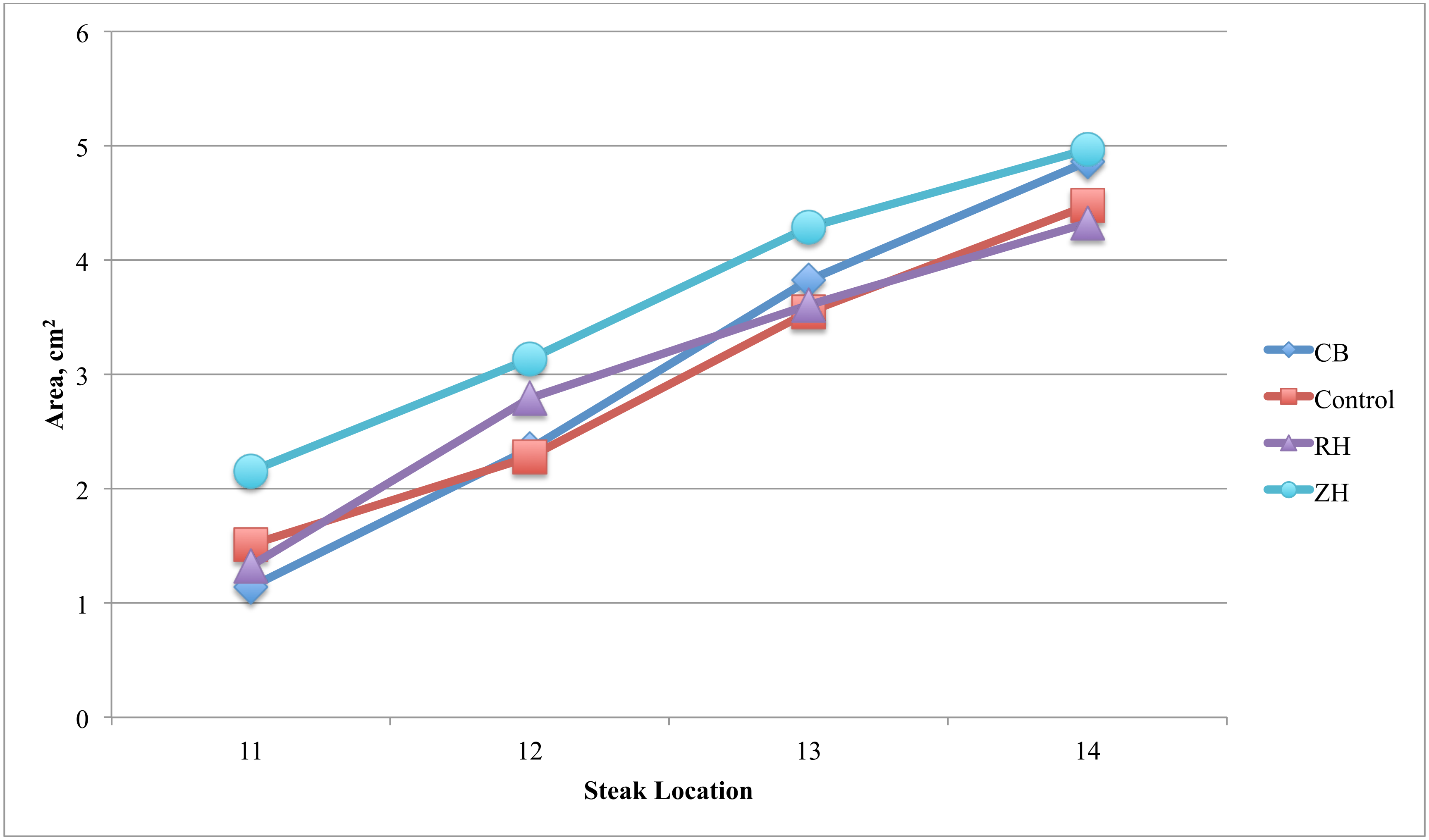

Figure A.30. Least squares means for Short Loin GM depth measurements interaction for treatment and steak location. GM depth- Depth of *gluteus medius* in cm**.** CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

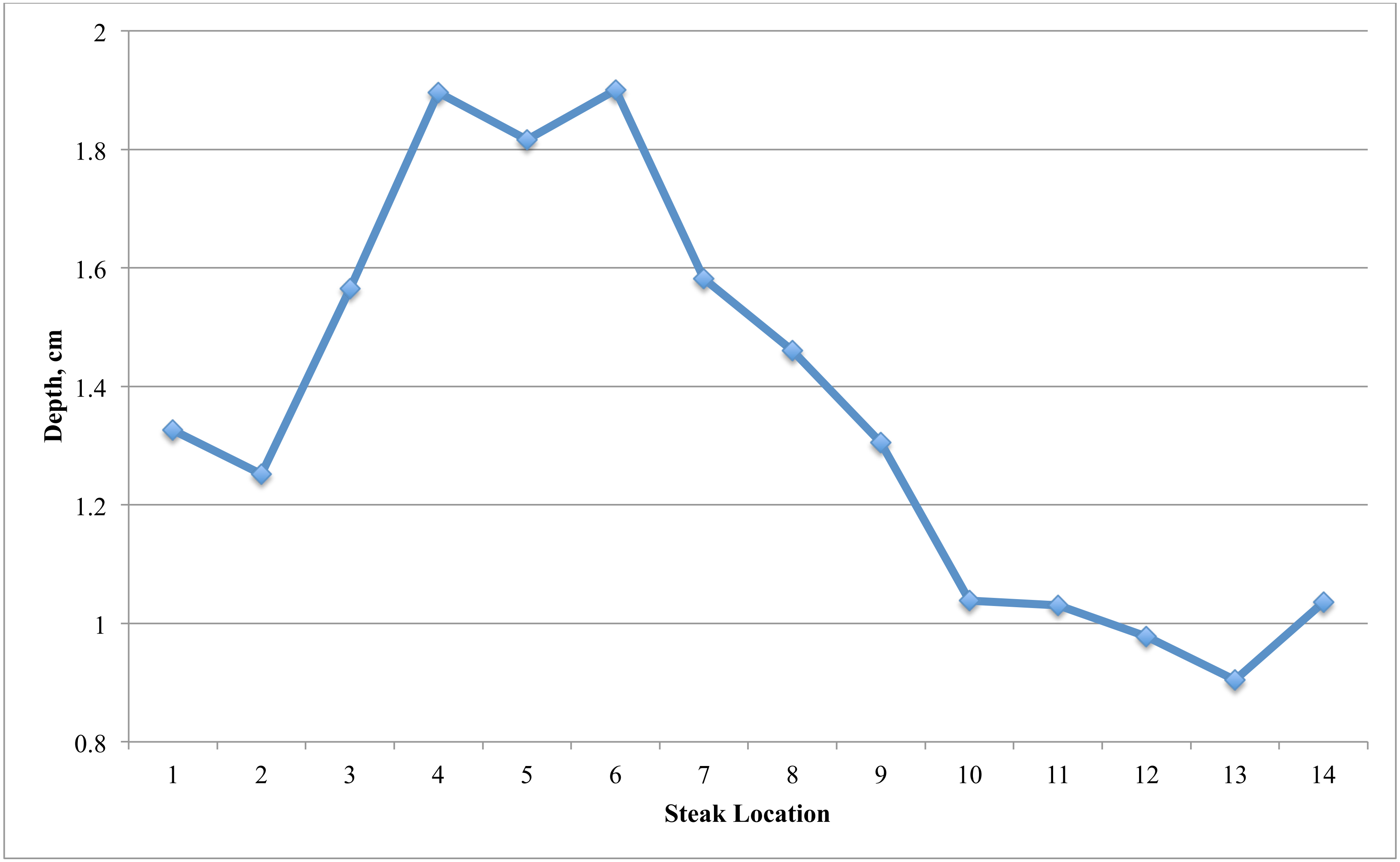

Figure A.31. Least squares means for Short Loin 100% Depth measurements Steak location Main effect. 100% Depth - depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm.

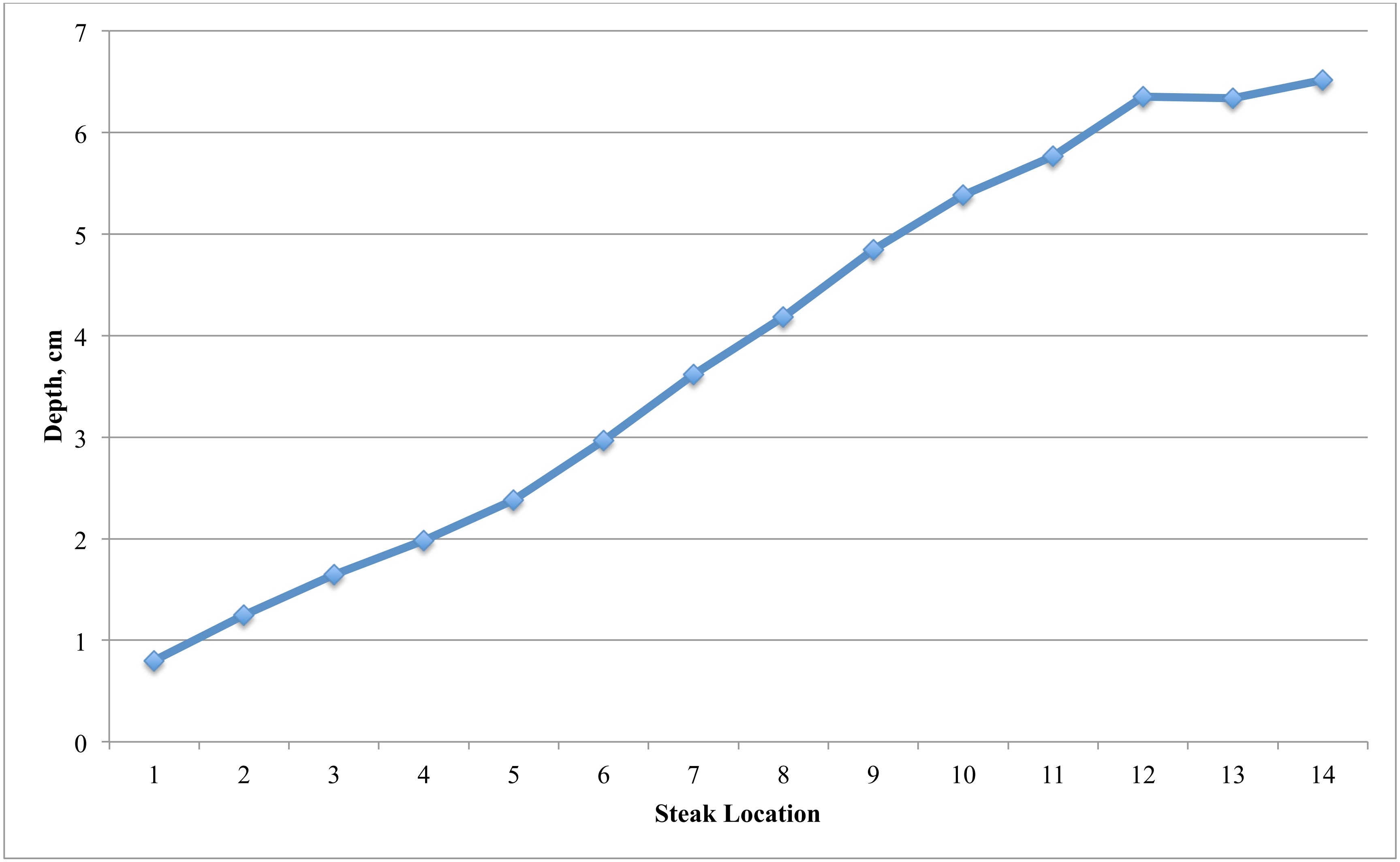

Figure A.32. Least squares means for Short Loin PM Depth measurements Steak location Main effect. PM Depth - depth of *psoas major* (dorsal to ventral) at 50% of the length of the *psoas major* in cm.

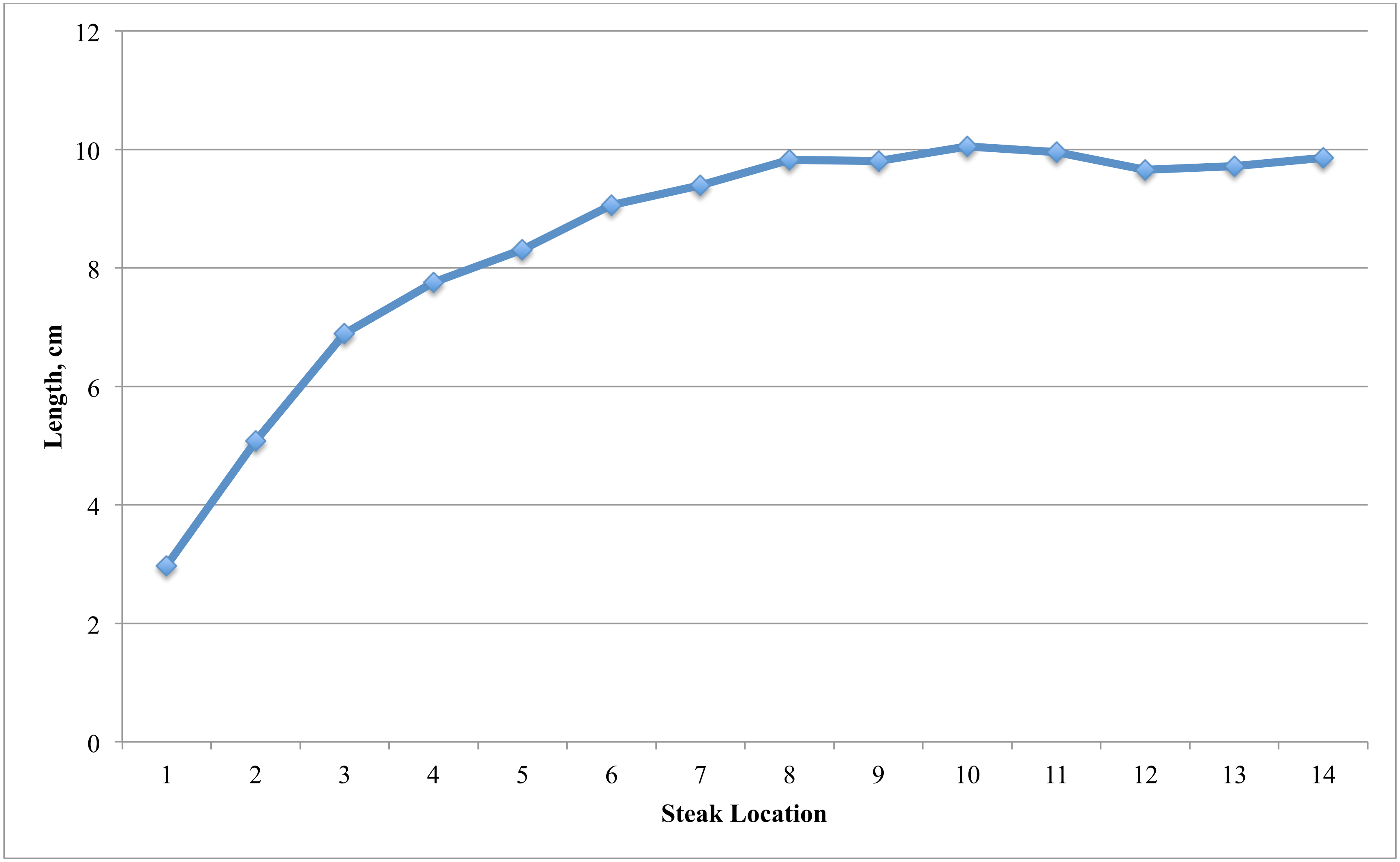

Figure A.33. Least squares means for Short Loin PM Length measurements Steak location Main effect. PM Length - length of *psoas major* (medial to lateral) in cm.

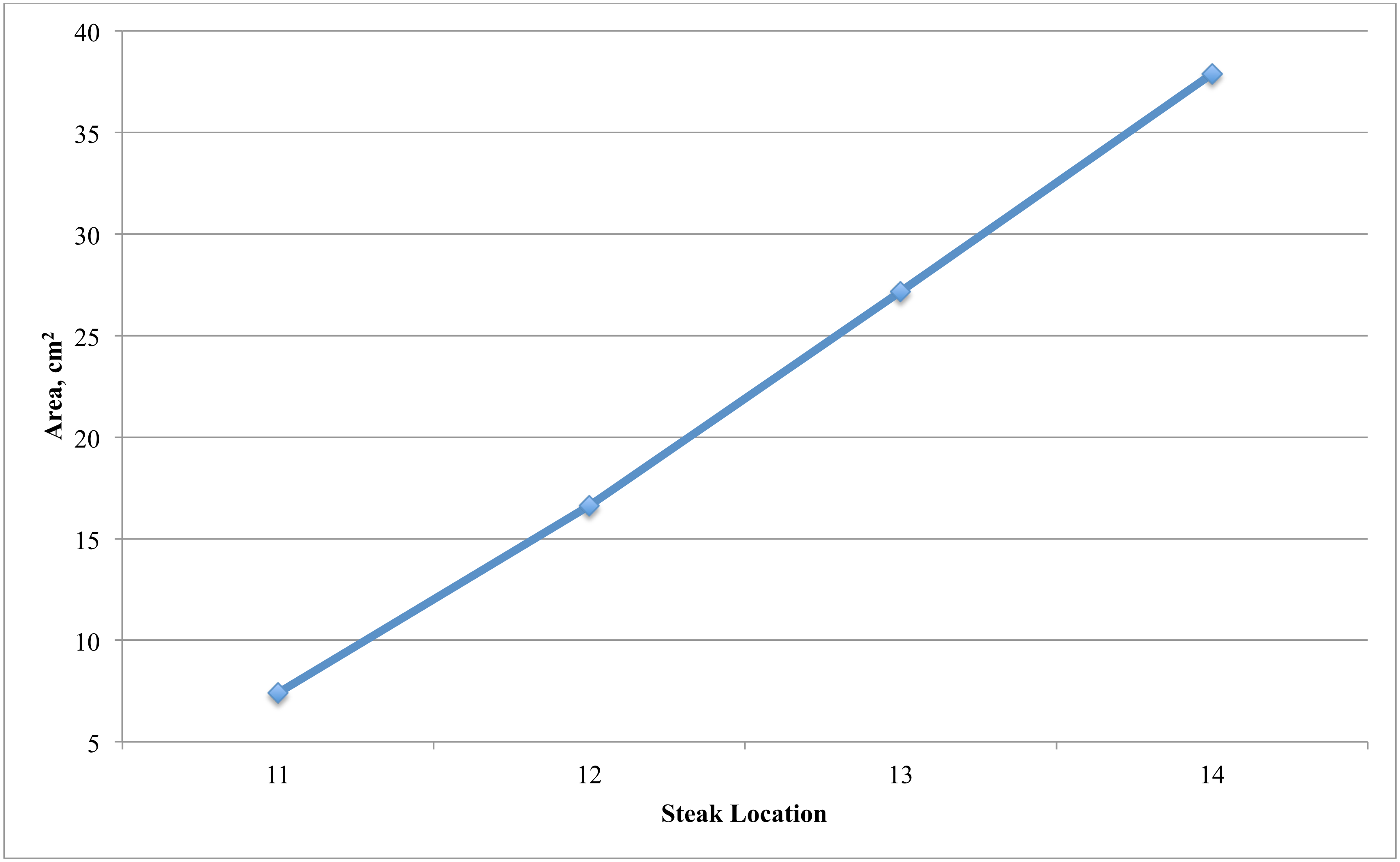

Figure A.34. Least squares means for Short Loin GM Area measurements Steak location Main effect. GM Area - area of *gluteus medius* in cm^2.

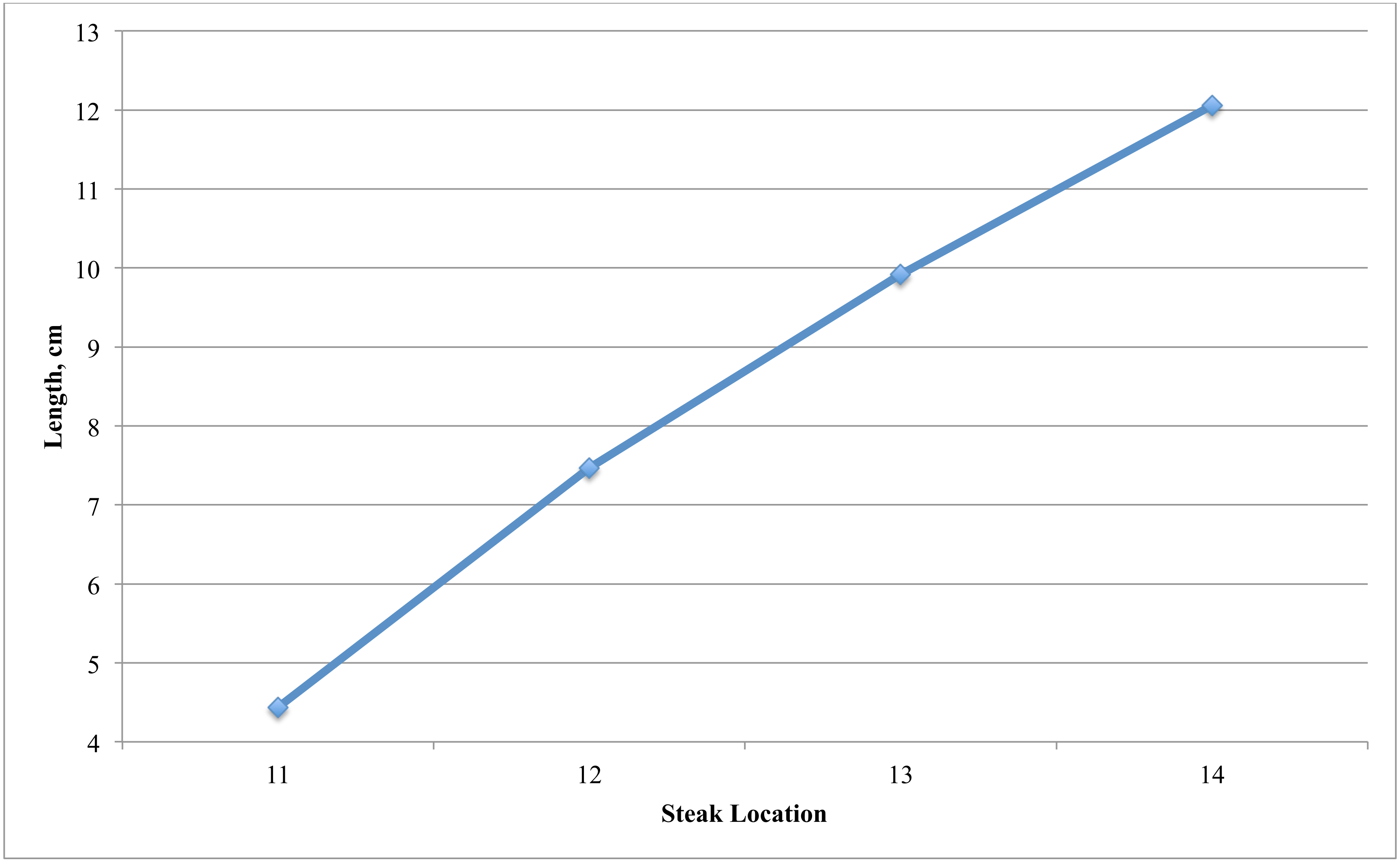

Figure A.35. Least squares means for Short Loin GM Length measurements Steak location Main effect. GM Length - length of *gluteus medius* (medial to lateral) in cm.

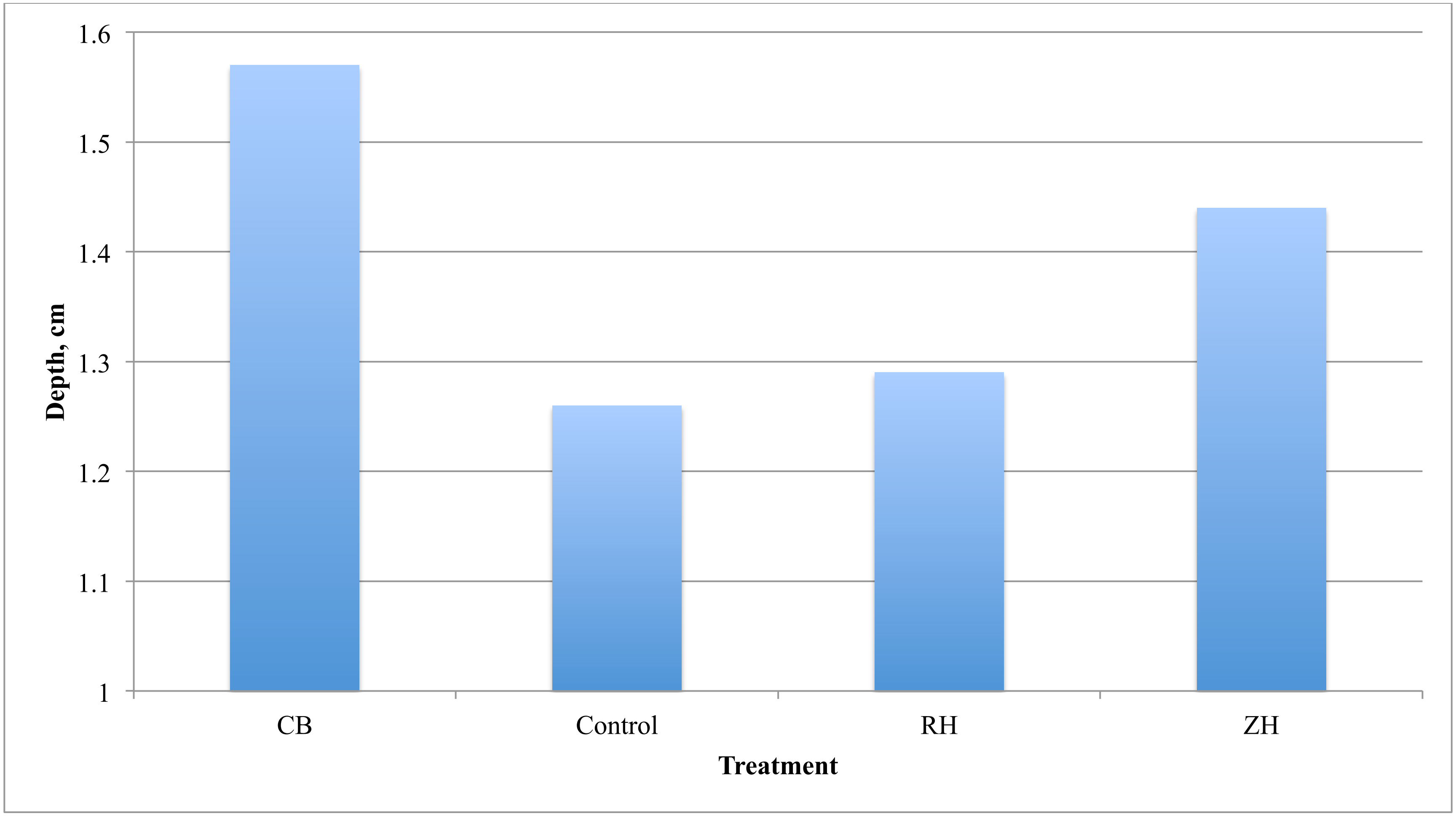

Figure A.36. Least squares means for Short Loin 100% Depth measurements Treatment Main effect. 100% Depth - depth of *longissimus lumborum* (dorsal to ventral) at 100% of the length of the *longissimus lumborum* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

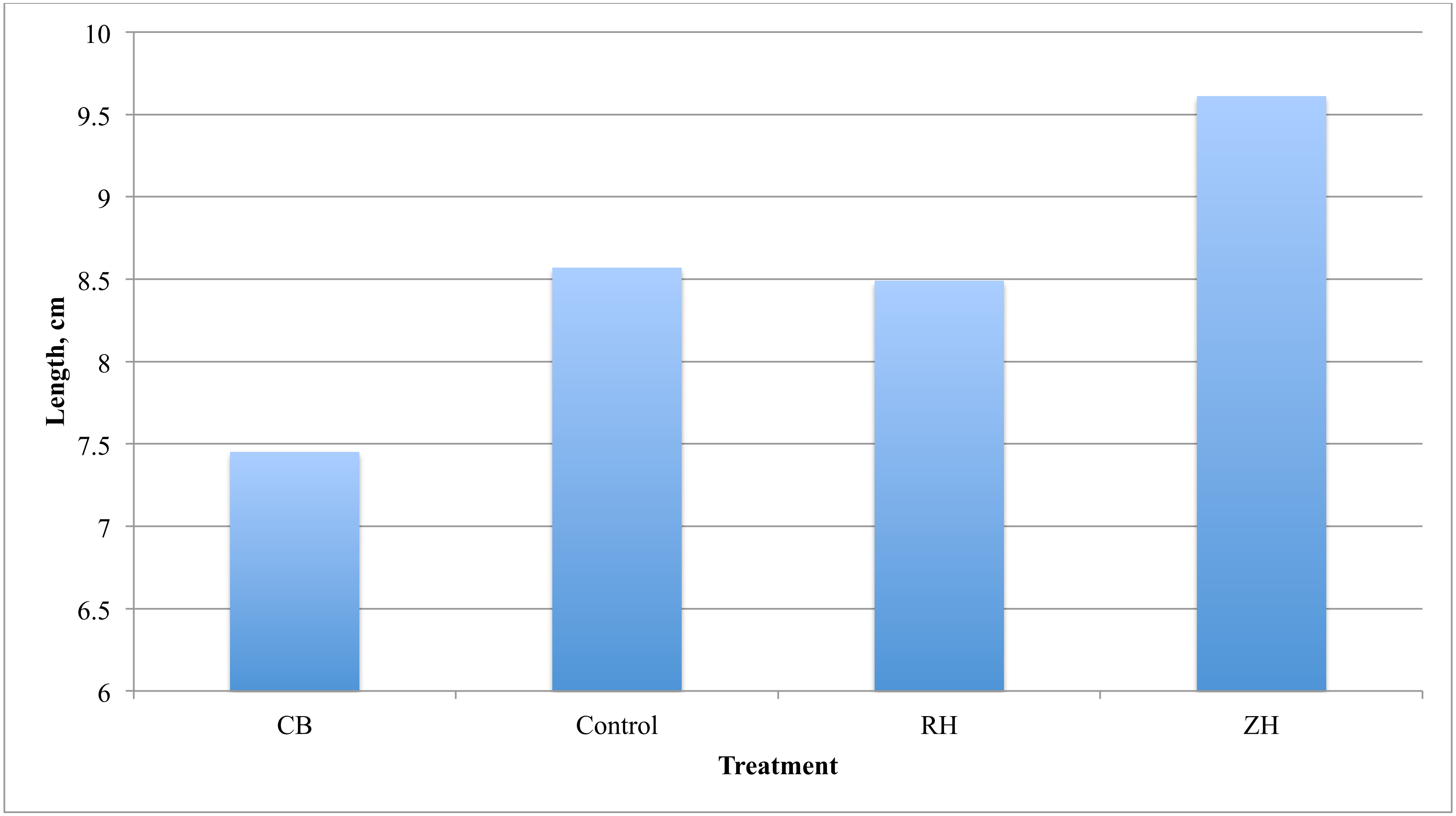

Figure A.37. Least squares means for Short Loin GM Length measurements Treatment Main effect. GM Length – Length of the *gluteus medius* (medial to lateral) in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

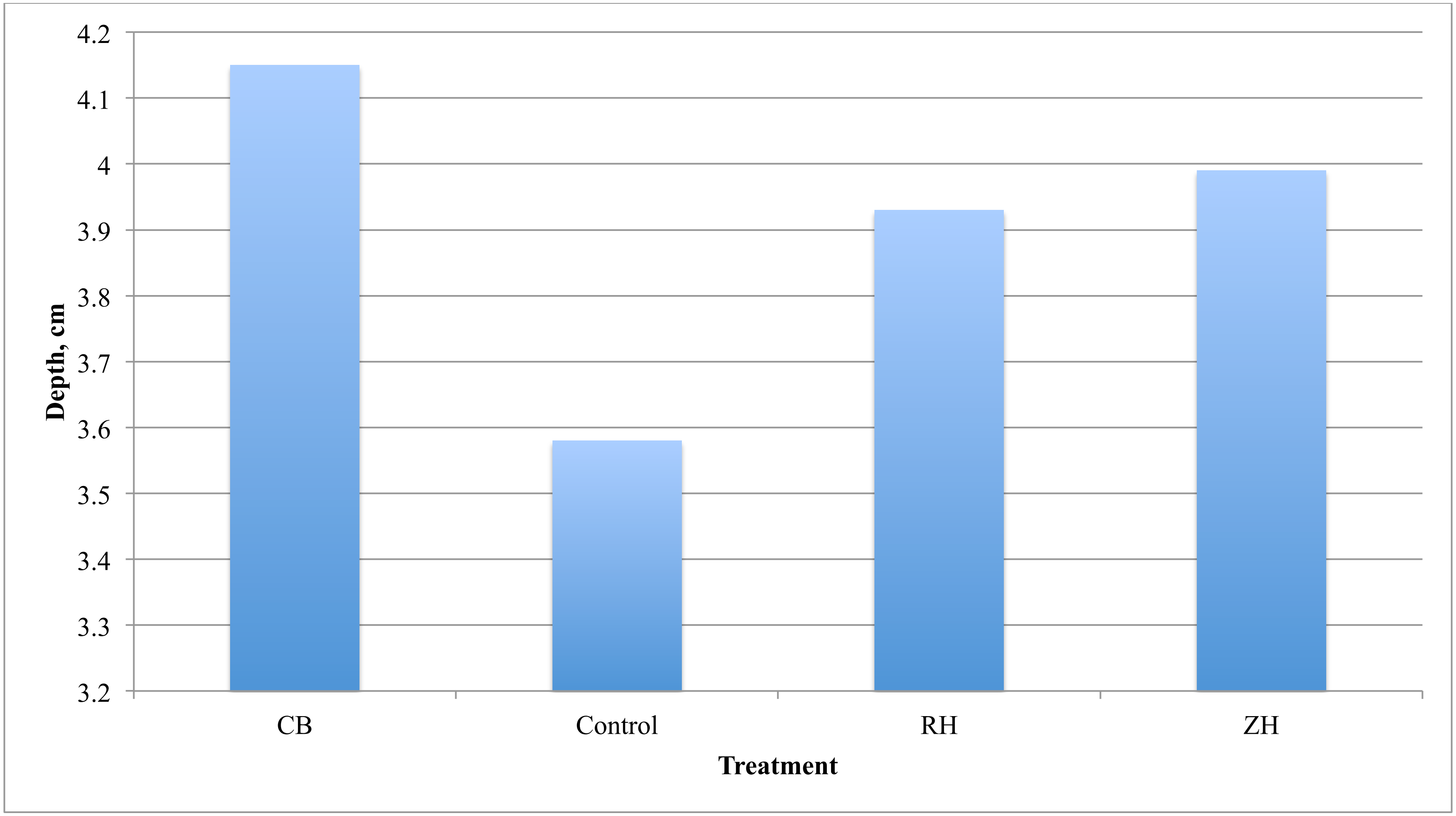

Figure A.38. Least squares means for Short Loin PM Depth measurements Treatment Main effect. PM Depth - depth of *psoas major* (dorsal to ventral) at 50% of the length of the *psoas major* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

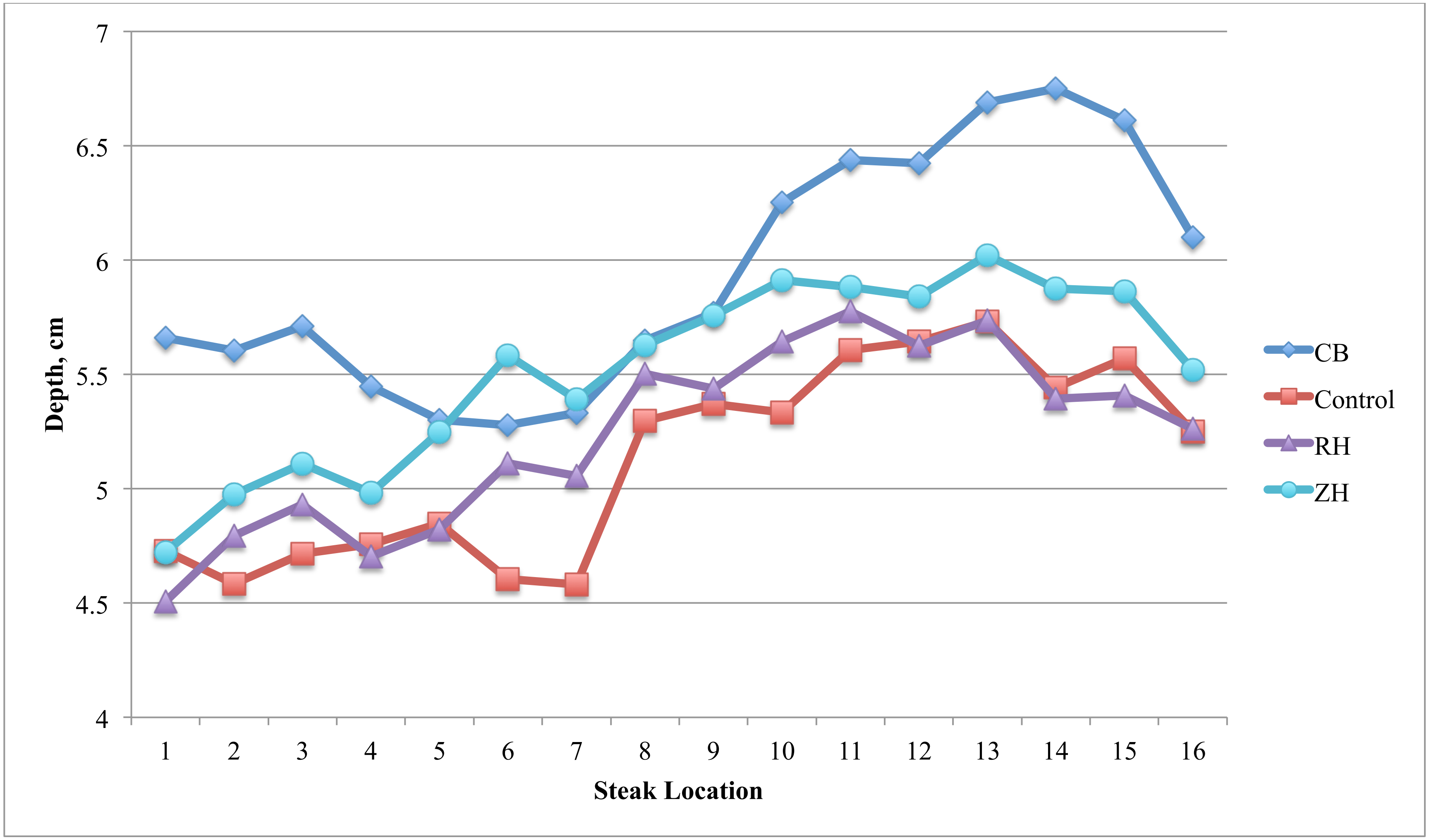

Figure A.39. Least squares means for Ribeye 87.5% Depth measurements interaction for treatment and steak location. 87.5% Depth measurement is the depth of the entire steak (dorsal to ventral) at 87.5% of the length of the entire steak in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

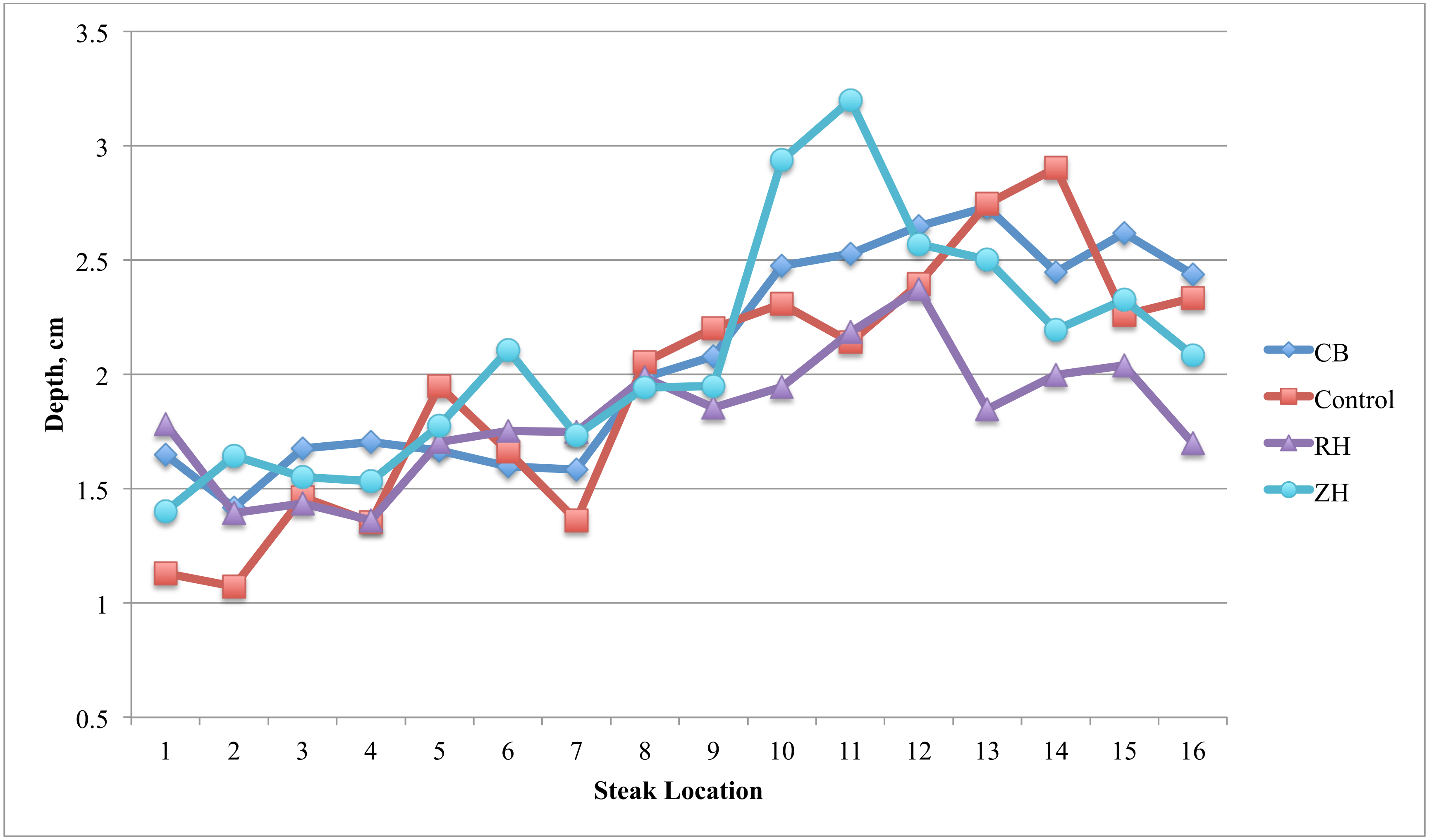

Figure A.40. Least squares means for Ribeye 87.5% Depth measurements interaction for treatment and steak location. 87.5% Depth measurement is the depth of the entire steak (dorsal to ventral) at 87.5% of the length of the entire steak in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

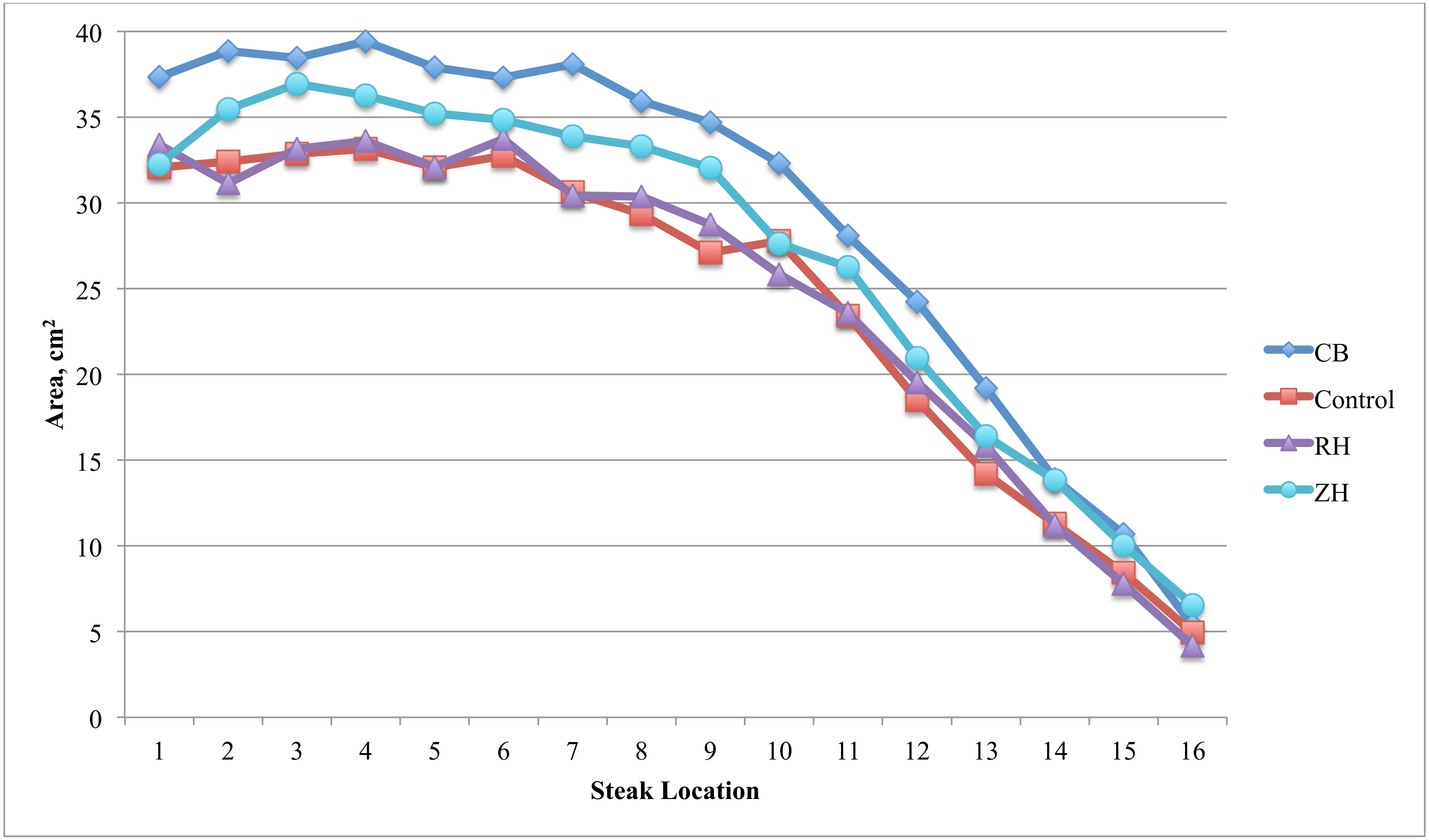

Figure A.41. Least squares means for Ribeye SD Area measurements interaction for treatment and steak location. SD Area- Area of *spinalis dorsi* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

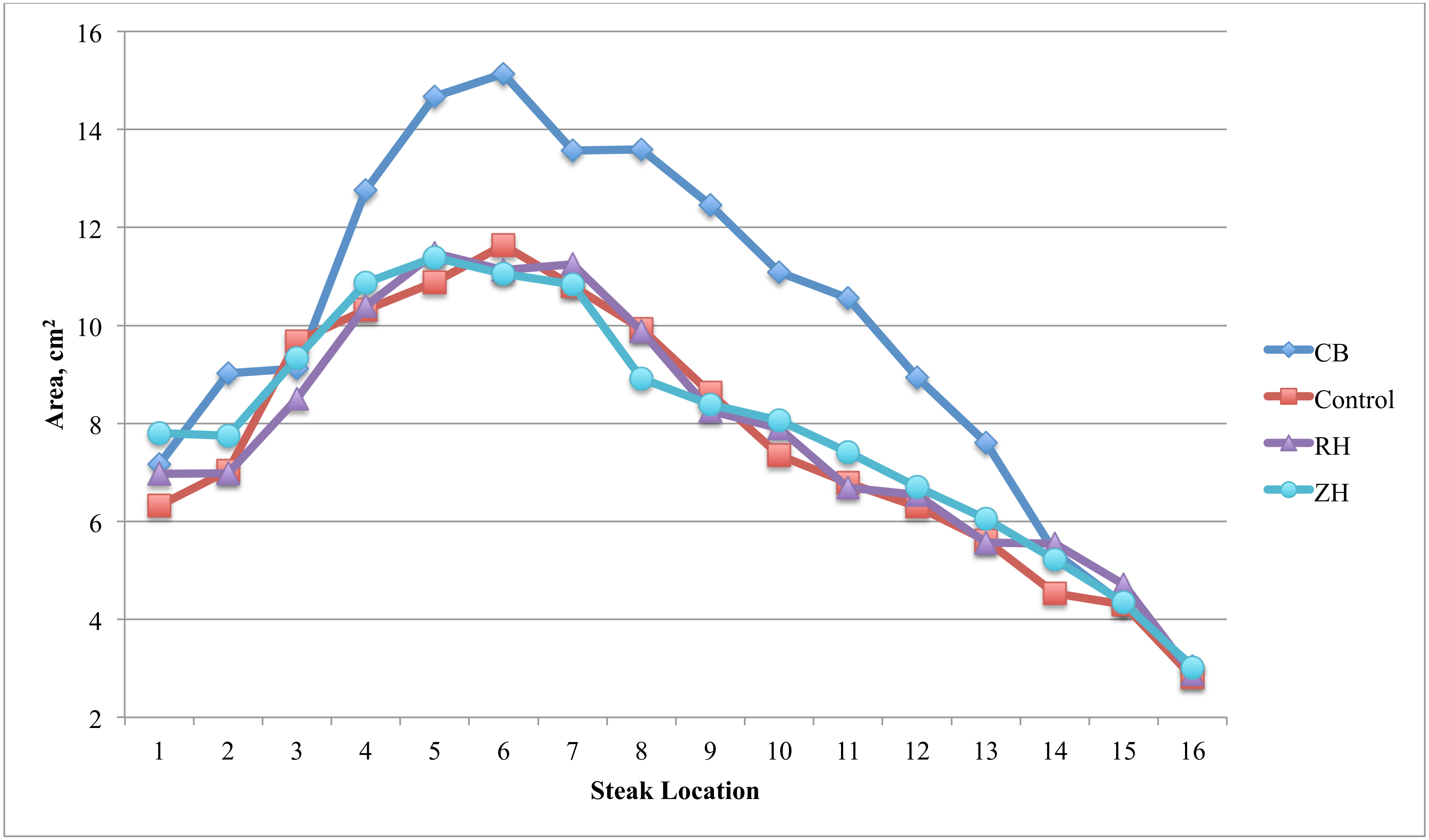

Figure A.42. Least squares means for Ribeye K Fat Area measurements interaction for treatment and steak location. K Fat Area- Area of kernel fat in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

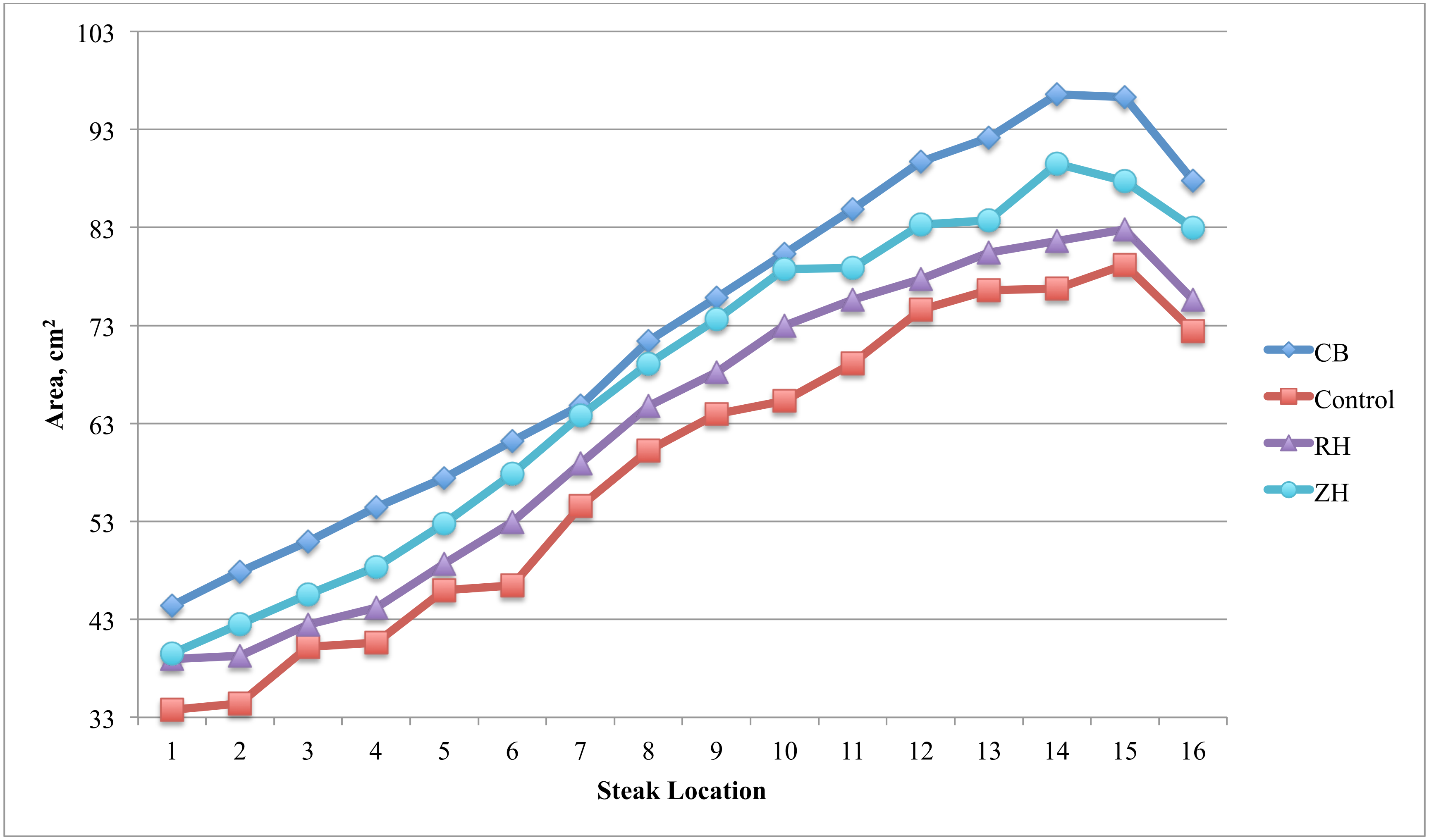

Figure A.43. Least squares means for Ribeye LT Area measurements interaction for treatment and steak location. LT Area- Area of *longissimus thoracis* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

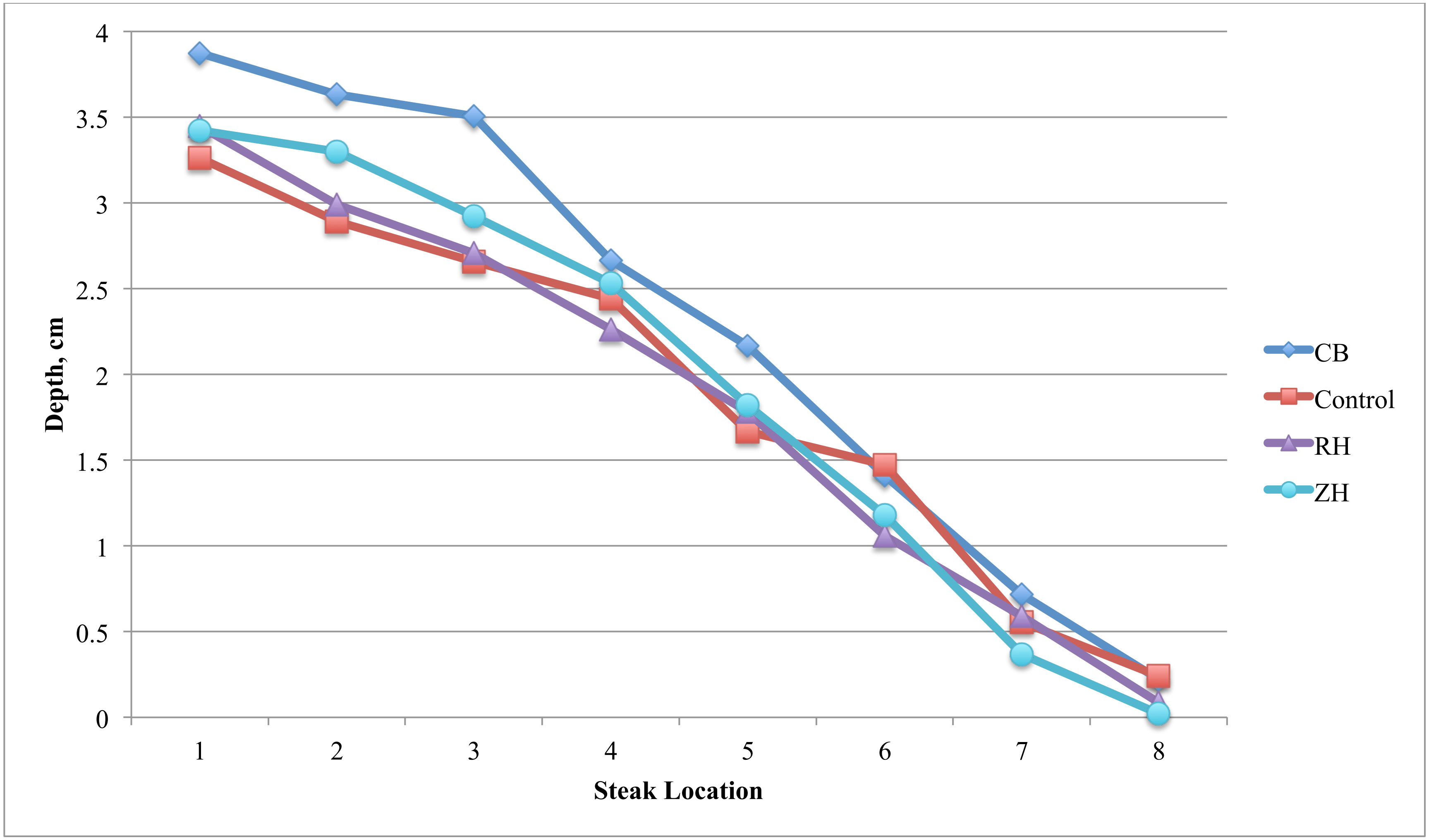

Figure A.44. Least squares means for Ribeye C Depth measurements interaction for treatment and steak location. C Depth - depth of the *complexus* (dorsal to ventral) at 50% of the length (medial to lateral) of the *complexus* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

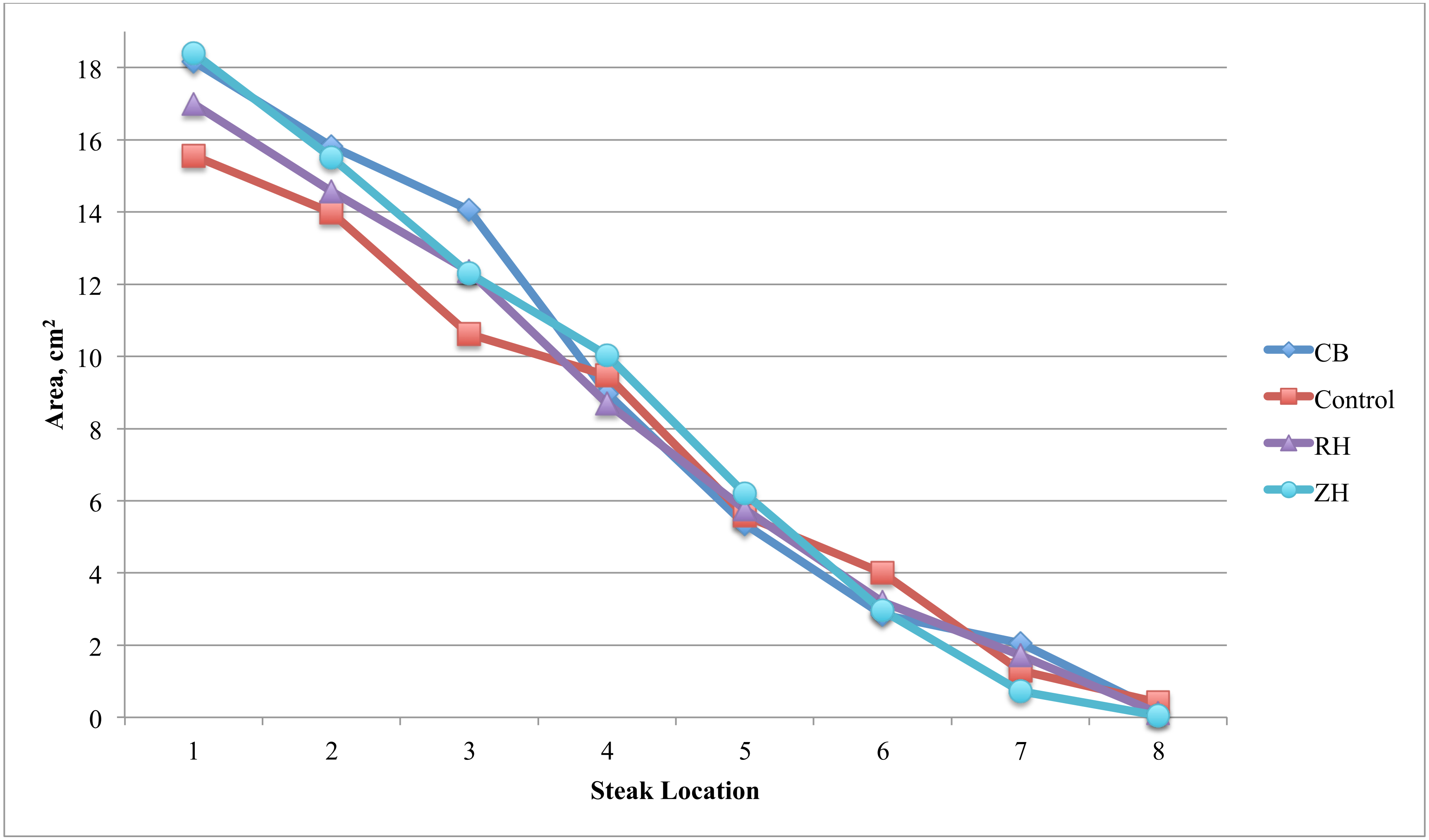

Figure A.45. Least squares means for Ribeye C Area measurements interaction for treatment and steak location. C Area –area of the *complexus* in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

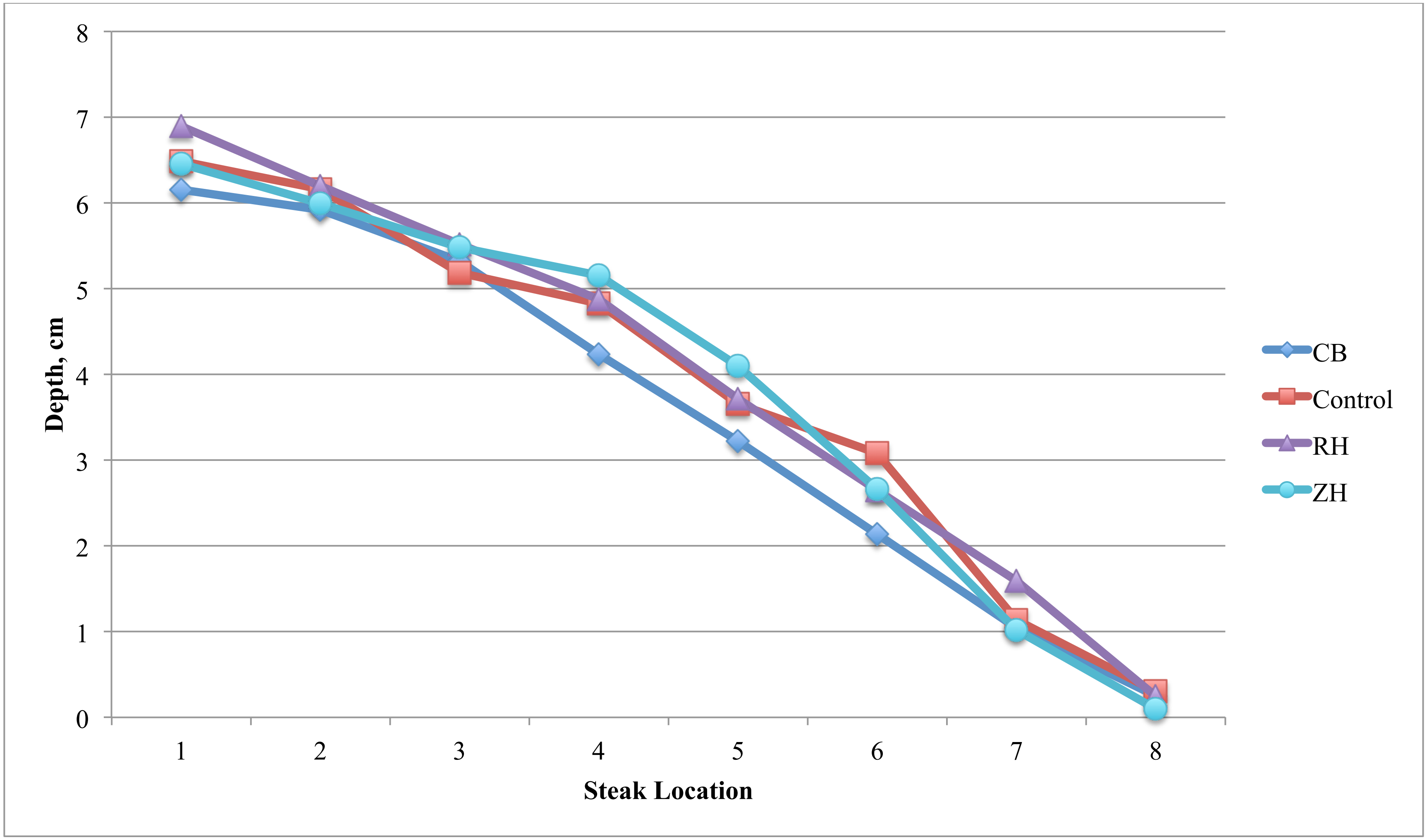

Figure A.46. Least squares means for Ribeye C Length measurements interaction for treatment and steak location. C Length – Length of the *complexus* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

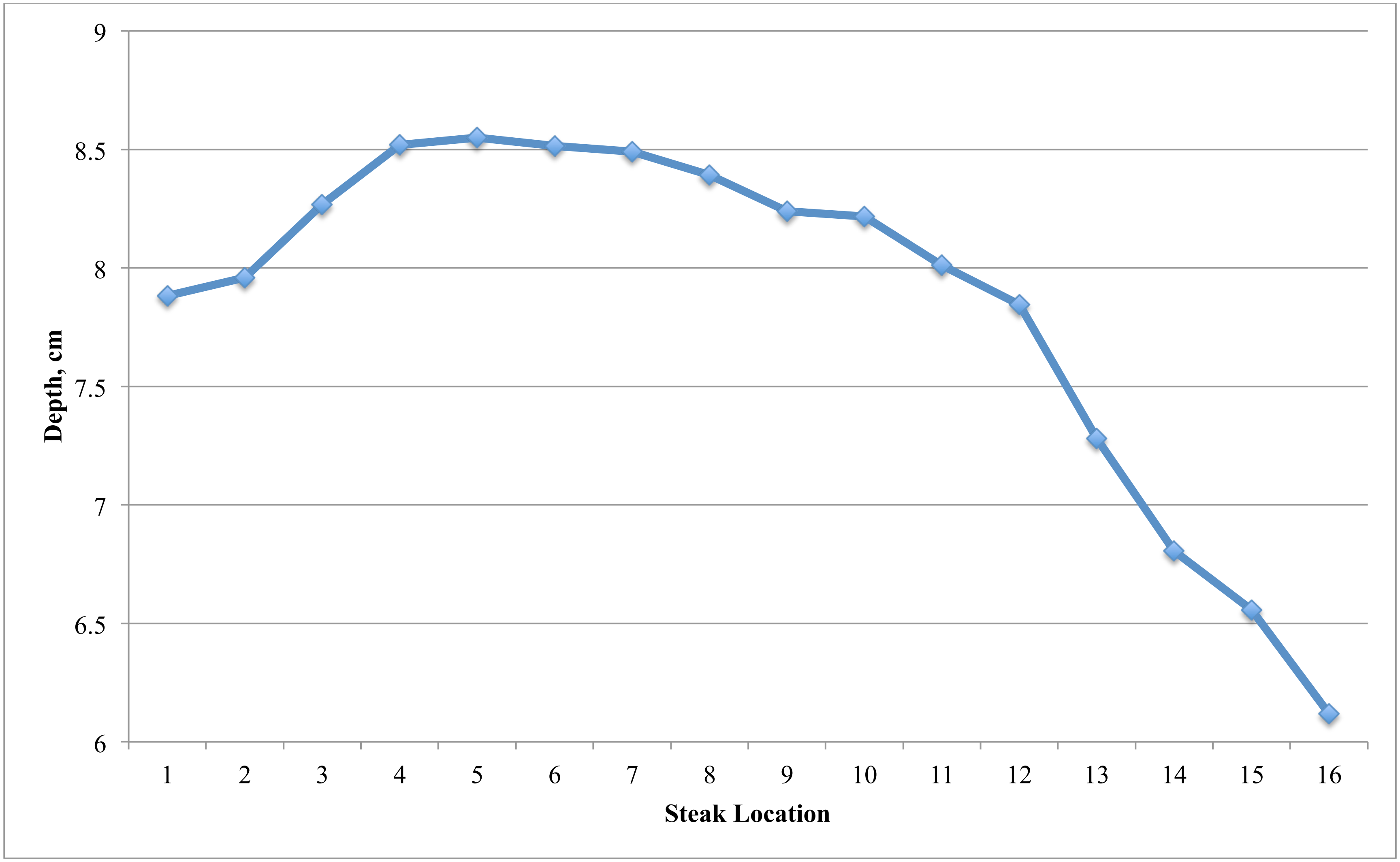

Figure A.47. Least squares means for Ribeye 50% Depth measurements Steak location Main effect. 50% Depth - depth of entire steak (dorsal to ventral) at 50% of the length of the entire steak in cm.

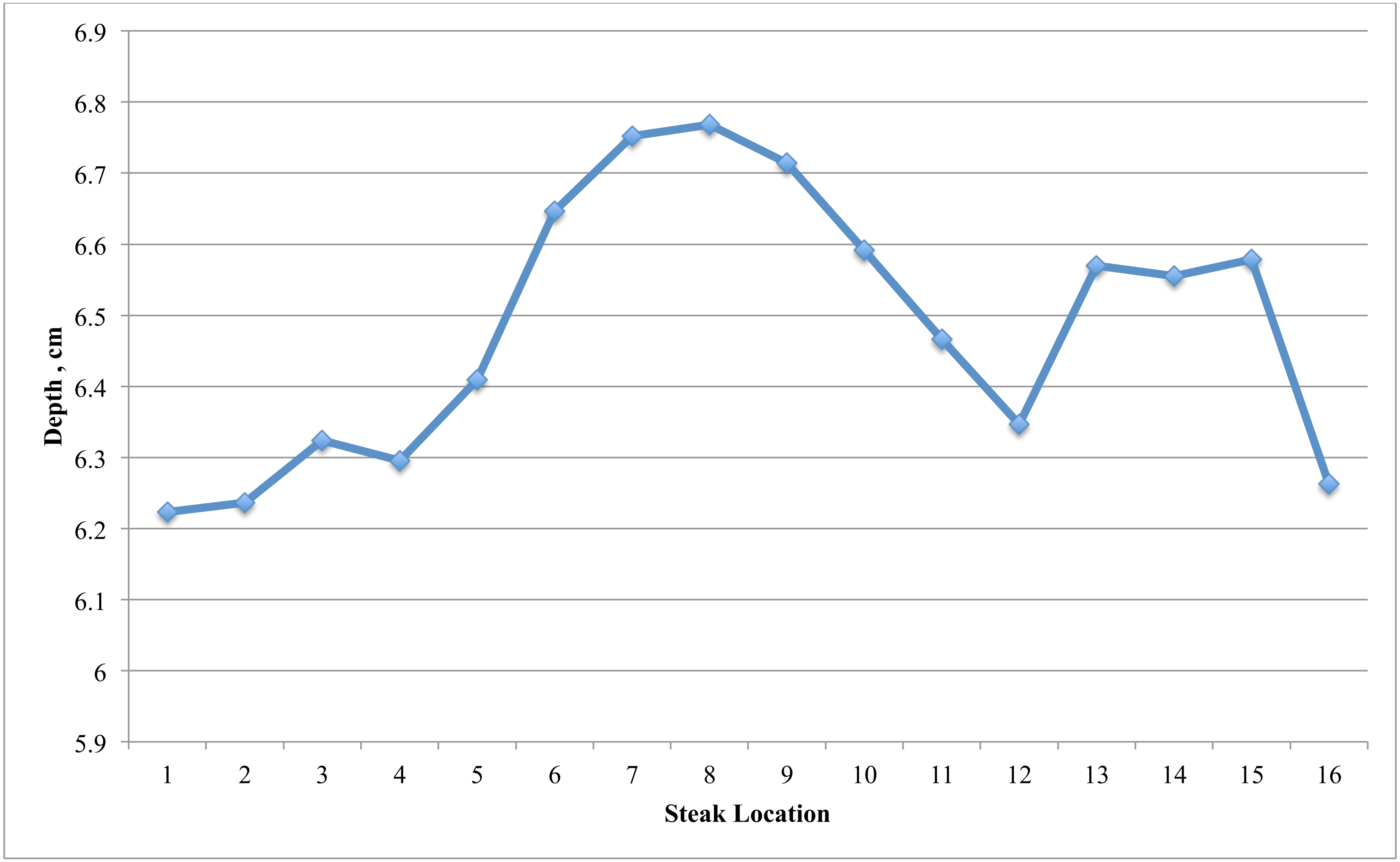

Figure A.48. Least squares means for Ribeye 75% Depth measurements Steak location Main effect. 75% Depth - depth of entire steak (dorsal to ventral) at 75% of the length of the entire steak in cm.

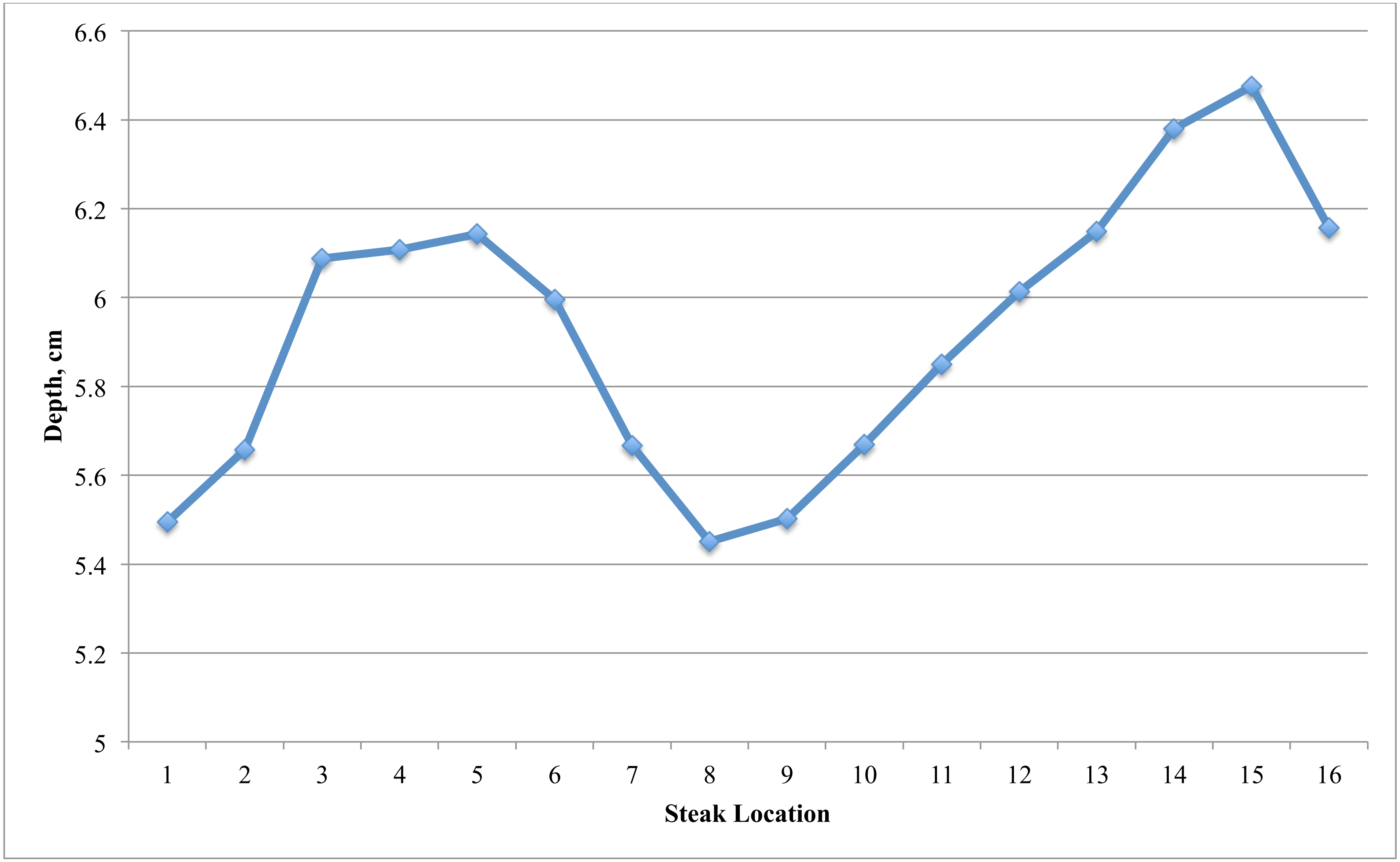

Figure A.49. Least squares means for Ribeye LT Depth measurements Steak location Main effect. LT Depth - depth of *longissimus thoracis* (dorsal to ventral) at 50% of the length (medial to lateral) *longissimus thoracis* in cm.

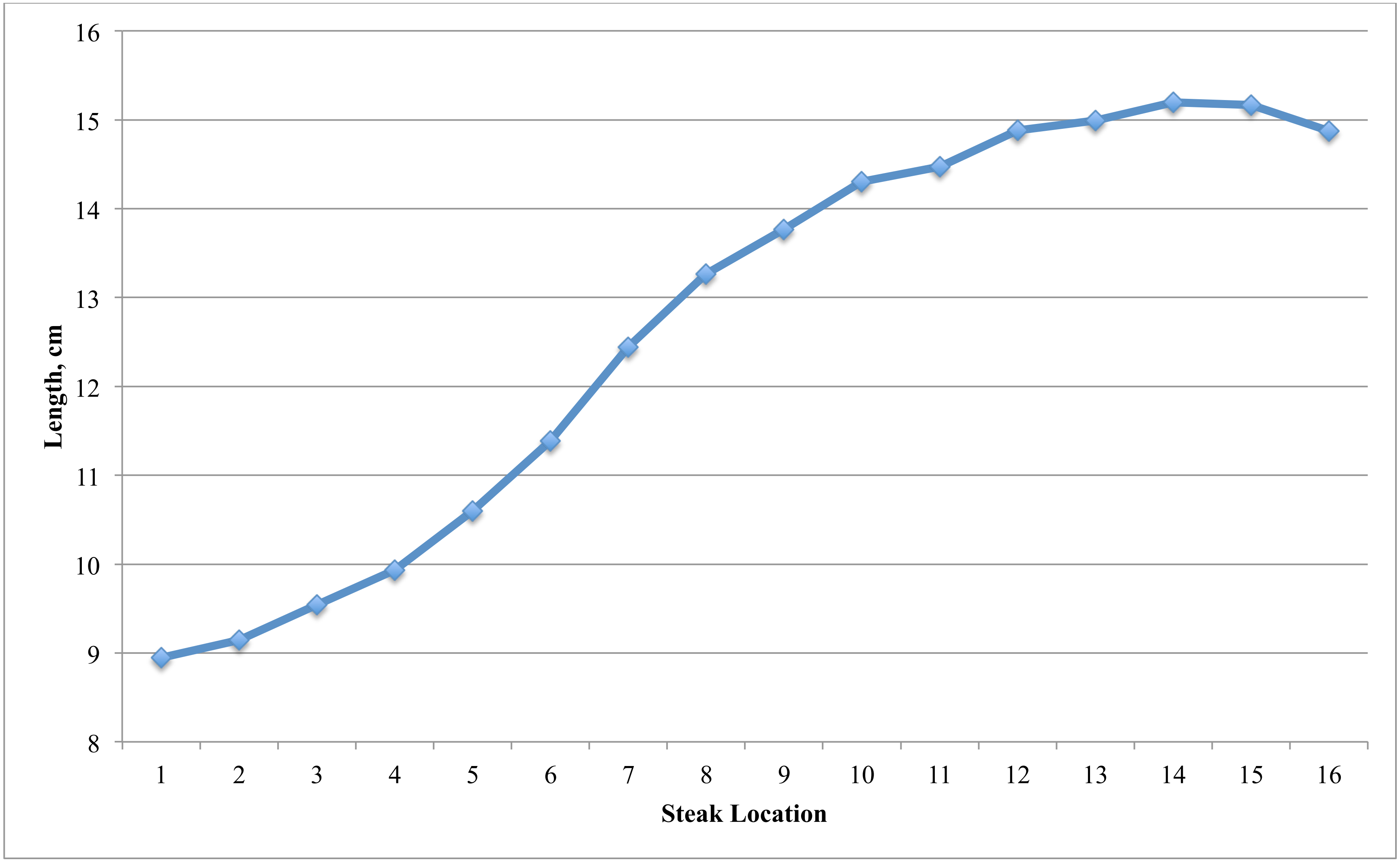

Figure A.50. Least squares means for Ribeye LT Length measurements Steak location Main effect. LT Length – Length of *longissimus thoracis* (medial to lateral) in cm.

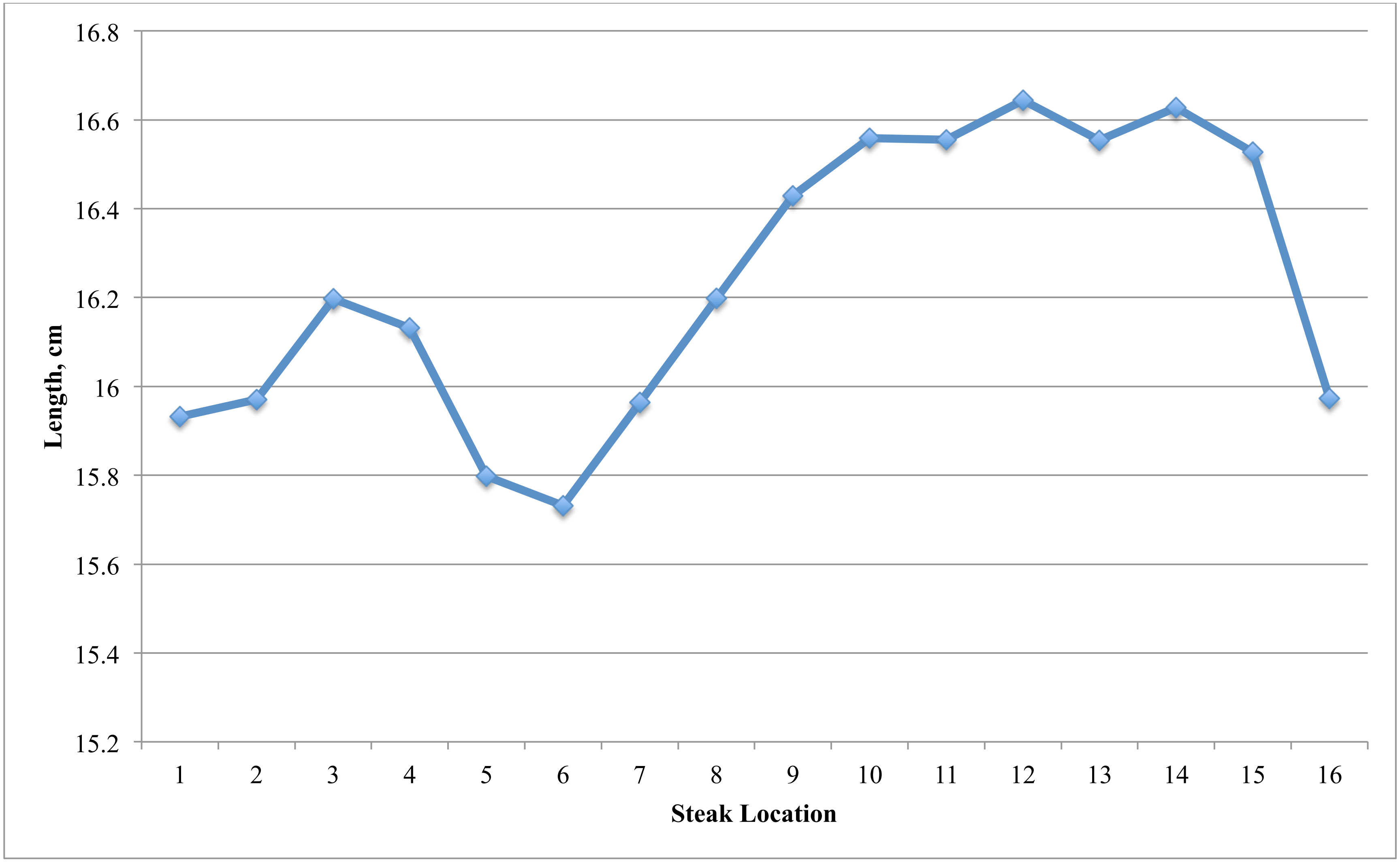

Figure A.51. Least squares means for Ribeye Length measurements Steak location Main effect. Length – Length of the entire steak (medial to lateral) in cm.

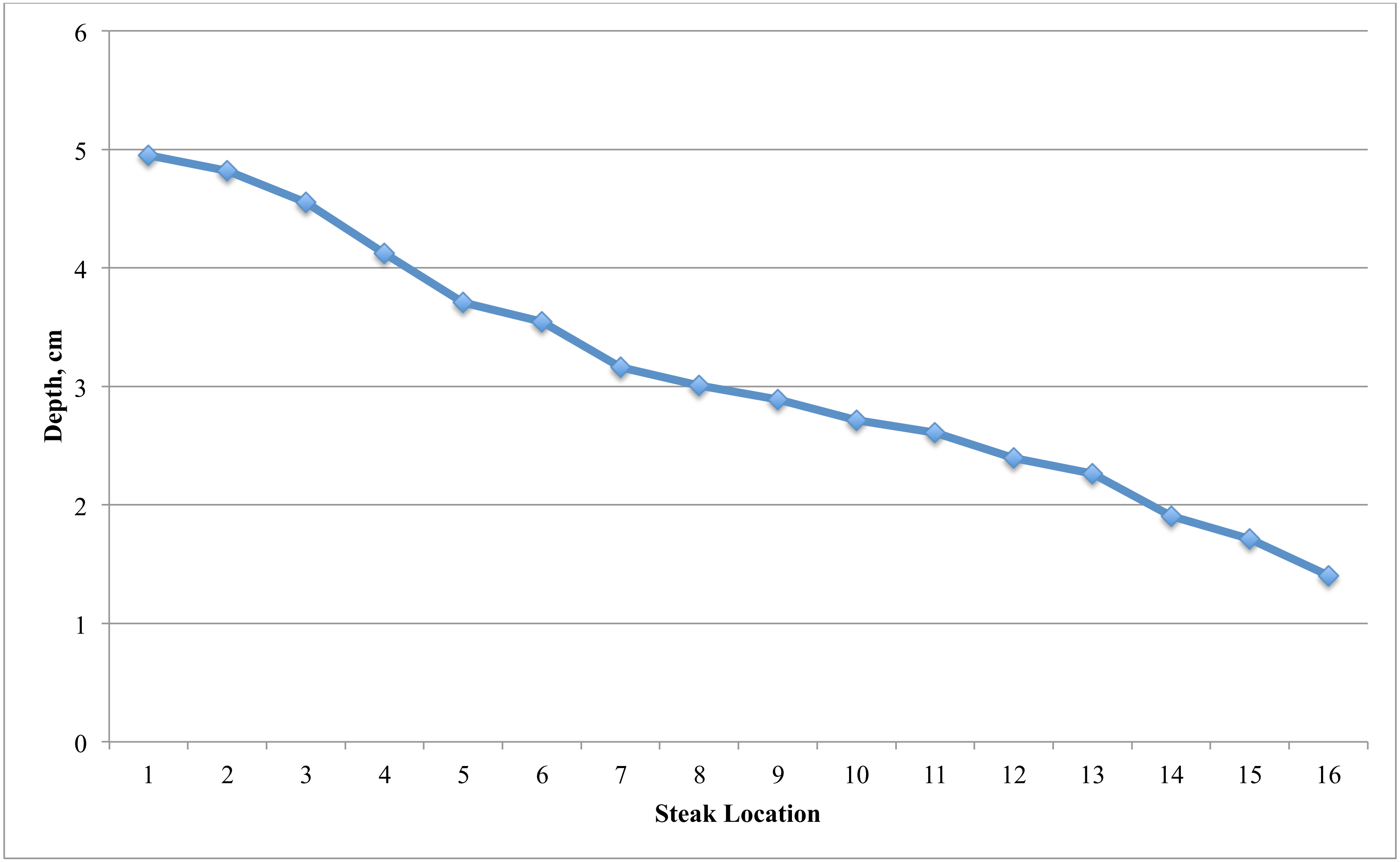

Figure A.52. Least squares means for Ribeye SD Depth measurements Steak location Main effect. SD Depth - depth of *spinalis dorsi* (dorsal to ventral) in cm.

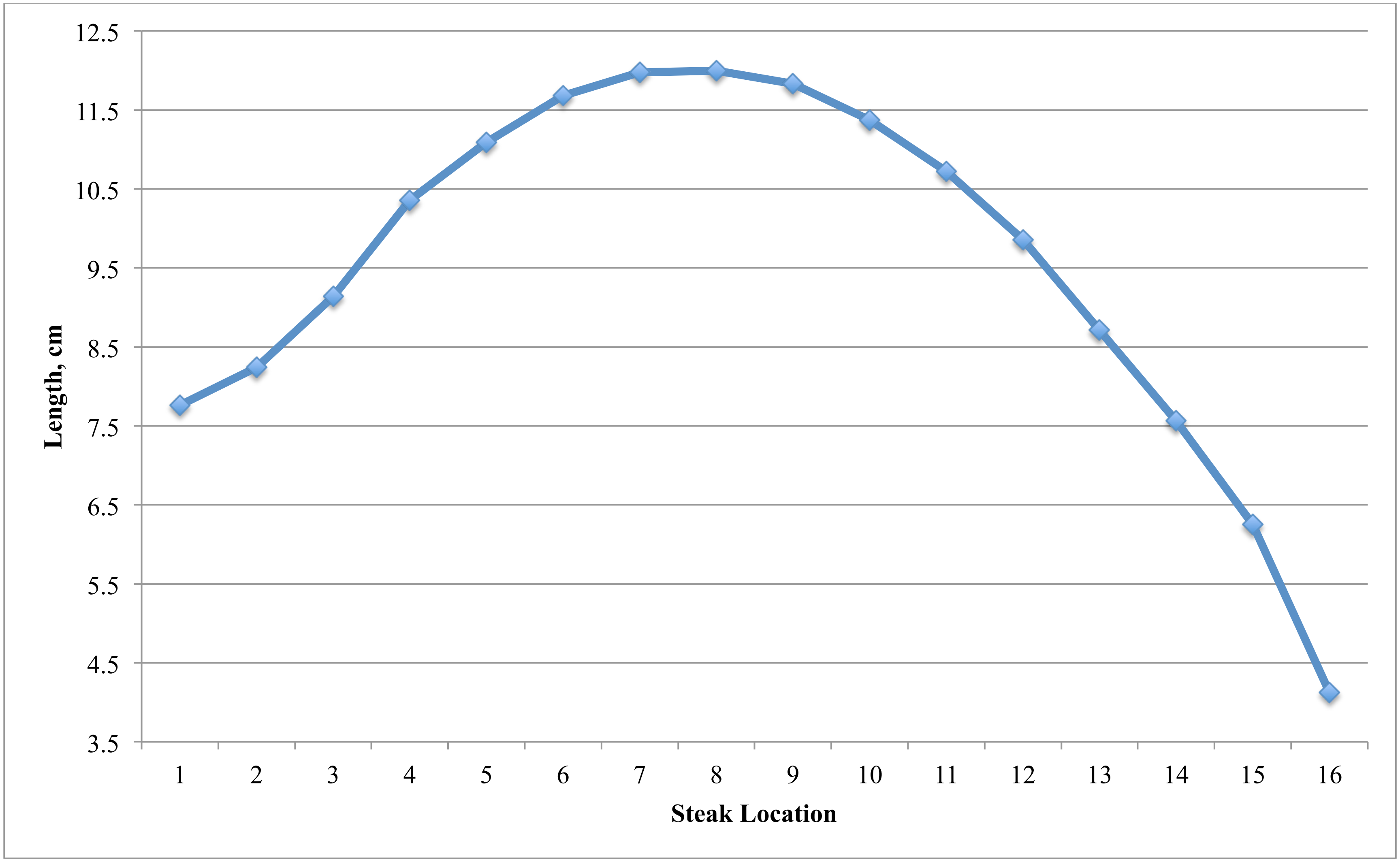

Figure A.53. Least squares means for Ribeye SD Length measurements Steak location Main effect. SD Length – Length of the *spinalis dorsi* (medial to lateral) in cm.

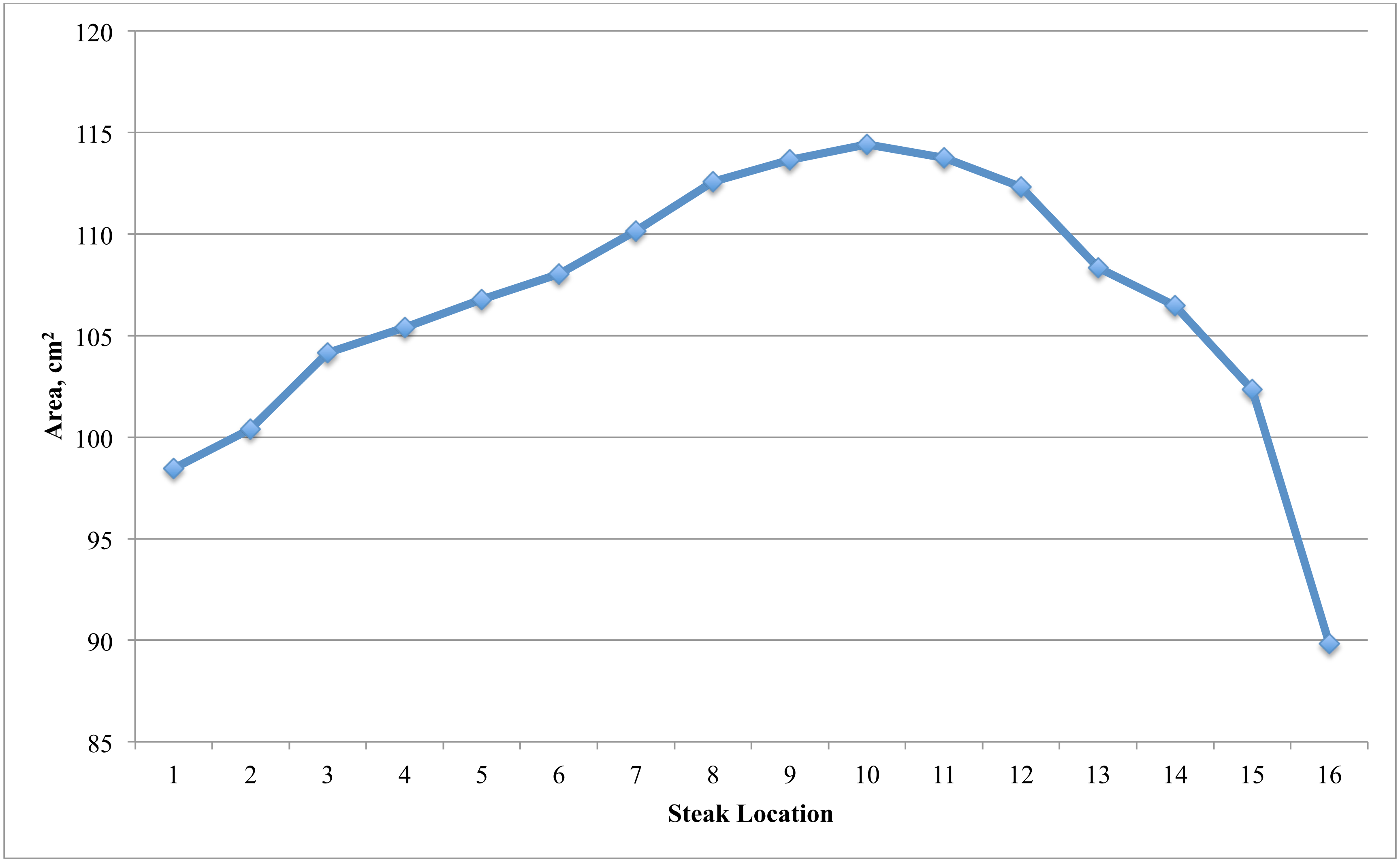

Figure A.54. Least squares means for Ribeye Total Area measurements Steak location Main effect. Total Area – Area of the whole steak including LT area, SD area, K Fat area, and C area in cm^2.

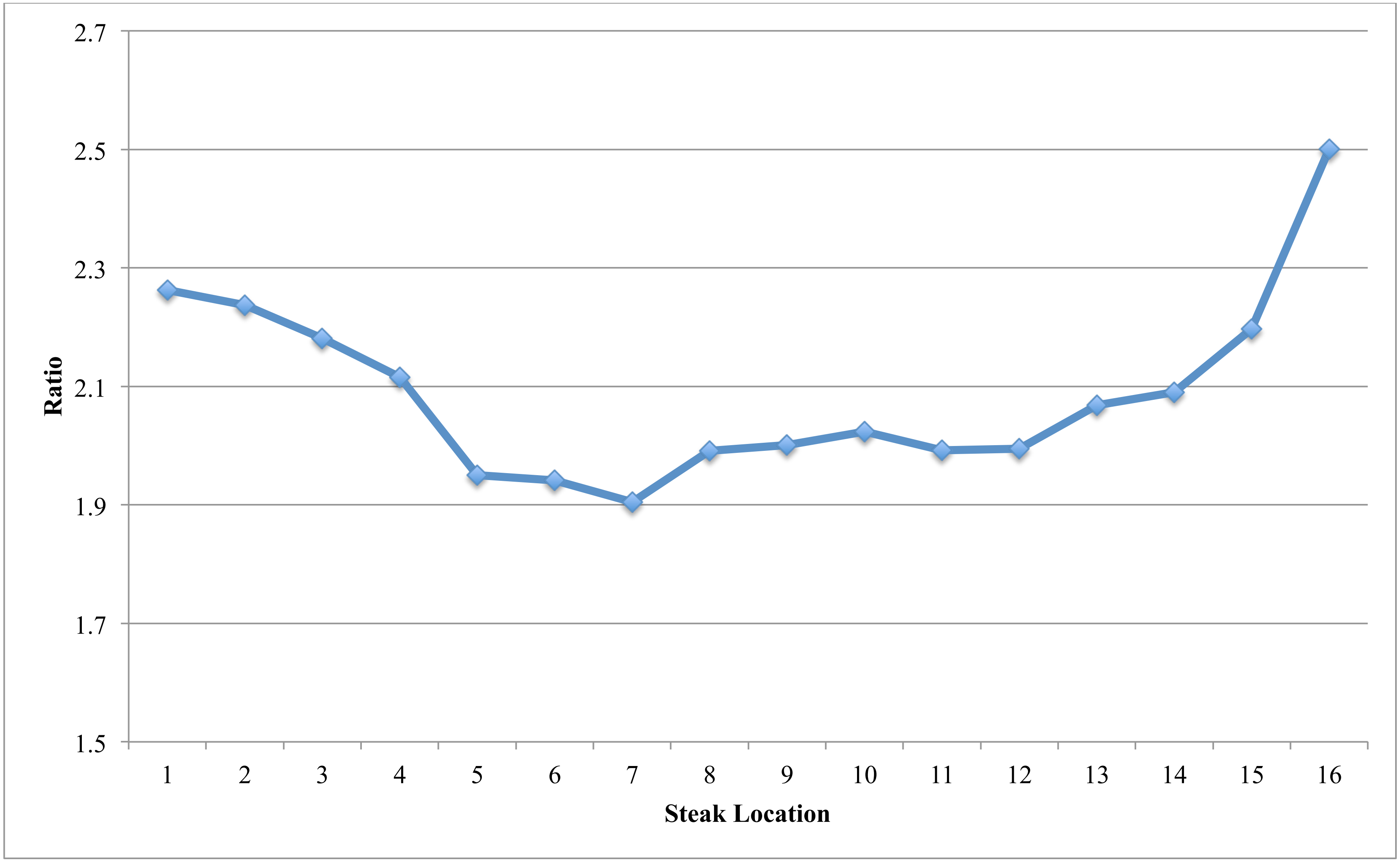

Figure A.55. Least squares means for Ribeye Ratio 25 measurements Steak Location Main effects. Ratio 25- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 25% of the length of the entire steak**.**

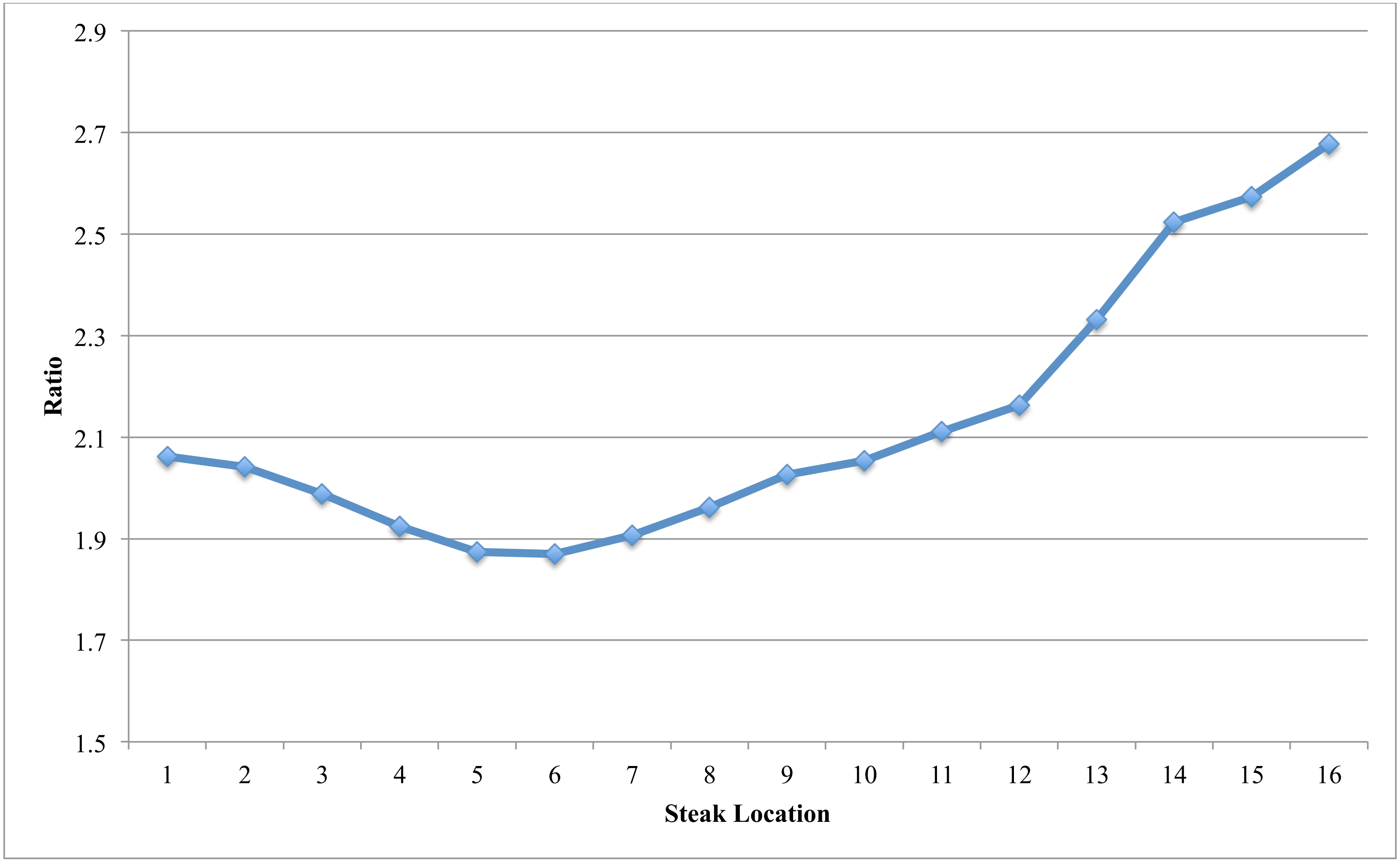

Figure A.56. Least squares means for Ribeye Ratio 50 measurements Steak Location Main effects. Ratio 50- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 75% of the length of the entire steak**.**

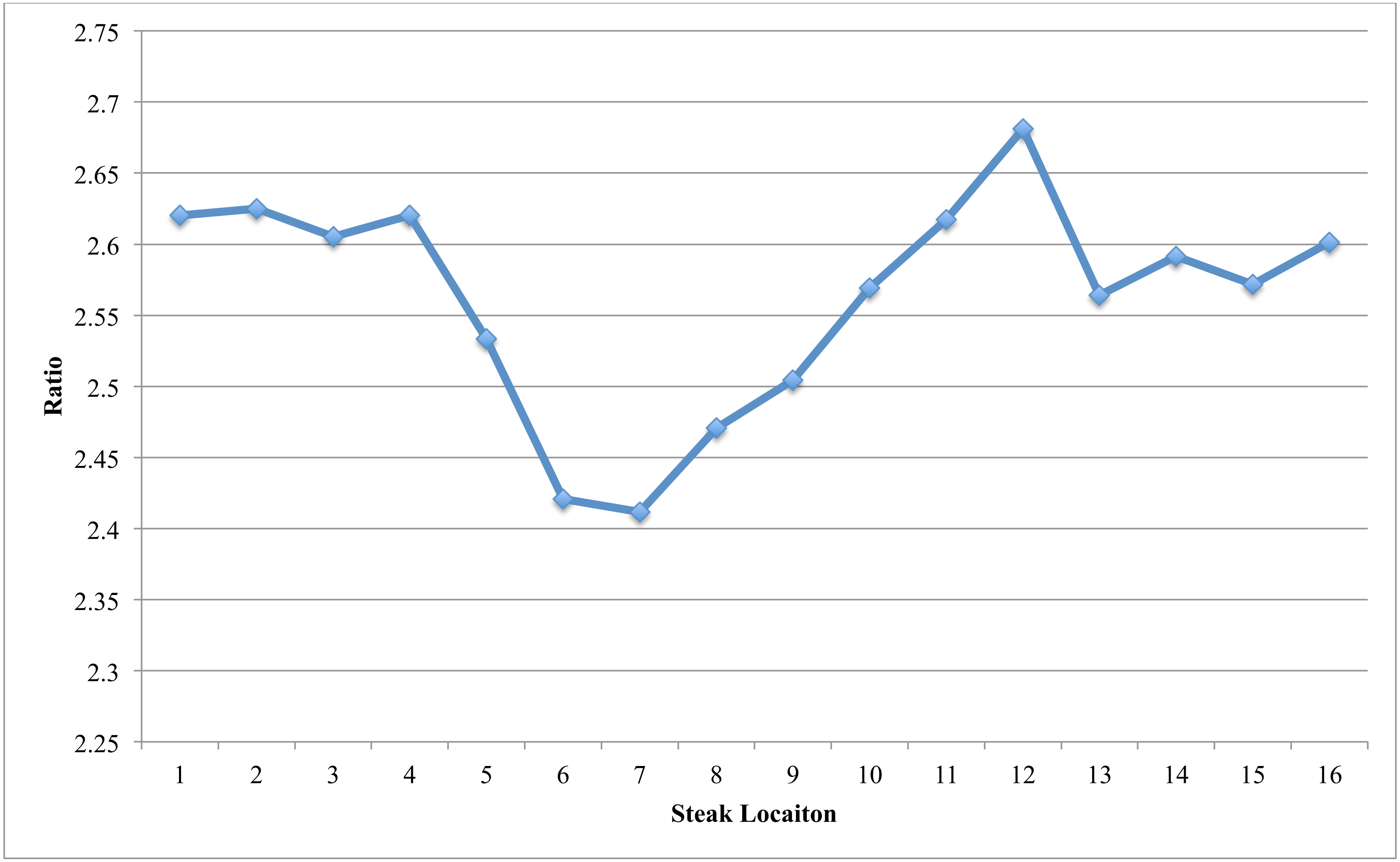

Figure A.57. Least squares means for Ribeye Ratio 75 measurements Steak Location Main effects. Ratio 75- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 25% of the length of the entire steak**.**

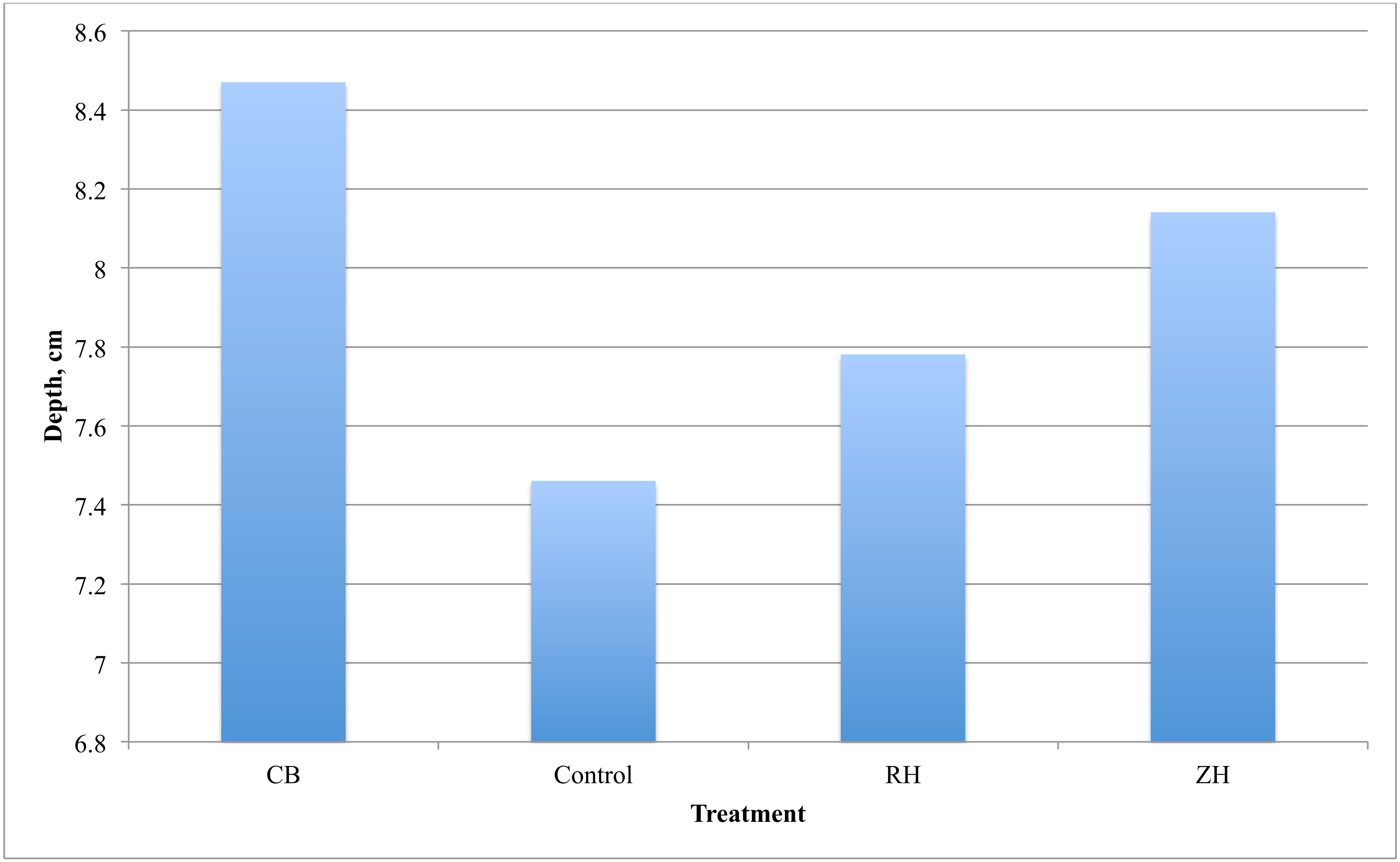

Figure A.58. Least squares means for Ribeye 25% Depth measurements Treatment Main effect. 25% Depth - depth of entire steak (dorsal to ventral) at 25% of the length of the entire steak in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

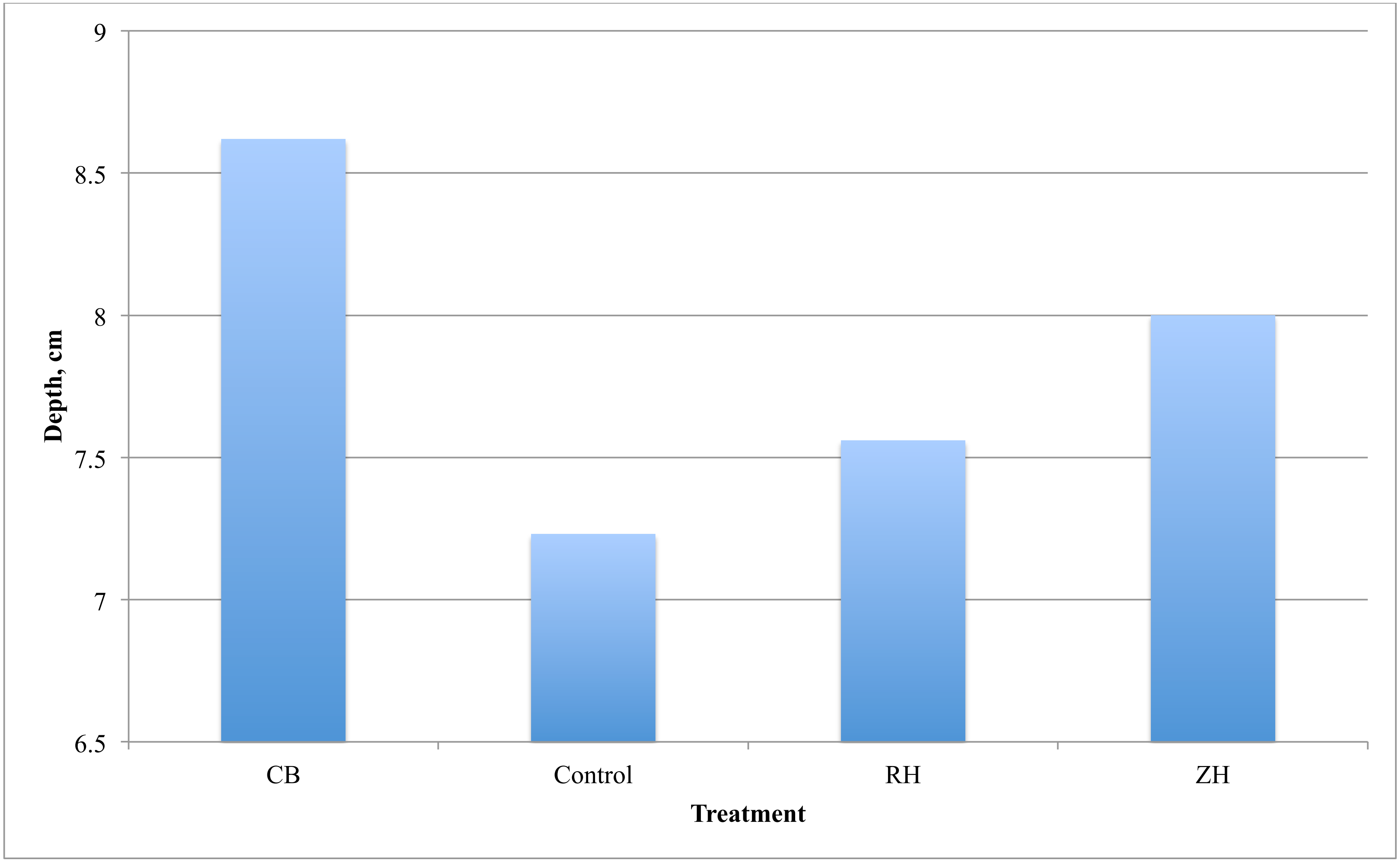

Figure A.59. Least squares means for Ribeye 50% Depth measurements Treatment Main effect. 50% Depth - depth of entire steak (dorsal to ventral) at 50% of the length of the entire steak in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

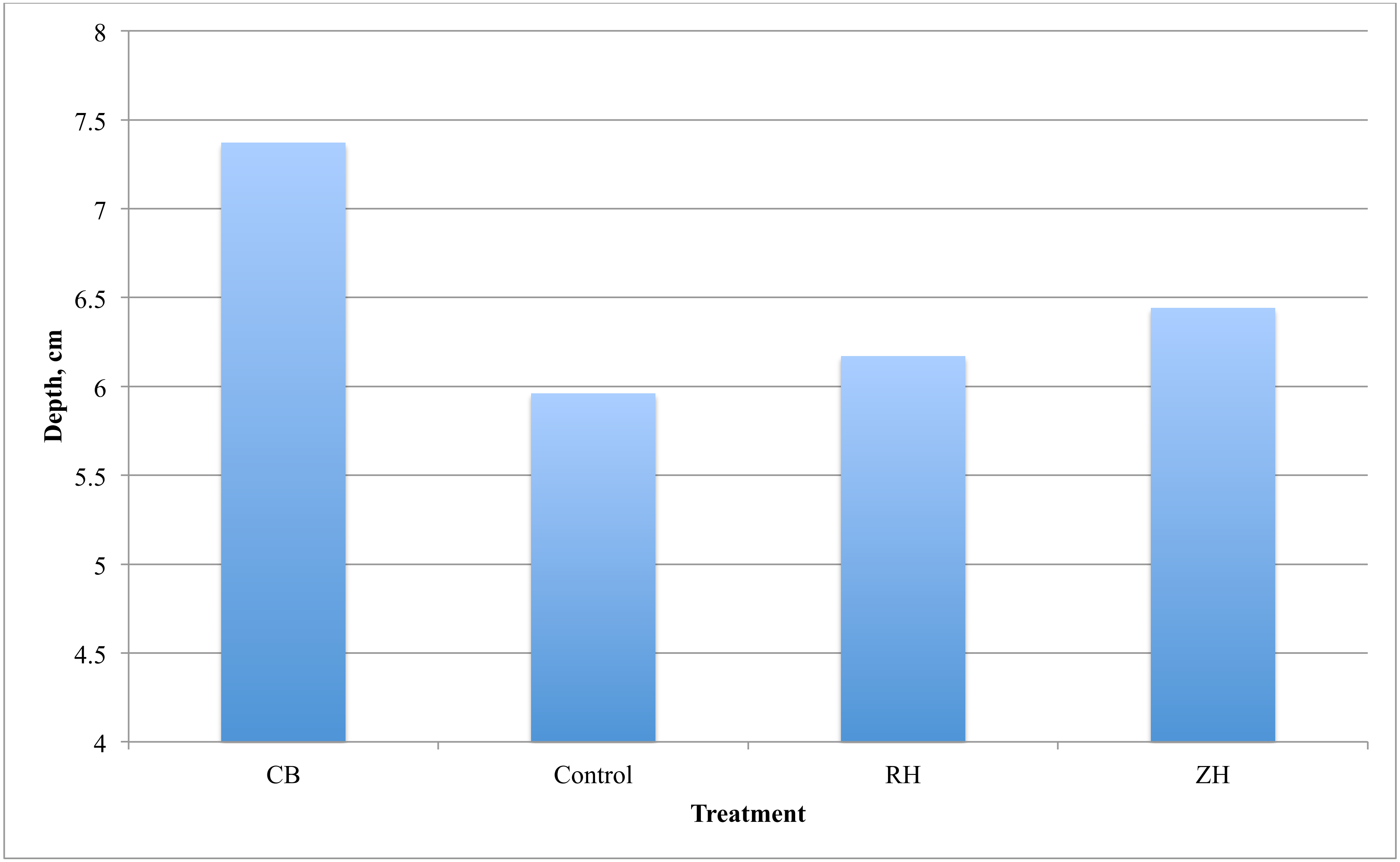

Figure A.60. Least squares means for Ribeye 75% Depth measurements Treatment Main effect. 75% Depth - depth of entire steak (dorsal to ventral) at 75% of the length of the entire steak in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

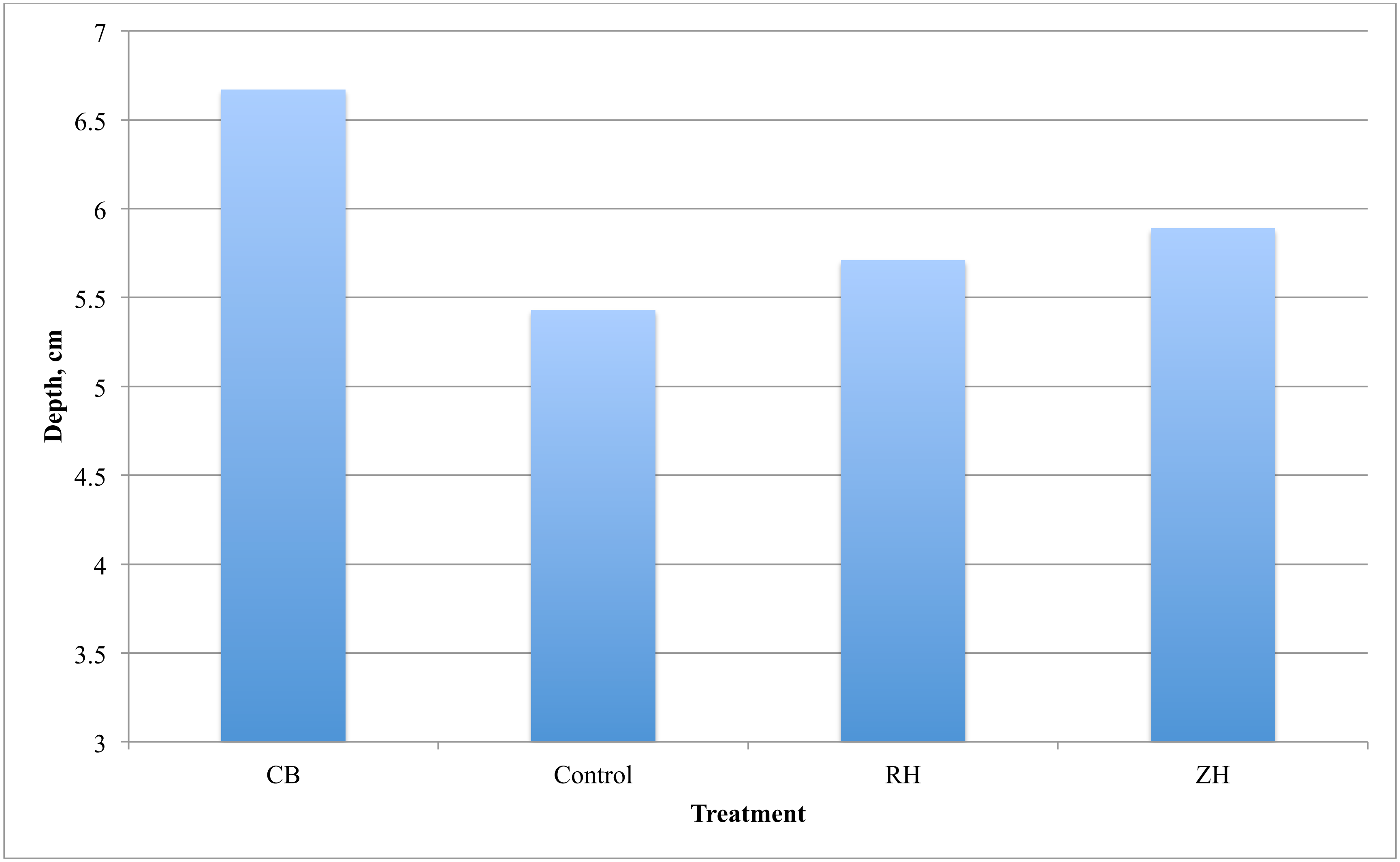

Figure A.61. Least squares means for Ribeye LT Depth measurements Treatment Main effect. LT Depth - depth of the *longisimus thoracis* (dorsal to ventral) at 50% of the length (medial to lateral) of *longisimus thoracis* in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

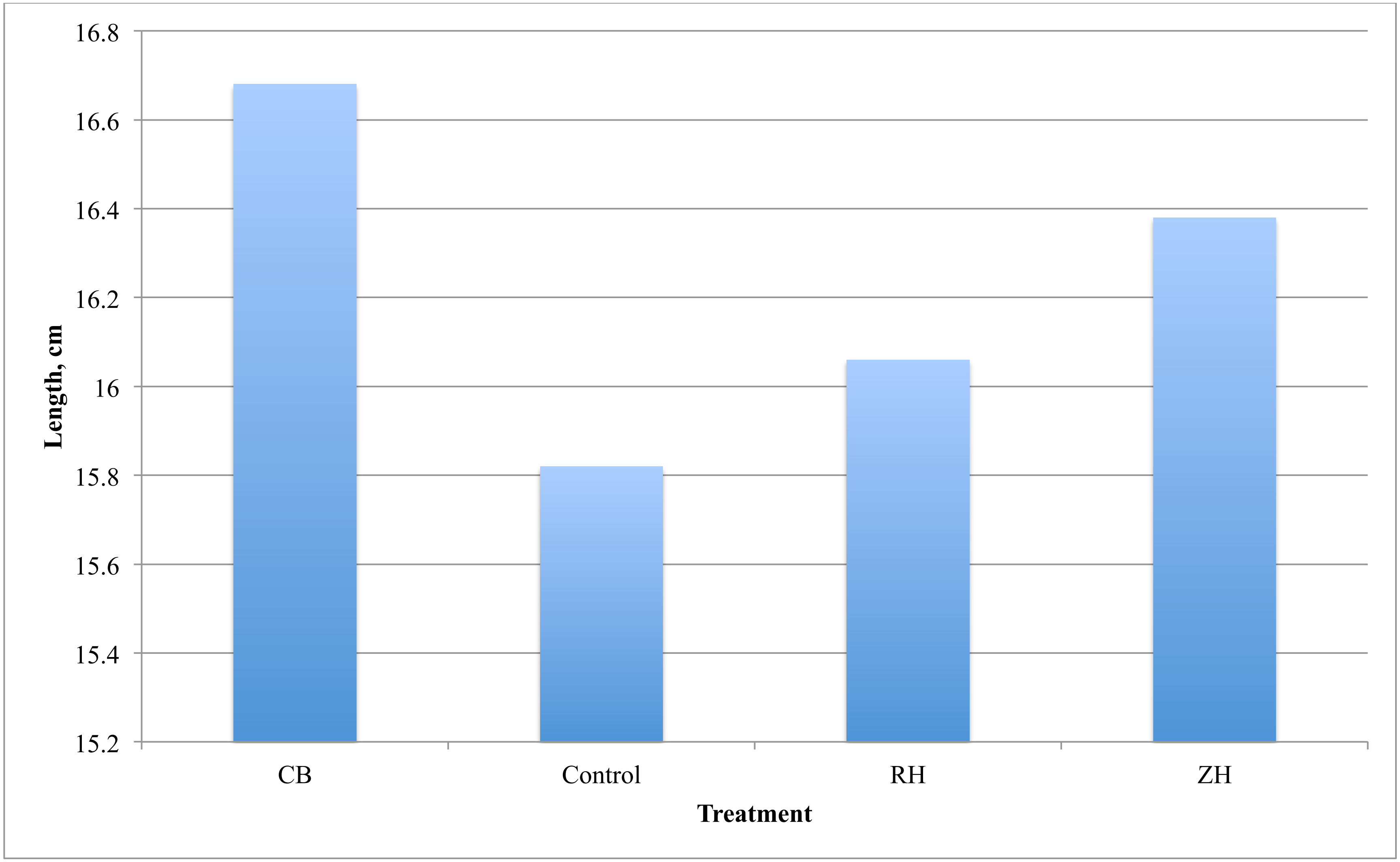

Figure A.62. Least squares means for Ribeye Length measurements Treatment Main effect. Length - Length of the entire steak (medial to lateral) in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

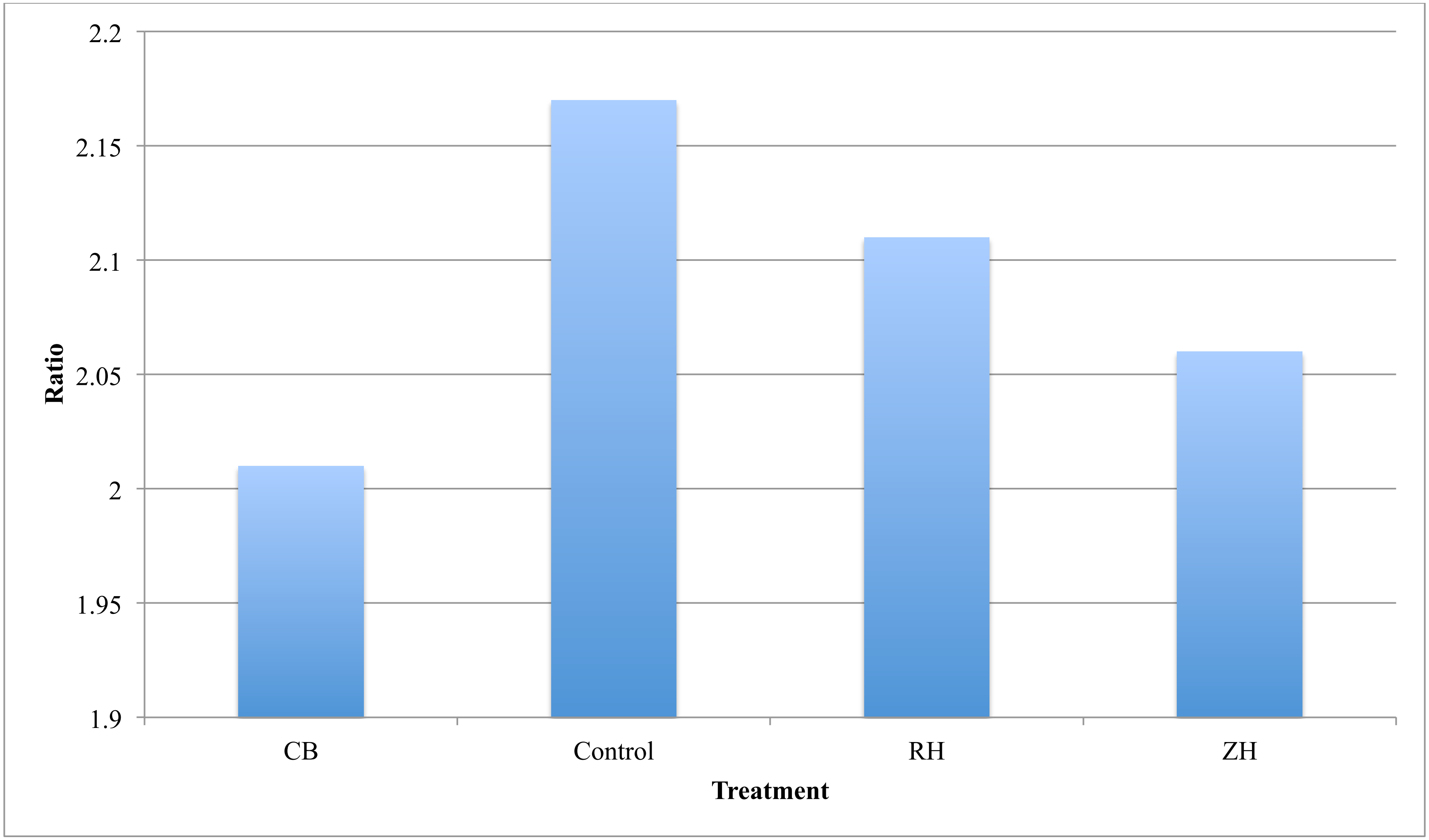

Figure A.63. Least squares means for Ribeye Ratio 25 measurements Treatment Main effects. Ratio 25- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 25% of the length of the entire steak. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

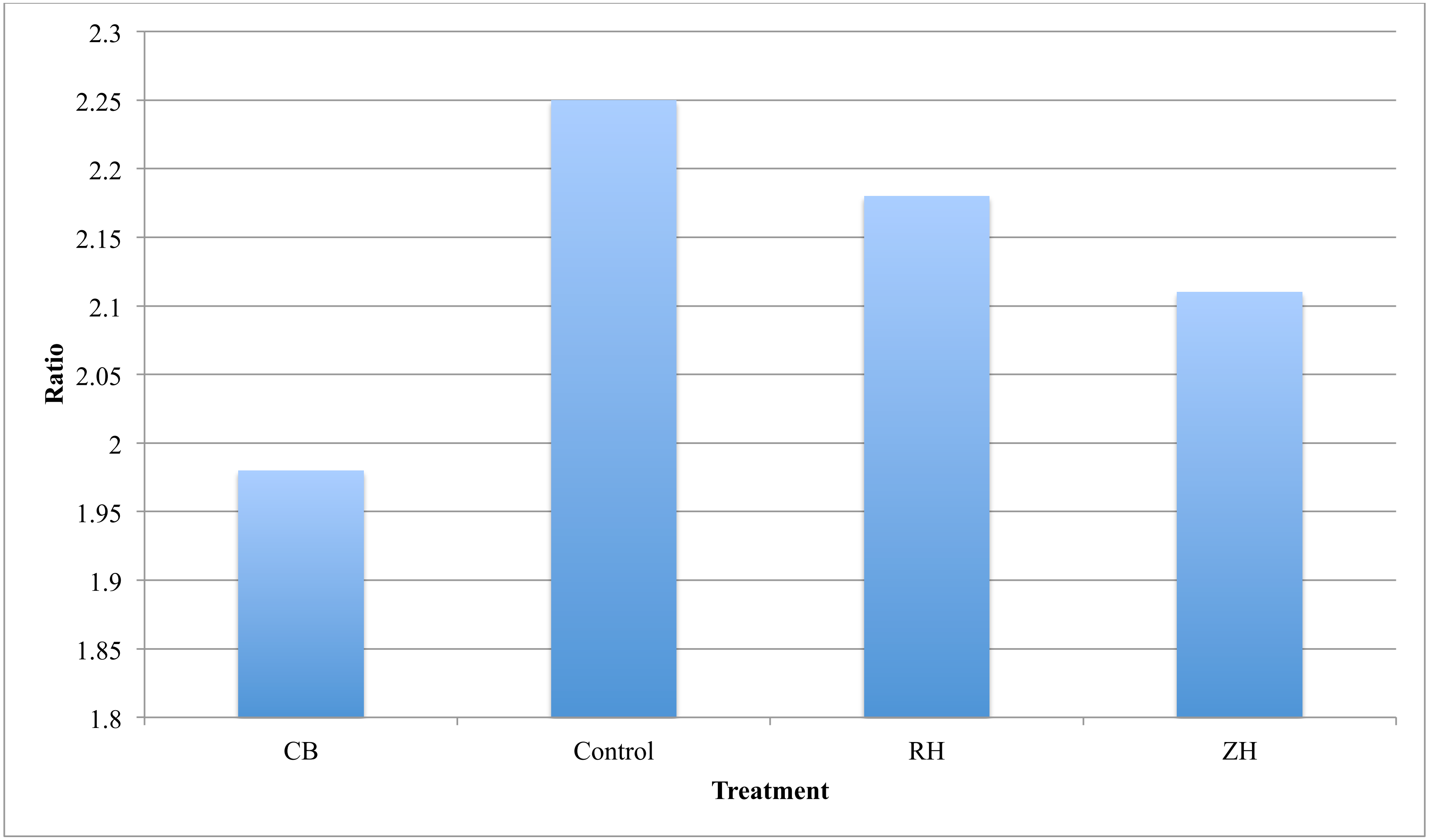

Figure A.64. Least squares means for Ribeye Ratio 50 measurements Treatment Main effects. Ratio 50- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 50% of the length of the entire steak. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

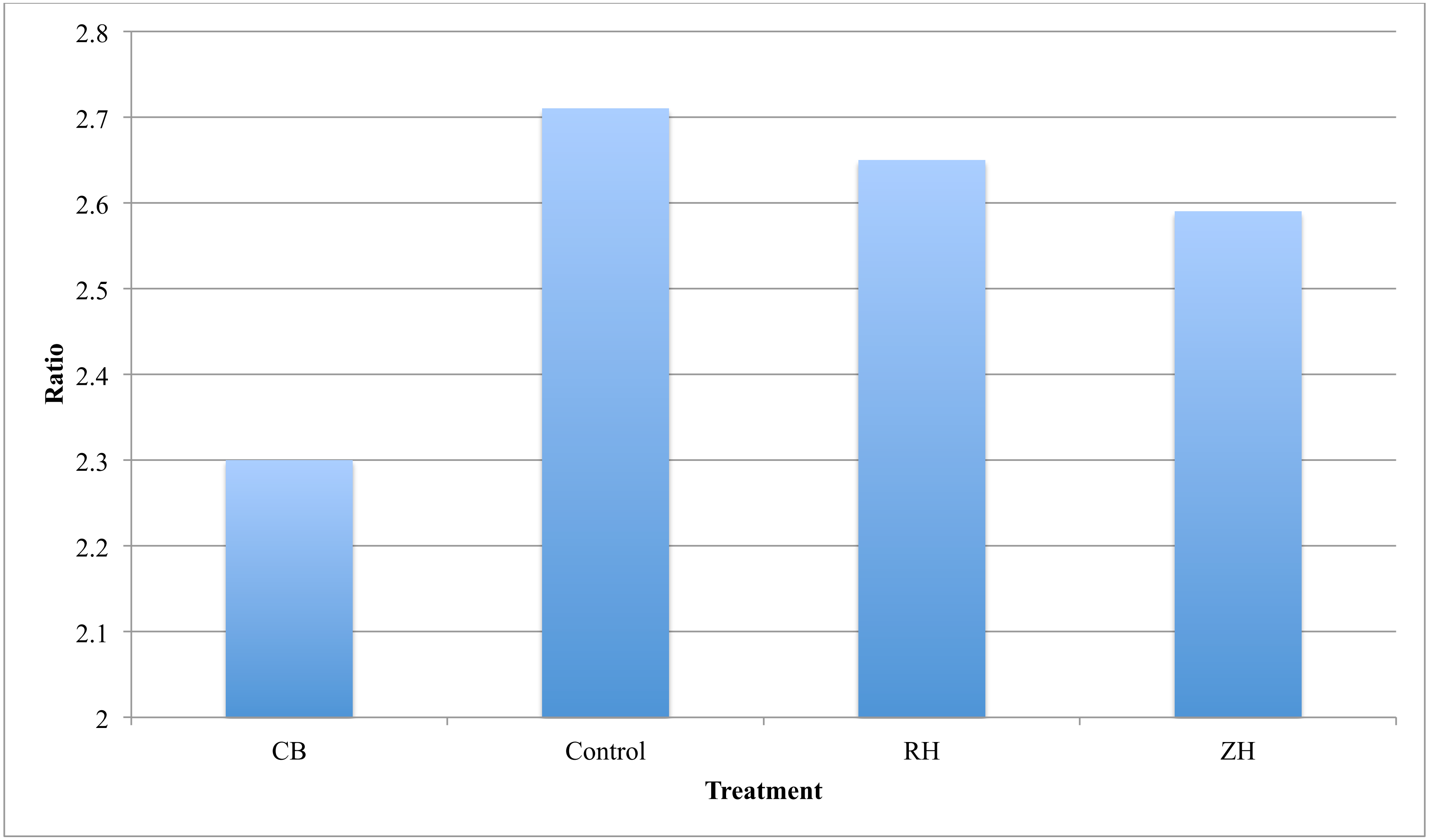

Figure A.65. Least squares means for Ribeye Ratio 75 measurements Treatment Main effects. Ratio 75- Ratio of the Length of the entire steak (medial to lateral) divided by the depth of the entire steak (dorsal to ventral) at 75% of the length of the entire steak. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

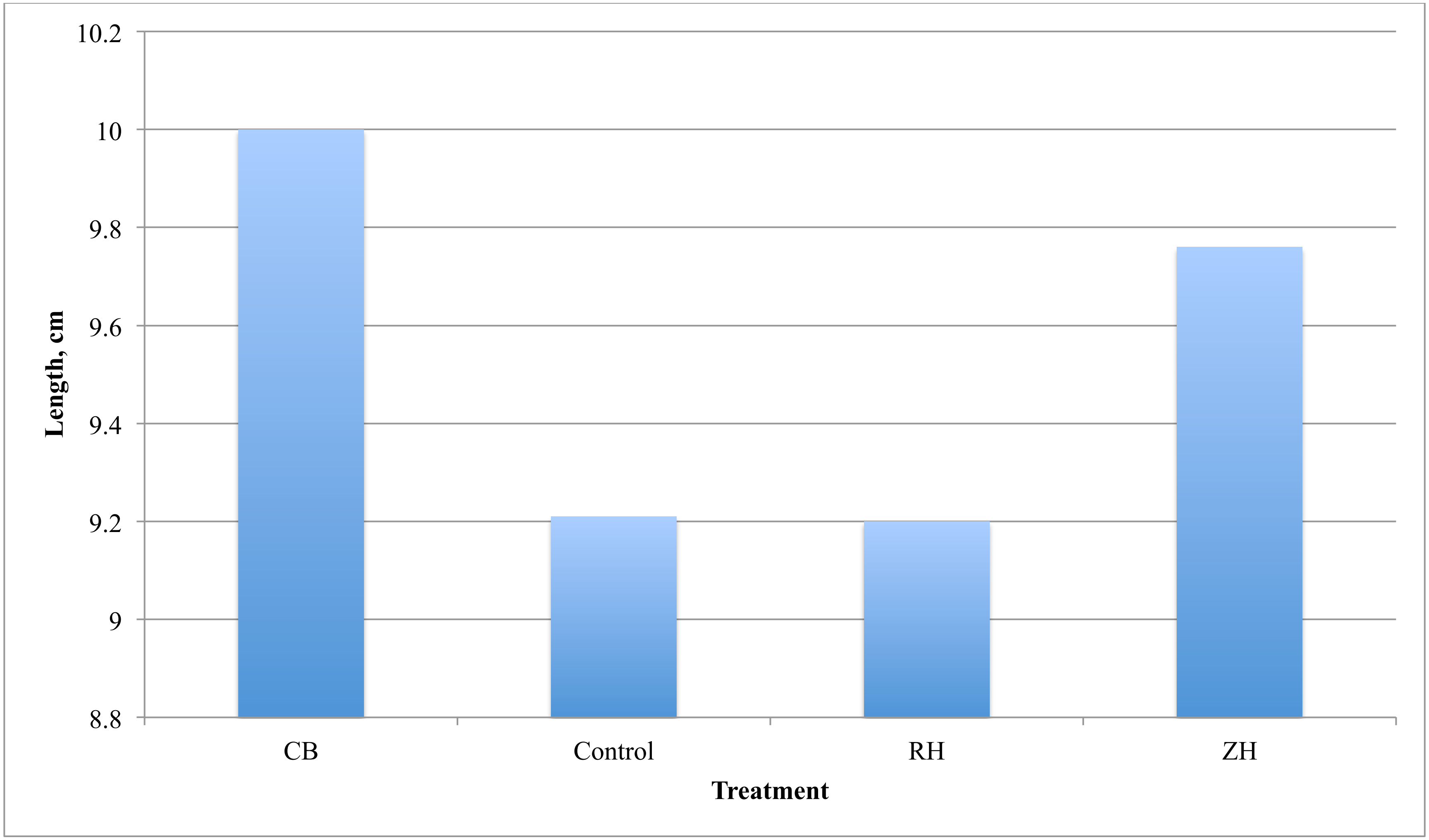

Figure A.66. Least squares means for Ribeye SD Length measurements Treatment Main effect. SD Length - length of the *spinalis dorsi* (medial to lateral) in cm. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.

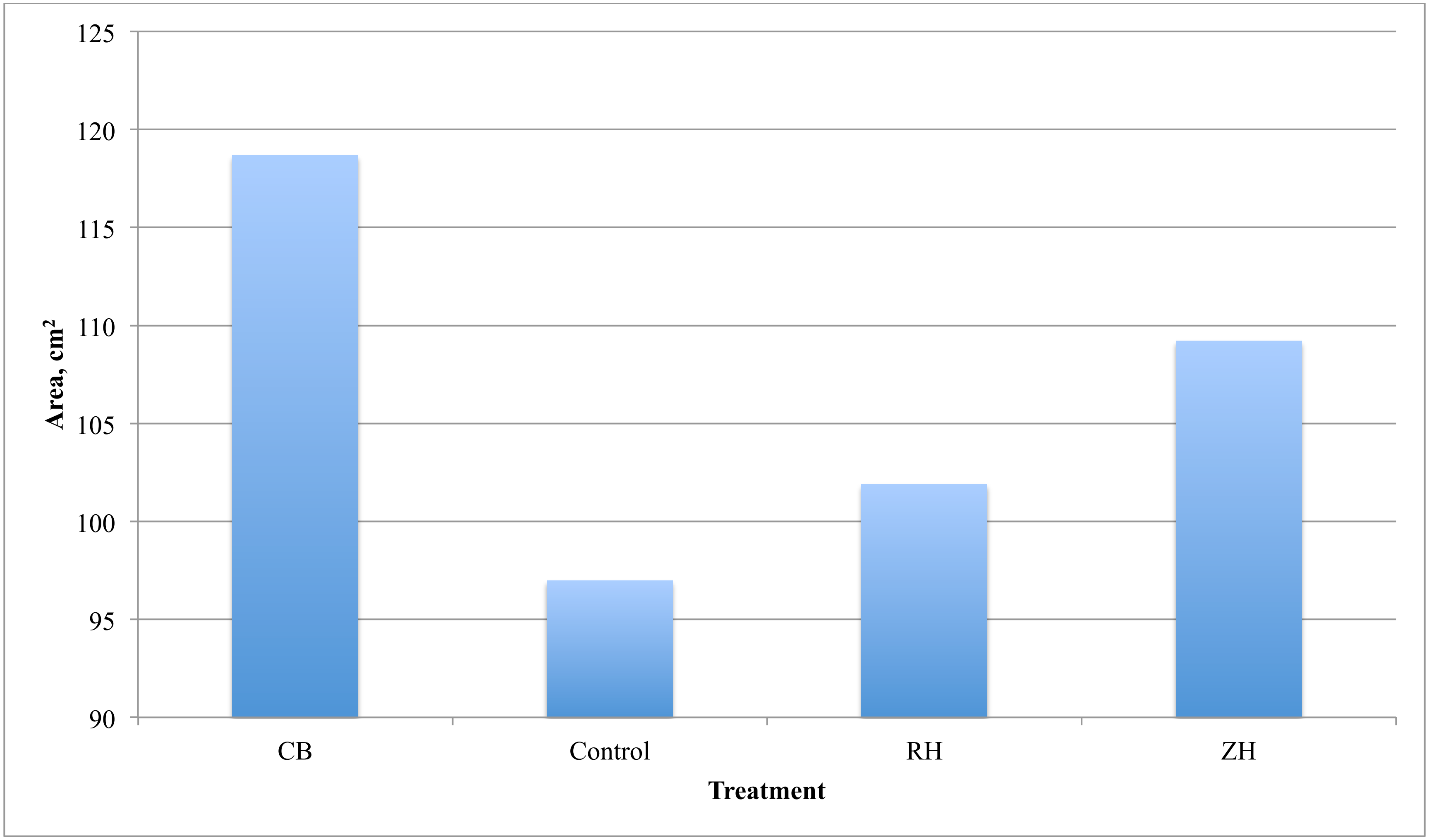

Figure A.67. Least squares means for Ribeye Total Area measurements Treatment Main effect. Total Area – Area of the whole steak including LT area, SD area, K Fat area, and C area in cm^2. CB– conventionally managed beef; Control – implanted with Revalor®-XS; RH – Revalor®-XS + Ractopamine hydrochloride; ZH – Revalor®-XS + Zilpaterol hydrochloride.