final report

Project code: V.EQT.1510

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Date published: September 2015

ISBN: 9781741919691

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Beta-agonists and cattle performance

A meta analysis

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This study is a meta-analysis of the effects of the beta-agonists zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RAC) on feedlot performance, carcase characteristics of cattle and Warner Bratzler shear force (WBSF) of muscles. It was conducted to evaluate the effect of the use of these agents on beef production and meat quality and to provide data that would be useful in considerations on the effect of these agents on meat in Meat Standards Australia evaluations. We conducted a comprehensive literature search and study assessment. Data were extracted from more than 50 comparisons for both agents and analysed using meta-analysis and meta-regression. Both agents markedly increased weight gain, hot carcase weight and longissimus muscle area and increased the efficiency of gain:feed. These effects were particular large for ZH, however, fat thickness and kidney, pelvic and heart fat were decreased by ZH. Zilpaterol markedly increased WBSF by 1.2 standard deviations and more than 0.8 kg, while RAC increased WBSF by 0.43 standard deviations and 0.2 kg. This work has provided critically needed information on the effects of ZH and RAC on production, efficiency and meat quality.

Executive summary

This study is a meta-analysis of the effects of the beta-agonists zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RAC) on feedlot performance, carcase characteristics of cattle and Warner Bratzler shear force (WBSF) of muscles. It was conducted to evaluate the effect of the use of these agents on beef production and meat quality and to provide data that would be useful in considerations of the effect of these agents on meat in Meat Standards Australia evaluations.

We conducted a comprehensive literature search using more than four databases, examination of literature in retrieved papers and contact with authors of papers. These papers were examined for suitability for inclusion in meta-analysis using predetermined study quality assessment criteria by two experienced examiners. More than 30 papers were identified for both ZH and RAC and these contained more than 50 comparisons. These data, however, provided challenges because the unit of evaluation was not always clear, nor consistent. A number of papers contained pseudo-replicated studies (where the effective number of observations was one per group), some were evaluated at the pen level, some at the animal, carcase or muscle level. The structure of data in studies was carefully evaluated in this study. Data were extracted from more than 50 comparisons for both agents and analysed using meta-analysis and meta-regression. The sensory information available did not clearly identify the unit of analysis and some studies were purposively sampled making these unsuitable for meta-analysis.

Both ZH and RAC markedly increased average daily gain, resulting in a higher final weight before slaughter for treated cattle and heavier hot carcase weight (HCW), dressing percentage and longissimus muscle area (LMA). The ZH treatment more markedly increased HCW than final feeding weight as assessed either by effect size or weight mean difference. In particular, ZH dramatically increased outcomes in some cases by more than 2 standardised mean differences (SMD). For ZH the fat thickness, marbling and kidney, pelvic and heart fat percentage and USDSA yield grade were decreased by treatment. These effects were also large (approaching or exceeding a standardised mean difference (SMD) of 0.8) and marbling was markedly reduced. It appears that ZH has a very large effect in partitioning of nutrients to muscle and away from other tissue pools. In general, the effects of RAC were similar, but less pronounced than ZH on feedlot efficiency. The effect of RAC treatment was not significant on fat thickness, marbling or kidney, pelvic and heart fat percentage. However, USDA yield grade was significantly decreased.

Treatment with ZH markedly increased WBSF by 1.2 standard deviations and more than 0.8 kg, while RAC increased WBSF by 0.43 standard deviations and 0.3 kg. In the case of ZH, the results were influenced by the unit of evaluation, ie pen or animal, cases and muscle. Reasons for this are not entirely clear, but significant differences existed in the raw means of the groups defined by unit of evaluation. These findings were consistent with similar observations of the effect of unit of evaluation for ZH studies on LMA and marbling. In all cases (LMA, marbling and WBSF), the pen studies showed a more pronounced effect of treatment than individual studies and the similarly observed effects in unweighted evaluations of the raw means of the effects suggest a biological, rather than statistical methods basis for the observation. These effects were not observed for the RAC trials.The

ZH results for WBSF were also influenced by the aging of the muscles. Increased aging reduced the effect size of the increase in WBSF. All ZH trials showed an increase in WBSF.

These findings support the previously identified physiological roles of the β-AA and provide a strong evidence for producers and others to examine and consider the effects of ZH and RAC on beef cattle production. Once these results have been critically reviewed by others, they can be immediately applied and used to formulate strategies to make best use of agents that markedly improve the efficiency of production.

This work provided critically needed information on the effects of ZH and RAC on production, efficiency and meat quality. We were able meet our goals in providing more precise and robust estimates of the effects of the β-AA on efficiency of production and carcase quality measures. We identified using meta-regression that the method of feeding cattle may influence responses to ZH and identified that aging of steaks can reduce the effects of ZH on WBSF.

Contents

1 Background

As the beef industry continues to adapt to changing consumer demands, beef producers develop and use research-based dietary additives to enhance the efficiency of gain, such as *β*-adrenergic agonists (***β*-AA**). The *β*-AA have improved the efficiency of gain and altered carcass characteristics and meat quality of several animal species (Pringle et al., 1993; Crome et al., 1996). Mexico and South Africa approved use of *β*-AA, including ZH and RAC, more than 10 years ago to improve feedlot performance. In 2003, RAC was approved for use in cattle in the United States, and ZH, was approved in 2006 for increased rate of weight gain, improved feed efficiency, and increased carcass leanness in cattle fed in confinement for slaughter during the last 20 to 40 d on feed.

There are many studies that have examined the effects of these*β*-AA on production and carcase attributes. However, some of these are pen studies that, hadquite variable statistical power. Consequently, some outcomes that were not significant in single studies appear to have consistent directions of effect when evaluated over the range of studies conducted. Under these conditions, meta-analytic methods provide a powerful tool to evaluate the body of evidence and to determine the effects of these interventions.

Meta-analysis is a formal method of epidemiologic study design used to provide a synthesis of previous studies. Studies in the agricultural and veterinary science are frequently randomised controlled trials and the quantitative evaluation of the efficacy of an intervention resulting from the meta-analysis can be made readily accessible to researchers, producers and advisors.

Both ZH and RAC are organic molecules that bind to β-adrenergic receptors, located in the cellular membranes. As reviewed by Dunshea et al., (2005) these compounds have been shown to indirectly lead to decreased lipogenesis (fat synthesis and storage) and increased lipolysis (fat mobilization and hydrolysis) (Liu and Mills 1989; Dunshea 1993; Mersmann 1998). The rate of fat accumulation in adipocytes or growth of the adipose tissue mass slows, particularly in ruminants, resulting in a leaner animal. The magnitude of these changes is influenced by dose and duration of treatment with the *β*-AA, the type of *β*-AA, and the species (Beerman 1993; Mersmann 1998; Moody et al., 2000).

In association with changes in fat metabolism there is evidence that *β*-AA also impact of protein metabolism. Pringle et al., (1993) and Crome et al., (1996)concluded that RAC improved growth performance and affected carcass characteristics in animals largely via increased protein synthesis (Moody, Hancock et al., 2000). As discussed by Mersmann (1998) and Moody et al., (2000), ZH appears to function through both increased protein synthesis and decreased protein degradation. Dunshea et al., (2005)reviewed a number of studies and concluded that changes in the both synthesis and degradation were implicated for both RAC and ZH.

Koohmaraiet et al., (2002)examined the effect of improvements in animal growth as functions of protein synthesis and protein degradation in the live animal and how these impacted on eating quality of the meat. They concluded that if improvements in growth were solely through increased protein synthesis then there was unlikely to be any effect on eating quality. If on the other hand the increased growth was due in part to decreased protein degradation, this would generally be reflected as a slower ageing rate in the carcass post-mortem, and hence at the same ageing time, the meat from growth enhanced animals would be more tender.

A previous review by Dunshea et al., (2005) showed that the effects of *β*-AA on meat quality were equivocal. The results tended to vary in direction and magnitude of the effects and also in their statistical significance. This meta-analysis aims to consolidate the

RESULTS from different studies to identify and quantify the effects of the β-AA (ZH and RAC) on feed intake, feedlot performance, carcass traits and meat quality in cattle. There appears to be less published information of the effects of the effects of β-AA on meat quality than in pigs and there is a need to consolidate the understandings obtained from the individual cattle studies.

2 Project objectives

The objective of this study was to evaluate the effects of β-adrenergic agonists on feedlot performance, carcass characteristics and meat quality of cattle, using meta-analytic methods. The outcomes of this meta-analysis include;

- a more precise estimate of the effects of β-AA (ZH and RAC) on performance outcomes and evaluation of sources of heterogeneity (variation) among the studies.
- An examination of heterogeneity which can be used to better target future research projects and resolve other hypotheses raised about the action of the products and gaps in current knowledge.
- An understanding of factors that give rise to heterogeneity in the studies can also lead to more effective treatments or modifications of management. Meta-regression is an extension of meta-analysis and allows the examination of factors that influence study results to be identified and quantified, thereby improving understandings of the best options for the successful use of β-AA in the field.

To achieve the objectives of this study a comprehensive literature search will be conducted to identify published and unpublished studies on the effect of β-AA on cattle performance, carcass characterises and meat quality. Suitable studies will be identified using selection criteria established by the research team. Data from studies will be extracted and analysed, using meta-analytic methods, to provide a pooled estimate of effect size for the outcomes of interest.

The main focus of this study is on the effect of each β-AA on production and meat quality and a general hypothesis that the β-AA, specifically ZH or RAC, will not alter production or carcase characteristics will be tested for each variable and β-AA.

3 Materials and methods

Literature Search

Our literature searches used PubMed, Google Scholar, ScienceDirect, Scirus, and CAB; contact with workers in the field; and investigation of references in papers. It was based on the following key words: zilpaterol or ractopamine, zilmax or optiflex, cattle, beef. We included studies contained within theses obtained from universities. A list of studies on ZH in beef cattle was also provided by Meat and Livestock Australia (MLA). We used these papers to identify other suitable papers for the meta-analysis. In many cases, authors of articles were contacted to provide clarity in regard to results and for additional information.

Inclusion and Exclusion Criteria

Studies were included or excluded in this study based on a series of criteria developed by the authors. Quality assessment criteria included randomization of study groups, appropriate analysis of data and comparability of treatment groups at entry to each trial. The extracted data were audited by two reviewers.

Trials were included in the analysis if they met the following criteria: full manuscripts from peer-reviewed journals, published after 1980, that evaluated use of ZH or RAC supplementation in cattle; had a description of randomization processes; reported the dose of fat supplements, animals studied were cattle; the paper contained sufficient datato determine the effect size for production outcomes (e.g., the number of cattle or pens, carcases or cuts of beef in each treatment and control group); a measure of effect amendable to effect size analysis for continuous data (e.g., standardized mean difference, **SMD**); a measure of variance (SE or SD)for each effect estimate or treatment and control comparisons. Effect size is the standardized difference between treatment and control groups means calculated using the standard deviations of control and treatment groups. Studies that could not be adequately interpreted in regard to origin of muscles, used purposive and non-representative sampling methods and where authors did not respond to clarify their approach were rejected.

Selection criteria were developed by SBS*cibus* for the inclusion and exclusion of studies. This included peer-reviewed papers that reported:

- Study design and number of: animal/pen, animal/group, pens/group
- Experimental and analytical unit (animal, pen, carcass, muscle)
- Test products: ZH or RAC,
- Days on feed
- Number days products fed
- Dosage of products fed (per kg DMI or per kg/hd/d)
- Diet and delivery methods of product
- Withdrawal period (days)
- Class of cattle; steers or heifers, bulls and cull cows (sensitivity analysis will be conducted on the class of cattle)
- Vaccination history and use of anthelmintics
- Other supplements and growth promoting products (implants)
- Housing and feeding systems
- Distance travelled to the abattoirs

Variables that were considered for the meta-analysis include:

Performance data

- Body weight (BW)
- Dry matter intake (DMI)
- Average daily gain (ADG)
- Gain:Feed ratio

Carcass characteristics

- Carcass pH
- Hot Carcass weight (HCW)
- Longissimus muscle area (LMA) (cm)
- Carcass colour score (scale 1 to 9)
- Marbling score
- Fat thickness (rib 12th)
- Yielding grade (scale 1 to 5)
- Dressing (%)
- Lean maturity score (0 to >200)
- Overall maturity score (0 to >200)
- Kidney, pelvic & heart (KPH) fat (%)

Cooking quality

- Warner –Bratzler shear force (WBSF) (kg)

Definitions of these variables are provided in Table 1. There was a lack of consistently reported sensory data for ZH and RAC studies, however, further literature searching for these is envisaged to assess whether there are sufficient studies reporting outcomes in a format suitable for analysis to evaluate.

Statistical analysis

We used Stata (Intercooled Stata v.12, USA) to analyze production and carcass data by standardized mean difference (**SMD**) which is also called effect size (**ES**) analysis, in which the difference between treatment and control groups means was standardized using the standard deviations of control and treatment groups. The SMD estimates were pooled using the methods of Cohen (1988) for the fixed effect and DerSimonian and Laird (1986) for the random effects models. If the paper reported separate estimates of measure of variance (SE or SD) for each group, these were recorded as such. The studies reported a common SE or SD and the estimate was used for both control and treatment groups. We also have provided a random effects weighted mean difference (**WMD**) between treated and control, with the weighting reflecting the inverse of the variance of the studies included according to nostandard method (Stata 12.0 Statacorp, Tx, USA).

Random effects models were conducted for each production outcome to estimate the effect size, 95% confidence intervals, and statistical significance of SMD. We recognize that there is a clustering effect that results from multiple comparisons to a single control group, but have determined that the variance inflation effect will be minor unless there are very large numbers of repeated comparisons. The statistical methods of meta-analytic procedures that were used in this paper have been previously published by the authors of this study (Lean et al., 2009).

Figure 1.shows the structure of data provided in this study. Efforts were made to clearly identify the units of interest used the studies and to clarify the measures of dispersion reported in documents. Authors were contacted to provide clarification of these measures and a number responded. If there was a lack of clarity in regards to the unit of measure a more conservative measure was used. Specifically, if muscle characteristics were measured and evaluated as the unit of analysis, but the muscles were obtained from pen fed studies, the unit used in our analysis was pen.

Forest plots**.** The effects of β-AA on production performance of beef cattle are displayed in the forest plots, using the estimated SMD of β-AA (Figures Appendix 1). Points to the left of the line represent a reduction in the outcome, whereas points to the right of the line indicate an increase in the outcome variable. Each square represents the mean effect size for that study. The upper and lower limit of the line connected to the square represents the upper and lower 95% confidence interval (CI) for the effect size.

The weighting of a study is estimated by the inverse of the variance of the effect size. Box sizes are proportional to the inverse variance of the estimates. The size of the square box reflects the relative weighting of the study to the overall effect size estimate with larger squares representing greater weight. Boxes draw attention to the studies with the greatest weight. The grey vertical line represents the mean difference of zero or no effect.

Assessment of heterogeneity. Variations among the trial level SMD were assessed using a chi-squared (**Q**) test of heterogeneity. Heterogeneity in studies reflects underlying differences in clinical diversity of the herds and β-AA used, differences in study design and analytical methods, and statistical variation around responses. Identifying the presence and sources of the heterogeneity improves understanding of the responses to β-AA. We used an α level of 0.10 because of the relatively poor power of the χ^2 test to detect heterogeneity among small numbers of trials (Egger and Smith 2001). Heterogeneity of results among the trials was quantified using the I^2 statistic (Higgins and Thompson 2002), who. developed this measure of the impact of heterogeneity on a meta-analysis, from mathematical criteria, that are independent of the number of studies and the treatment effect metric. I^2 is a transformation of the square root of the χ^2 heterogeneity statistic divided by its degrees of freedom and describes the proportion of total variation in study estimates that is due to heterogeneity. Negative values of I^2 were assigned a value of zero, consequently the value I^2 lies between 0 and 100%. An I^2 value greater than 50% may be considered indicative of substantial heterogeneity.

Meta-regression. Meta-regression analyses were used to explore the source of heterogeneity of response, using the individual SMD for each trial as the outcome and the associated standard error as the measure of variance. It is appropriate to use meta-regression to explore sources of heterogeneity even if an initial overall test for heterogeneity is non-significant (Higgins and Thompson 2002). This also allows us to quantify the magnitude as a function of the *a priori* defined covariate changing and exploring reasons for heterogeneity (i.e. possible/probable study-level predictors). Meta-regression is also a technique that can formally test whether there is evidence of different effects in different subgroups of trials (Knapp and Hartung 2003). In order to include more than one covariate in the model, we used the methods of Knapp and Hartung (2003). This method was extended to the case of more than one covariate in the meta-regression, and the use of the smoothed within-trial variance estimates to improve hypothesis testing with regard to the significance levels. The permutation test approach for assessing the statistical significance of meta-regression methods suggested by Higgins and Thompson (2004), and programmed by Harbord and Higgins (2008) and Harbord and Steichen (2004), was used in this paper to reduce the risk of type I error.

Meta-regression analysis was conducted by first screening individual variables using a P-value of ≤ 0.10. All variables with P-value of ≤ 0.10 were entered into a forward stepwise weighted meta-regression, until all remaining variables were significant at $P<0.05$. Factors that were examined include: the unit of study (pen or animal or cut of meat), initial value of the study variable in the control group in each study (eg DMI of control), duration of feeding in the study (days on feed) and period or duration of treatment with each β-AA (eg RAC was fed for 30 days). Data were screened for plausible quadratic relationships for these variables by visual appraisal of univariable scatter plots between the covariate and SMD of each study.

***Publication bias*.** The presence of publication bias is commonly investigated using funnel plots. A funnel plot is a simple scatter plot of the intervention effect estimates from individual studies plotted against measures of each study's size or precision. The plot is commonly presented with the effect estimates on the horizontal scale, and a measure of variance on the vertical axis. The name 'funnel plot' arises because precision of the estimated intervention effect increases as the size of the study increases. Effect estimates from small studies will therefore scatter more widely at the bottom of the graph and the spread narrows for larger studies. In the absence of bias the plot should approximately resemble a symmetrical (inverted) funnel. If there is bias, for example because smaller studies without statistically significant effects remain unpublished, this will lead to an asymmetrical appearance of the funnel plot and a gap will be evident in a bottom corner of the graph. In this situation, the effect calculated in a meta-analysis will tend to overestimate the intervention effect. The more pronounced the asymmetry, the more likely it is that the bias will be substantial.

4 Results

Table 1.Definitions of carcass characteristics used in the papers

Carcass parameters	Definitions
Hot carcass weight (HCW)(kg)	Weight of a carcass just prior to chilling
Dressing percentage (%)	The percentage of the live animal weight that becomes carcass weight after slaughter. It is determined by dividing the carcass weight by the live weight, then multiplying by 100.
Fat thickness (12^{th} rib) (%)	Fat thickness is a measure of the thickness of external fat on a carcass. The measurement is taken on the cut surface of the ribeye between the 12th and 13th ribs at a point three-fourths of the ribeye length from the split chine bone.
Longissimus muscle area(LMA) (cm^2)	The longissimus is the muscle lateral to the semispinalis. It is the longest subdivision of the sacrospinalis that extends forward into the transverse processes of the posterior cervical vertebrae.
Colour score	Scale: of 1 to 9; with 1 = light pink, and 9=dark maroon, normal cherry red beef colour=5
Lean maturity score Overall maturity score	Maturity is a measure of the physiological maturity of the carcass being assessed Scores: 0 to 99= A maturity; 100 to 199= B maturity; >200= C maturity
Marbling score (MS)	Marbling, or intramuscular fat, is the distribution of fat within the lean of the ribeye muscle. Graders evaluate the amount and distribution of marbling at the cut surface of the ribeye between the 12th and 13th ribs. Scores: 300= slight; 400= small; 500= modest
Calculated yield grades	Yield grades are used to identify carcasses that differ in yield of boneless, closely trimmed retail cuts from the round, loin, rib, and chuck. Four factors determine yield grade: 13th rib fat thickness, ribeye area, hot carcass weight, and precent KPH (kidney, pelvic and heart fat). Of these, fat thickness has the largest effect followed by ribeye area. The formula for calculating yield grade is: *2.5 + (2.5 * fat thickness) + (0.2 * %KPH) + (.0038 * hot carcass weight) - (0.32 * ribeye area)*. Yield grades range from 1 through 5. A yield grade 5 carcass would have the lowest cutability and would be characterized as light muscled and/or excessively fat.
Warner-Bratzler shear force (WBSF) (kg)	The amount of force that is needed to shear muscles measured using Warner-Bratzler shear force test. The more force needed, the tougher the meat is. Warner-Bratzler shear force is performed using a Warner-Bratzler shear blade and crosshead speed of 200 or 250 mm/minute.
Cooking loss (%)	Cooking loss refers to the reduction in weight of beef during the cooking process. The major components of cooking losses are thawing, dripping and evaporation.

Table 2. List of studies in different countries, breed and class of cattle, days on feed and period of feeding zilpaterol

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Zilpaterol (days)
Avendano-Reyes et al., 2006	Mexico	RCT	Charolais, Limousin, Zebu, Brangus	Steer	105	33
Baxa et al., 2010	USA	2 x 2 factorial design	English x continental cross	Steer	91	30
Baxa et al., 2010	USA	2 x 2 factorial design	English x continental cross	Steer	91	30
Beckett et al., 2009- (1)	USA	RCT	Holstein	Steer	230	10
Beckett et al., 2009- (2)	USA	RCT	Holstein	Steer	230	20
Beckett et al., 2009- (3)	USA	RCT	Holstein	Steer	230	40
Beckett et al., 2009- (4)	USA	RCT	Holstein	Steer	230	10
Beckett et al., 2009- (5)	USA	RCT	Holstein	Steer	230	20
Beckett et al., 2009- (6)	USA	RCT	Holstein	Steer	230	40
Elam et al., 2009- (1)	USA	RCT	British, British x Continental cross-bred	Steer	167	20
Elam et al., 2009- (2)	USA	RCT	British, British cross	Steer	136	30
Elam et al., 2009- (3)	USA	RCT	British cross	Steer	240	40
Garmyn et al., 2011	USA	3 x 2 factorial design	British x Continental cross-bred	Steers	152	23
Garmyn et al., 2010	USA	RCT	Holstein	Steers	172	20
Hilton et al., 2009	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Steers	159	30
Holland et al., 2010	USA	2 x 4 factorial design	British & British - Continental	Steers & bull calves	108	20
Holmer et al., 2009- (1)	USA	RCT	Holstein	Steers		20
Holmer et al., 2009- (2)	USA	RCT	Holstein	Steers		30
Kellermeir et al., 2009	USA	2 x 2 factorial design	English-continental cross	Steers	91	30
Kellermeir et al., 2009	USA	2 x 2 factorial design	English-continental cross	Steers	91	30
Lawrence et al., 2011- (1)	USA	RCT	Calf-fed Holstein	Steer	230	20
Lawrence et al., 2011- (2)	USA	RCT		Cull cows	91	20
Luque et al., 2011	USA	RCT		Heifers		
Montgomery et al., 2009a-(1)	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Steers	88	20

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Zilpaterol (days)
Montgomery et al., 2009a-(2)	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Steers	108	40
Montgomery et al., 2009a-(3)	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Heifers	88	20
Montgomery et al., 2009a-(4)	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Heifers	108	40
Montgomery et al., 2009b	USA	2 x 2 factorial design	Bos Taurus-English, Bos Taurus-continental	Steers	164	30
Neill et al., 2008 – (1)	USA	2 x 2 factorial design	Cross-bred	Cull mature beef cows	70	34
Neill et al., 2008 – (2)	USA	2 x 2 factorial design	Cross-bred	Cull mature beef cows	70	34
Parr et al., 2010	USA	3 x 2 factorial design	British x Continental cross-bred	Steers	164	23
Robles-Estrada et al., 2009	Mexico	RCT	20% Zebu, 20%Hereford, 10% angus, 50%Charolais	Heifers	42	3
Scramlin et al., 2010	USA	RCT	1/2 & 1/4 Brahman x Continental cross-bred	Steers	104	30
Vasconcelos et al., 2008- (1)	USA	4 x 4 factorial design	British & British x Continental cross-bred	Steers	136, 157, 177, 198	20
Vasconcelos et al., 2008- (2)	USA	4 x 4 factorial design	British & British x Continental cross-bred	Steers	136, 157, 177, 198	30
Vasconcelos et al., 2008- (3)	USA	4 x 4 factorial design	British & British x Continental cross-bred	Steers	136, 157, 177, 198	40
Rathmann et al., 2012	USA	2 x 3 factorial design	British x Continental cross-bred	Heifers	127, 148, 167	20
Rodas-Gonzales et al., 2012	USA	2 x 2 factorial design	British Cross-bred	Steers	143, 163	20
Romero et al., 2009	Mexico	RCT	Brahman x Swiss	Steers	100	40
Guzman et al., 2012	Mexico	RCT	Bos indicus x Bos Taurus	Lactating Beef cows		30
Strydom et al., 2009	South Africa	RCT	Bonsmara	Steers	Not provided	30
Peterson, 2011	USA	3x4 Factorial	Cross-bred	Yearling heifers		
Brooks et al., 2010- (1)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (2)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (3)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (4)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (5)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (6)	USA	RCT	Cross-bred	Steer	Not provided	Not provided

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Zilpaterol (days)
Brooks et al., 2010- (7)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (8)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Brooks et al., 2010- (9)	USA	RCT	Cross-bred	Steer	Not provided	Not provided
Garmyn et al., 2011	USA	3 x 2 factorial design	British x Continental cross-bred	Steers	142	23
Garmyn et al., 2011	USA	4 x 2 factorial design	British x Continental cross-bred	Steers	142	24
Garmyn et al., 2011	USA	5 x 2 factorial design	British x Continental cross-bred	Steers	142	25
Garmyn et al., 2011	USA	6 x 2 factorial design	British x Continental cross-bred	Steers	142	26
Garmyn et al., 2011	USA	7 x 2 factorial design	British x Continental cross-bred	Steers	142	27
Garmyn et al., 2010	USA	RCT	Holstein	Steers		
Hansen et al., 2012- (1)	South Africa	RCT	Bonsmara	Steers	120	30
Hansen et al., 2012- (2)	South Africa	RCT	Bonsmara	Steers	120	30
Hilton et al., 2009	USA	2 x 2 factorial design	Bos taurus x English, Bos taurus x continental	Steers	159	30
Hilton et al., 2009	USA	2 x 2 factorial design	Bos taurus x English, Bos taurus x continental	Steers	159	31
Hilton et al., 2009	USA	2 x 2 factorial design	Bos taurus x English, Bos taurus x continental	Steers	159	32
Kellermeir et al., 2009	USA	2 x 2 factorial design	English x continental cross	Steers	91	30
Kellermeir et al., 2009	USA	2 x 2 factorial design	English x continental cross	Steers	91	30
Kellermeir et al., 2009	USA	2 x 2 factorial design	English x continental cross	Steers	91	30
Leheska et al., 2009- (1)	USA	2 x 2 factorial design	Bos taurus- English, Bos taurus-continental	Steers	150 or 145	20
Leheska et al., 2009- (2)	USA	3 x 2 factorial design	Bos taurus- English, Bos taurus-continental	Steers	170 or 165	40
Leheska et al., 2009- (3)	USA	4 x 2 factorial design	Bos taurus- English, Bos taurus-continental	Heifers	150 or 145	20
Leheska et al., 2009- (4)	USA	5 x 2 factorial design	Bos taurus- English, Bos taurus-continental	Heifers	170 or 165	40
Rathmann et al., 2009- (1)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (2)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (3)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Zilpaterol (days)
Rathmann et al., 2009- (4)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (5)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (6)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (7)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (8)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rathmann et al., 2009- (9)	USA	4 x4 factorial design	British & British-Continental cross	Steers	136, 157, 177, 198	20
Rodas-Gonzales et al., 2012	USA	2 x 2 factorial design	British Cross-bred	Steers		
Rodas-Gonzales et al., 2012	USA	2 x 2 factorial design	British Cross-bred	Steers		
Rodas-Gonzales et al., 2012	USA	2 x 2 factorial design	British Cross-bred	Steers		
Rodas-Gonzales et al., 2012	USA	2 x 2 factorial design	British Cross-bred	Steers		
Hansen et al., 2012- (1)	South Africa	RCT	Bonsmara	Steers	120	30
Hansen et al., 2012- (2)	South Africa	RCT	Bonsmara	Steers	120	30
Strydom et al., 2009	South Africa	RCT	Bonsmara	Steers	Not provided	30

Table 3. Dose, feeding and housing systems, delivery method of zilpaterol

Authors	Dose	Delivery method of zilpaterol	Distance travelled to abattoir (km)	Withdrawal of zilpaterol before slaughter (days)	Feeding system	Housing
Avendano-Reyes et al., 2006	60mg/steer/hd	Mixed with minerals	5	3	Group-fed	Pen
Baxa et al., 2010	8.3mg/kg DM	Water-based slurry	193	3	Group-fed	Pen
Baxa et al., 2010	8.3mg/kg DM	Water-based slurry	193	3	Group-fed	Pen
Beckett et al., 2009- (1)	8.3mg/kg DM	Liquid supplement (Ultraferm)+ urea		3	Group-fed	Pen
Beckett et al., 2009- (2)	8.3mg/kg DM	Liquid supplement		3	Group-fed	Pen
Beckett et al., 2009- (3)	8.3mg/kg DM	Liquid supplement		3	Group-fed	Pen
Beckett et al., 2009- (4)	8.3mg/kg DM	Mixed with ground corn		3	Group-fed	Pen
Beckett et al., 2009- (5)	8.3mg/kg DM	Mixed with ground corn		3	Group-fed	Pen
Beckett et al., 2009- (6)	8.3mg/kg DM	Mixed with ground corn		3	Group-fed	Pen
Elam et al., 2009- (1)	8.33mg/kg DM		Exp1 (100km), Exp2 (2km)	3	Group-fed	Pen
Elam et al., 2009- (2)	8.33mg/kg DM			3	Group-fed	Pen
Elam et al., 2009- (3)	8.33mg/kg DM			3	Group-fed	Pen
Garmyn et al., 2011	8.3mg/kg DM		198	3	Group-fed	Pen
Garmyn et al., 2010	8.3mg/kg DM	Mixed with ground corn		3	Group-fed	Pen
Hilton et al., 2009	8.3mg/kg DM			5	Group-fed	Pen
Holland et al., 2010	8.3mg/kg DM		431	3,10,17,24	Group-fed	Pen
Holmer et al., 2009- (1)	8.3mg/kg DM			3	Group-fed	Commercial feeding yards (Exp 1)& pens (Exps 2,3)
Holmer et al., 2009- (2)	8.3mg/kg DM			3	Group-fed	Commercial feeding yards (Exp 1)& pens (Exps 2,3)
Kellermeir et al., 2009	8.38mg/kg DM			3	Group-fed	Pen
Lawrence et al., 2011- (1)	8.3mg/kg DM	Mixed with ground corn		3	Group-fed	Pen
Lawrence et al., 2011- (2)	8.33mg/kg DM			4	Group-fed	Pen
Luque et al., 2010	8.33mg/kg DM				Not provided	
Montgomery et al., 2009a-(1)	8.3mg/kg DM	Mixed with finishing diet	CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Montgomery et al., 2009a-(2)	8.3mg/kg DM	Mixed with finishing diet	CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Montgomery et al., 2009a-(3)	8.3mg/kg DM	Mixed with finishing diet	CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen

Authors	Dose	Delivery method of zilpaterol	Distance travelled to abattoir (km)	Withdrawal of zilpaterol before slaughter (days)	Feeding system	Housing
Montgomery et al., 2009a-(4)	8.3mg/kg DM	Mixed with finishing diet	CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Montgomery et al., 2009b	8.3mg/kg DM	Mixed with finishing diet	109	5	Group-fed	Pen
Neill et al., 2008 –(1)	106.25mg/head	Mixed with concentrate	210	3	Group-fed	Pen
Neill et al., 2008-(2)	106.25mg/head	Mixed with concentrate	210	3	Group-fed	Pen
Parr et al., 2010	8.3mg/kg DM	Mixed with finishing diet	177	3	Group-fed	Pen
Robles-Estrada et al., 2009	0.15mg/kg BW	Mixed with finishing diet	14	3	Group-fed	Pen
Scramlin et al., 2010	75mg/head	Mixed with type B protein, minerals, monensin and tylosin	32	3	Group-fed	Pen
Vasconcelos et al., 2008- (1)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Vasconcelos et al., 2008- (2)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Vasconcelos et al., 2008- (3)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2012	8.33mg/kg DM	Finishing diet		4	Group-fed	Pen
Rodas-Gonzales et al., 2012	8.33mg/kg DM	Affixed to ground corncob	559km (heavy group) & 503km (light group)		Group-fed	Pen
Romero et al., 2012	800g/t feed			20	Group-fed	Pen
Guzman et al., 2012	0.15mg/kg BW/d				Not reported	Not reported
Strydom et al., 2009	6ppm			2	Group-fed	pen
Brooks et al., 2010- (1)	6.8g/t of 90% DM					
Brooks et al., 2010- (2)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (3)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (4)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (5)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (6)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (7)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (8)	6.8g/t of 90% DM				Group-fed	Pen
Brooks et al., 2010- (9)	6.8g/t of 90% DM				Group-fed	Pen
Hansen et al., 2011- (1)	0.15mg/kg LW			3	Group-fed	Pen
Hansen et al., 2011- (2)	0.15mg/kg LW			3	Group-fed	Pen
Leheska et al., 2009- (1)	8.3mg/kg DM		CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Leheska et al., 2009- (2)	8.3mg/kg DM		CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Leheska et al., 2009- (3)	8.3mg/kg DM		CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Leheska et al., 2009- (4)	8.3mg/kg DM		CA site= 1603km, ID site=410km, TX site=101km	5	Group-fed	Pen
Rathmann et al., 2009- (1)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen

Authors	Dose	Delivery method of zilpaterol	Distance travelled to abattoir (km)	Withdrawal of zilpaterol before slaughter (days)	Feeding system	Housing
Rathmann et al., 2009- (2)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (3)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (4)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (5)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (6)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (7)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (8)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Rathmann et al., 2009- (9)	8.33mg/kg DM	Mixed with corn-based premix		3	Group-fed	Pen
Hansen et al., 2012- (1)	0.15mg/kg BW/d	Topdressing		4	Group-fed	Pen
Hansen et al., 2012- (2)	0.15mg/kg BW/d	Topdressing		4	Group-fed	Pen

Table 4. Supplementation, vaccination, antibiotics, anti-parasitic treatments and growth implants

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Avendano-Reyes et al., 2006	Vitamins (Se, E, LAPISA)	Novox 50 &Albendaphorte 10%	Novox 50 &Albendaphorte 10%	Synovex-C (100mg P4 & 10mg E2)	Synovex-C (100mg P4 & 10mg E2)
Baxa et al., 2010				TE-IS (16mg Estradiol& 80mg TBA implants)	Revalor S (24mg Estradiol& 120mg TBA implants)
Baxa et al., 2010				TE-IS (16mg Estradiol& 80mg TBA implants)	Revalor S (24mg Estradiol& 120mg TBA implants)
Beckett et al., 2009- (1)		Yes Details not provided	Yes Details not provided	Synovex-S (100mg P4 & 20mg E2)	Revalor IS (16mg Estradiol& 80mg TBA implants
Beckett et al., 2009- (2)		Yes Details not provided	Yes Details not provided	Synovex-S (100mg P4 & 20mg E2)	Revalor IS (16mg Estradiol& 80mg TBA implants
Beckett et al., 2009- (3)		Yes Details not provided	Yes Details not provided	Synovex-S (100mg P4 & 20mg E2)	Revalor IS (16mg Estradiol& 80mg TBA implants
Beckett et al., 2009- (4)		Yes Details not provided	Yes Details not provided		
Beckett et al., 2009- (5)		Yes Details not provided	Yes Details not provided		
Beckett et al., 2009- (6)		Yes Details not provided	Yes Details not provided		
Elam et al., 2009- (1)	Monensin (control group only, and during withdrawal period for all)	Vista 5 SQ	Ivomec Pour-On	Revalor-IS (16mg Estradiol& 80mg TBA implants	Revalor-IS (16mg Estradiol& 80mg TBA implants
Elam et al., 2009- (2)	Monensin (control group only, and during withdrawal period for all)	Vista 5 SQ, Vision 7	Cydetin, fenbendazol (Safe-Guard)	Revalor S (24mg Estradiol& 120mg TBA implants)	Revalor S (24mg Estradiol& 120mg TBA implants)
Elam et al., 2009- (3)	Monensin (control group only, and during withdrawal period for all)	Vista 5 SQ, Vision 7	Ivomec Pour-On	Revalor-IS (16mg Estradiol& 80mg TBA implants	Revalor S (24mg Estradiol& 120mg TBA implants)
Garmyn et al., 2011	Non-supplemented groups were used in the analysis	Vista 5, Vista 7 with Spur	fenbendazol (Safe-Guard). Ivomec	REX-XS (40mg E2 & 200mg TBA implants)- No implants groups used	
Garmyn et al., 2010	Ultraferm	Yes Details not provided	Yes Details not provided		
Hilton et al., 2009	Vitamin A & D; Groups with no "monensin andtylosin" were included	Titanium 5	Safe-Guard		
Holland et al., 2010	Control groups supplemented with monensin and tylosin	Vista 5 SQ, Vision 7 with Spur	Ivomec Pour-On	Zeranol (Ralgro)	
Kellermeir et al., 2009				TE-IS (16mg Estradiol& 80mg TBA implants)	
Holmer et al., 2009- (1)					
Holmer et al., 2009- (2)					
Kellermeir et al., 2009				TE-IS (16mg Estradiol& 80mg TBA implants)	

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Lawrence et al., 2011- (1)		Yes Details not provided	Yes Details not provided		
Lawrence et al., 2011- (2)		Not provided	Safe- Gaurd, Ivomec	Revalor 200 (20mg Estradiol& 200mg TBA implants)	
Luque et al., 2010					
Montgomery et al., 2009a-(1)	Monensin and Tylosin in the basal diet, Not in finishing diets	Titanium 5	Safe-Guard		
Montgomery et al., 2009a-(2)	Monensin and Tylosin in the basal diet, Not in finishing diets	Titanium 5	Safe-Guard		
Montgomery et al., 2009a-(3)	Monensin and Tylosinin the basal diet, Not in finishing diets	Titanium 5	Safe-Guard		
Montgomery et al., 2009a-(4)	Monensin and Tylosin in the basal diet, Not in finishing diets	Titanium 5	Safe-Guard		
Montgomery et al., 2009b	1,000,000 IU of vitamin A; 200,000 IU of vitamin D	Vision 7 with Spur, Reliant IBR/Lepto	Safe-Guard, Tiguvon	Ralgro	Revalor-S
Neill et al., 2008-(1)	Non-supplemented groups were used		Dectomax Pour On	Revalor 200 (20mg Estradiol & 200mg TBA implants)	
Neill et al., 2008-(2)	Non-supplemented groups were used		Dectomax Pour On		
Parr et al., 2010	Groups with no implants were included	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On		
Robles-Estrada et al., 2009	Synt-ADE	IBR, Piramide 4 + Presponse SQ, Ultrabac-7 (Clostridials)	Bimectin		Synovex plus
Scramlin et al., 2010	Monensin , Tylosin& ADE	Clostridials, IBR, BVD RSV (respiratory syncytial virus)	Yes	Component E-S (20mg E2 & 200mg P4)	Component T-ES (24mg E2 and 120mg TBA)
Vasconcelos et al., 2008- (1)	Monensin and Tylosin in control group only & Vitamins, mineral	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Vasconcelos et al., 2008- (2)	Monensin and Tylosin in control group only & Vitamins, mineral	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Vasconcelos et al., 2008- (3)	Monensin and Tylosin in control group only & Vitamins, mineral	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Rathmann et al., 2012	Micotil	Vista 3 SQ	Safe-Guard &Ivomec Pour On	Revalor-IH (8mg E2 & 80mg TBA)	Revalor-H (14mg E2 & 140mg TBA)
Rodas-Gonzales et al., 2012		modified-live 5-way viral vaccine	Safe-Guard &Ivomec injection	Revalor XS (40mg E2 & 200mg TBA)	
Romero et al., 2012					
Guzman et al., 2012					
Strydom et al., 2009				Revalor-S (28mg E2 &140mg TBA	
Brooks et al., 2010- (1)					
Brooks et al., 2010- (2)					
Brooks et al., 2010- (3)					
Brooks et al., 2010- (4)					

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Brooks et al., 2010- (5)					
Brooks et al., 2010- (6)					
Brooks et al., 2010- (7)					
Brooks et al., 2010- (8)					
Brooks et al., 2010- (9)					
Hansen et al., 2011- (1)	Groups with no supplements (Vitamin D_3) were included				
Hansen et al., 2011- (2)	Groups with no supplements (Vitamin D_3) were included				
Leheska et al., 2009- (1)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (2)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (3)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (4)		Titanium 5	Safe-Guard		
Rathmann et al., 2009- (1)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (2)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (3)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (4)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (5)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (6)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (7)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (8)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (9)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Hansen et al., 2012- (1)	Trials without supplemented included				
Hansen et al., 2012- (2)	Trials without supplemented included				

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Scramlin et al., 2010	Monensin, Tylosin& ADE	Clostridial, IBR, BVD RSV (respiratory syncytial virus)	Yes	Component E-S (20mg E2 & 200mg P4)	Component T-ES (24mg E2 and 120mg TBA)
Vasconcelos et al., 2008- (1)	Monensin and Tylosin in control group only & Vitamins, minerals	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Vasconcelos et al., 2008- (2)	Monensin and Tylosin in control group only & Vitamins, minerals	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Vasconcelos et al., 2008- (3)	Monensin and Tylosin in control group only & Vitamins, minerals	Vista 5 & Vision 7 with Spur	Safe-Guard &Ivomec Pour On	Revalor IS (16mg E2 & 80mg TBA)	
Rathmann et al., 2012	Micotil	Vista 3 SQ	Safe-Guard &Ivomec Pour On	Revalor-IH (8mg E2 & 80mg TBA)	Revalor-H (14mg E2 & 140mg TBA)
Rodas-Gonzales et al., 2012		modified-live 5-way viral vaccine	Safe-Guard &Ivomec injection	Revalor XS (40mg E2 & 200mg TBA)	
Romero et al., 2012					
Guzman et al., 2012					
Strydom et al., 2009				Revalor-S (28mg E2 &140mg TBA	
Brooks et al., 2010- (1)					
Brooks et al., 2010- (2)					
Brooks et al., 2010- (3)					
Brooks et al., 2010- (4)					
Brooks et al., 2010- (5)					
Brooks et al., 2010- (6)					
Brooks et al., 2010- (7)					
Brooks et al., 2010- (8)					
Brooks et al., 2010- (9)					
Hansen et al., 2011- (1)	Groups with no supplements (Vitamin D3) were included				
Hansen et al., 2011- (2)	Groups with no supplements (Vitamin D3) were included				
Leheska et al., 2009- (1)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (2)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (3)		Titanium 5	Safe-Guard		
Leheska et al., 2009- (4)		Titanium 5	Safe-Guard		
Rathmann et al., 2009- (1)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (2)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (3)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (4)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Rathmann et al., 2009- (5)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (6)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (7)	Vitamins, mineral; and Monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (8)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Rathmann et al., 2009- (9)	Vitamins, mineral; and monensin and tylosin in the basal diet of control group only	Vista 5, Vista 7 with Spur	Safe-Guard		
Hansen et al., 2012- (1)	Trials without supplements included				
Hansen et al., 2012- (2)	Trials without supplements included				

Table 5. Experimental unit, number of cattle and pens per group, body weight, dry matter intake and G:F ratio in cattle fed zilpaterol

Author	Experimental unit	No of animals/group		No of animal/pen	No of pens/group	Body weight (kg)			Average daily gain (kg/hd/d)			Dry matter intake (kg/hd/d)			G:F ratio		
		Control	ZH	3	3	Control	ZH	SE	Control	ZH	SE	Control	ZH	SE	Control	ZH	SE
Avendano-Reyes et al., 2006	Pen	17	17	3	6	478.200	497.700	1.740	1.580	2.140	0.033	8.510	8.460	0.024	0.185	0.253	0.004
Baxa et al., 2010	Pen	570	570	90 to 100	6	598.600	600.200	9.230	1.810	1.920	0.083	10.310	10.210	0.269	0.176	0.188	0.004
Baxa et al., 2010	Pen	570	570	90 to 100	6	598.600	600.200	9.230	1.810	1.920	0.083	10.310	10.210	0.269	0.176	0.188	0.004
Beckett et al., 2009-(1)	Pen	584	587	81 to 100	6	642.400	645.900	2.900	1.390	1.420	0.031	9.870	9.590	0.160	0.141	0.148	0.004
Beckett et al., 2009-(2)	Pen	584	582	81 to 100	6	642.400	647.800	2.900	1.390	1.430	0.031	9.870	9.600	0.160	0.141	0.150	0.004
Beckett et al., 2009-(3)	Pen	584	581	81 to 100	6	642.400	655.800	2.900	1.390	1.500	0.031	9.870	9.630	0.160	0.141	0.156	0.004
Beckett et al., 2009-(4)	Pen	90	90	9	10	588.000	587.400	0.890	1.330	1.350	0.057	9.140	8.850	0.156	0.146	0.153	0.006
Beckett et al., 2009-(5)	Pen	90	90	9	10	588.000	594.000	0.890	1.330	1.430	0.057	9.140	9.060	0.156	0.146	0.158	0.006
Beckett et al., 2009-(6)	Pen	90	89	9	10	588.000	591.900	0.890	1.330	1.410	0.057	9.140	8.660	0.156	0.146	0.164	0.006
Elam et al., 2009-(1)	Pen	1008	1008	70 to 98	6 to 7	568.100	569.200	12.310	1.030	1.190	0.057	9.230	9.170	0.120	0.111	0.129	0.006
(N is estimated for 4 Exps)		(estimate from 4 Exps)	(estimate from 4 Exps)														
Elam et al., 2009-(2)	Pen	1008	1008	71 to 98	6 to 7	568.100	566.400	12.310	1.030	1.270	0.057	9.230	9.240	0.120	0.111	0.138	0.006
Elam et al., 2009-(3)	Pen	1008	1008	72 to 98	6 to 7	568.100	566.300	12.310	1.030	1.290	0.057	9.230	9.190	0.120	0.111	0.140	0.006
Holland et al., 2010	Pen	186	186	6	32	579.000	584.000	4.000	1.360	1.510	0.170	10.070	9.650	0.150	0.135	0.157	0.016
Lawrence et al., 2011	Pen	160	160	10	16	619.100	640.500	10.200	2.170	2.750	0.120	17.200	17.300	0.300	0.126	0.160	0.007
Luque et al., 2010		24	24		1												
Montgomery et al., 2009a-(1)	Pen	80	80	10	4	564.000	574.000	19.000	1.080	1.550	0.160	8.950	8.780	0.410	0.120	0.176	0.012
Montgomery et al., 2009a-(2)	Pen	80	80	10	4	566.000	580.000	19.000	1.200	1.540	0.160	9.230	8.990	0.410	0.129	0.171	0.012
Montgomery et al., 2009a-(3)	Pen	80	80	10	4	510.000	516.000	24.000	1.150	1.360	0.100	8.560	8.070	0.580	0.134	0.168	0.005
Montgomery et al., 2009a-(4)	Pen	80	80	10	4	513.000	521.000	24.000	1.120	1.340	0.100	8.780	8.340	0.580	0.126	0.162	0.005
Montgomery et al., 2009b	Pen	940	940	94	10	559.300	571.900	3.440	1.420	1.620	0.054	9.020	8.700	0.080	0.156	0.186	0.005
Neill et al., 2008-(1)	Pen	12	12	6	2	623.300	622.000	24.700							0.130	0.120	0.025
Neill et al., 2008-(2)	Pen	12	12	6	2	633.300	636.000	24.700							0.140	0.150	0.025

Author	Experimental	No of animals/group		No of animal/pen	No of pens/ group	Body weight			Average daily gain			Dry matter intake			G:F ratio		
Parr et al., 2010	Pen	27	27	4	7	594.000	605.000	6.300	1.420	1.490	0.033	9.160	9.260	0.159	0.155	0.160	0.003
Robles-Estrada et al., 2009	Pen	32	32	8	4	497.900	449.100	4.000	1.150	1.830	0.110	8.980	9.100	0.260	0.129	0.202	0.010
Scramlin et al., 2010	Pen	100	100	8	10	546.620	549.750	1.450	0.950	1.050	0.050				0.107	0.128	0.005
Vasconcelos et al., 2008-(1)	Pen	35	35	5	7	596.300	606.900	4.920	1.330	1.480	0.050	8.900	8.990	0.137	0.150	0.165	0.004
Vasconcelos et al., 2008-(2)	Pen	35	35	5	7	596.300	602.500	4.920	1.330	1.490	0.050	8.900	8.510	0.137	0.150	0.175	0.004
Vasconcelos et al., 2008-(3)	Pen	35	35	5	7	596.300	604.200	4.920	1.330	1.520	0.050	8.900	8.500	0.137	0.150	0.179	0.004
Rathmann et al., 2012	Pen	1647	1647	77 to 106	18	542.800	547.100	3.920	1.470	1.610	0.030	9.150	8.970	0.040	0.160	0.180	0.003
Rodas-Gonzales et al., 2012	Pen	19	20		12												
Romero et al., 2012	Pen	5	5		1				1.590	1.770	0.030	11.100	11.300	0.360			
Guzman et al., 2012	Not Provided	39	38			385.000	395.000	2.200	0.041	0.375	0.074						
Strydom et al., 2009	Animal	12	12			568.600	575.500	6.070	2.100	2.400	0.132	13.300	12.500	0.289			
Peterson, 2011	Pen	36	36	9	4	593.100	598.900	2.680	0.670	0.880	0.100	9.160	9.003	0.160	7.120	9.590	0.060

Table 6a. No of animal per group, experimental unit, no of animals and carcasses per group for analysing carcass characteristics

Authors	Experimental unit	No of animals per group		No of animals per pen	No of pens per group	No of carcass/subprimal/loin per group	No of selected carcasses from each pen
		Control	ZH				
Avendano-Reyes et al., 2006	Animal	17	17		6		
Baxa et al., 2010	Pen	570	570	90 to 100	6		
Baxa et al., 2010	Pen	570	570	90 to 100	6		
Beckett et al., 2009-(1)	Pen	584	587	81 to 100	6		
Beckett et al., 2009-(2)	Pen	584	582	81 to 100	6		
Beckett et al., 2009-(3)	Pen	584	581	81 to 100	6		
Beckett et al., 2009-(4)	Pen	90	90	9	10		
Beckett et al., 2009-(5)	Pen	90	90	9	10		
Beckett et al., 2009-(6)	Pen	90	89	9	10		
Elam et al., 2009-(1)	Pen	1008	1008	70 to 98	6		
Elam et al., 2009-(2)	Pen	1008	1008	71 to 98	6		
Elam et al., 2009-(3)	Pen	1008	1008	72 to 98	6		
Garmyn et al., 2011	Subprimal	16	16	4	7	16	
Garmyn et al., 2010	Carcass side	48	54			48	
Hilton et al., 2009	Pen	50	50	5	10		5
Holland et al., 2010	Pen	186	186	6	32		2
Kellermeir et al., 2009	Carcass	570	570	NA		30	7 to 8
Lawrence et al., 2011-(1)	Individual loin	50	50	NA	NA	NA	
Lawrence et al., 2011-(2)	Pen	160	160	10	16		
Luque et al., 2010	Carcass	24	24			24	
Montgomery et al., 2009a-(1)	Pen	80	80	10	4		10
Montgomery et al., 2009a-(2)	Pen	80	80	10	4		10
Montgomery et al., 2009a-(3)	Pen	80	80	10	4		10
Montgomery et al., 2009a-(4)	Pen	80	80	10	4		10
Montgomery et al., 2009b	Pen	940	940	94	10		5
Neill et al., 2008-(1)	Pen	12	12	6	2	NA	NA
Neill et al., 2008-(2)	Pen	12	12	6	2	NA	NA
Parr et al., 2010	Pen	27	27	4	7		27
Robles-Estrada et al., 2009	Pen	32	32	4	4		

Authors	Experimental unit	No of animals per group Control	ZH	No of animals per pen	No of pens per group	No of carcass/subprimal/loin per group	No of selected carcasses from each pen
Scramlin et al., 2010	Pen	100	100	10	10	75	7 to 8
Vasconcelos et al., 2008-(1)	Pen	35	35	5	7		5
Vasconcelos et al., 2008-(2)	Pen	35	35	5	7		5
Vasconcelos et al., 2008-(3)	Pen	35	35	5	7		5
Rathmann et al., 2012*	Pen	1647	1647	77 to 106	18		
Rodas-Gonzales et al., 2012	Animal	19	20	NA	12	12	
Romero et al., 2012	Animal	5	5	NA	1		
Strydom et al., 2009	Animal	12	12	10			

Table 6b. Carcass pH, hot carcass weight (HCW), longissimus muscle area (LMA) and carcass colour score

Author	Carcass pH			Hot carcass weigh (kg)			Longissimus muscle area (cm)			Carcass colour score (scale 1 to 9)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Avendano-Reyes et al., 2006	5.439	5.429	0.007	291.700	313.600	1.330	66.750	75.230	1.370			
Baxa et al., 2010				371.100	392.600	5.970	90.100	101.100	1.280			
Baxa et al., 2010				382.200	402.600	5.970	94.800	107.000	1.280			
Beckett et al., 2009-(1)				394.400	406.000	2.600	81.200	86.300	1.300	5.030	5.070	0.024
Beckett et al., 2009-(2)				394.400	407.400	2.600	81.200	90.100	1.300	5.030	5.120	0.024
Beckett et al., 2009-(3)				394.400	411.600	2.600	81.200	89.700	1.300	5.030	5.090	0.024
Beckett et al., 2009-(4)				357.900	367.200	6.800	80.000	88.000	0.920	5.040	5.040	0.045
Beckett et al., 2009-(5)				357.900	372.500	6.800	80.000	89.400	0.920	5.040	5.020	0.045
Beckett et al., 2009-(6)				357.900	369.000	6.800	80.000	89.200	0.920	5.040	5.000	0.045
Elam et al., 2009-(1)				389.300	402.900	2.600	87.690	95.630	0.676	4.930	4.900	0.065
Elam et al., 2009-(2)				389.300	405.600	2.600	87.690	97.810	0.676	4.930	4.910	0.065
Elam et al., 2009-(3)				389.300	407.500	2.600	87.690	98.000	0.676	4.930	4.850	0.065
Garmyn et al., 2011				373.000	384.000	13.500	90.000	94.300	2.200			
Garmyn et al., 2010				351.500	356.000	2.170	77.000	79.600	1.010			
Hilton et al., 2009	5.470	5.480	0.020				89.000	97.000	1.460	6.520	6.180	0.190
Holland et al., 2010				369.000	380.000	1.500	89.700	94.800	0.800	4.920	4.960	0.090
Kellermeir et al., 2009				376.970	397.550	9.174	87.890	99.030	2.664			
Kellermeir et al., 2009				389.690	400.000	9.174	96.440	111.570	2.664			
Lawrence et al., 2011-(1)				393.700	405.200	4.270	81.400	86.900	1.170			
Lawrence et al., 2011-(2)				369.200	390.100	5.400	86.500	93.300	1.100			
Luque et al., 2010	5.480	5.530	0.420									
Montgomery et al., 2009a-(1)				353.700	366.700	8.300	84.000	91.900	1.700	5.080	5.200	0.140
Montgomery et al., 2009a-(2)				354.800	374.700	8.300	85.500	94.100	1.700	5.060	5.310	0.140
Montgomery et al., 2009a-(3)				320.000	331.000	14.000	85.000	90.800	1.700	5.050	5.280	0.100

Author	Carcass pH			Hot carcass weigh (kg)			Longissimus muscle area (cm)			Carcass colour score (scale 1 to 9)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Montgomery et al., 2009a-(4)				323.000	336.000	14.000	86.800	93.700	1.700	5.090	5.350	0.100
Montgomery et al., 2009b				369.000	384.000	1.560	91.700	101.100	0.850	5.120	5.050	0.046
Neill et al., 2008-(1)	5.600	5.600	0.070	364.800	371.700	11.610	87.800	87.500	3.830	6.100	6.100	0.630
Neill et al., 2008-(2)	5.600	5.700	0.070	376.700	380.900	11.610	92.000	101.400	3.830	5.900	5.200	0.630
Parr et al., 2010				390.000	409.000	4.300						
Robles-Estrada et al., 2009				309.000	320.100	2.940	93.500	99.400	1.830			
Scramlin et al., 2010	5.460	5.470	0.010	357.790	370.680	1.360	34.190	37.950	0.430			
Vasconcelos et al., 2008-(1)				383.900	401.100	3.400	90.400	99.600	0.898			
Vasconcelos et al., 2008-(2)				383.900	400.200	3.400	90.400	100.600	0.898			
Vasconcelos et al., 2008-(3)				383.900	402.000	3.400	90.400	99.700	0.898			
Rathmann et al., 2012				344.900	356.000	2.670	86.160	91.760	0.820			
Rodas-Gonzales et al., 2012				357.770	402.720	7.370	88.970	101.050	2.540			
Romero et al., 2012												
Strydom et al., 2009				339.100	353.500	4.600	75.500	83.900	2.650			
Peterson, 2011					375.300	4.000	384.500	4.000	83.490			

Table 6c. Marbling score, fat thickness, carcass yield and dressing percentage

Author	Marbling score (300 to 500)			Fat thickness (cm)			Yield grade (scale 1 to 5)			Dressing (%)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Avendano-Reyes et al., 2006				1.650	1.360	0.058				61.000	63.010	0.217
Baxa et al., 2010	369.500	339.900	6.530	1.520	1.400	0.033				62.940	65.420	0.139
Baxa et al., 2010	353.400	323.500	6.530	1.500	1.350	0.033				63.310	65.570	0.139
Beckett et al., 2009-(1)	474.900	455.200	5.300	0.762	0.762	0.020				61.350	62.910	0.160
Beckett et al., 2009-(2)	474.900	445.100	5.300	0.762	0.711	0.020				61.350	62.860	0.160
Beckett et al., 2009-(3)	474.900	451.500	5.300	0.762	0.737	0.020				61.350	62.770	0.160
Beckett et al., 2009-(4)	423.400	407.100	8.600	0.686	0.635	0.380				60.850	62.490	0.240
Beckett et al., 2009-(5)	423.400	393.100	8.600	0.686	0.610	0.380				60.850	62.700	0.240
Beckett et al., 2009-(6)	423.400	391.300	8.600	0.686	0.584	0.380				60.850	62.340	0.240
Elam et al., 2009-(1)	434.300	420.000	11.610	1.530	1.430	0.046	3.320	2.950	0.081	63.380	64.740	0.812
Elam et al., 2009-(2)	434.300	406.000	11.610	1.530	1.400	0.046	3.320	2.830	0.081	63.380	65.030	0.812
Elam et al., 2009-(3)	434.300	402.000	11.610	1.530	1.390	0.046	3.320	2.830	0.081	63.380	65.190	0.812
Garmyn et al., 2011	492.000	524.000	26.100	1.640	1.410	0.120	3.400	3.000	0.170			
Garmyn et al., 2010	426.000	440.000	10.100	0.887	0.871	0.363	2.900	2.790	0.076			
Hilton et al., 2009	435.000	376.000	12.500	1.180	0.910	0.020	3.360	3.090	0.080			
Holland et al., 2010	440.000	424.000	13.500	1.360	1.310	0.040	2.910	2.690	0.070			
Kellermeir et al., 2009	41.500	37.160	2.184	1.640	1.430	0.065	3.610	3.410	0.062			
Kellermeir et al., 2009	35.610	37.170	2.184	1.350	1.280	0.065	2.720	1.980	0.173	35.610	32.170	2.184
Lawrence et al., 2011-(1)				0.870	0.800	0.050	3.250	2.960	0.080			
Lawrence et al., 2011-(2)	38.600	36.300	0.500	1.390	1.410	0.070	2.670	2.530	0.120	59.450	61.010	0.220
Luque et al., 2010												
Montgomery et al., 2009a-(1)	461.000	432.000	17.000	1.310	1.200	0.110	2.990	2.610	0.130	62.700	64.000	1.200
Montgomery et al., 2009a-(2)	462.000	398.000	17.000	1.260	1.200	0.110	2.870	2.550	0.130	62.800	64.600	1.200

Author	Marbling score (300 to 500)			Fat thickness (cm)			Yield grade (scale 1 to 5)			Dressing (%)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Montgomery et al., 2009a-(3)	461.000	457.000	23.000	1.390	1.300	0.090	2.740	2.460	0.140	62.700	64.200	1.100
Montgomery et al., 2009a-(4)	470.000	437.000	23.000	1.350	1.350	0.090	2.630	2.420	0.140	63.000	64.600	1.100
Montgomery et al., 2009b	422.000	391.000	4.900	1.180	1.050	0.031	2.600	2.110	0.052	64.800	66.000	0.110
Neill et al., 2008-(1)	426.000	459.000	39.200	1.070	0.950	0.152	2.800	2.700	0.280	59.800	58.500	0.710
Neill et al., 2008-(2)	435.000	414.000	39.200	0.920	1.030	0.152	2.500	2.200	0.280	59.600	60.100	0.710
Parr et al., 2010	487.000	507.000	14.900	1.550	1.570	0.074						
Robles-Estrada et al., 2009	3.560	3.280	0.270	0.850	0.640	0.080				62.200	64.200	0.450
Scramlin et al., 2010	545.800	524.500	8.660	1.240	1.070	0.050	2.900	2.340	0.060	65.490	67.420	0.180
Vasconcelos et al., 2008-(1)	451.200	420.100	12.580	1.490	1.350	0.054	3.120	2.680	0.072	64.400	66.100	0.228
Vasconcelos et al., 2008-(2)	451.200	405.200	12.580	1.490	1.240	0.054	3.120	2.500	0.072	64.400	66.400	0.228
Vasconcelos et al., 2008-(3)	451.200	396.800	12.580	1.490	1.220	0.054	3.120	2.540	0.072	64.400	66.600	0.228
Rathmann et al., 2012	441.800	436.600	2.420	1.540	1.460	0.040	Blank	Blank	blank	63.530	65.050	0.100
Rodas-Gonzales et al., 2012	356.320	361.500	9.370	1.199	1.214	0.118	2.360	1.800	0.240			
Romero et al., 2012										54.400	58.600	0.440
Strydom et al., 2009	220.800	196.700	9.940	1.420	0.910	0.142	3.270	2.520	0.220			
Peterson, 2011	431.000	5.530	408.570	5.530	431.000	1.270	3.120	2.970	0.040	64.400	66.400	0.228

Table 6d. Lean and overall maturity and 'kidney, pelvic and heart' fat percentage in control and Zilpaterol treated cattle

Author	Lean maturity score (0 to >200)			Overall maturity score (0 to >200)			Kidney, pelvic & heart fat (%)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Avendano-Reyes et al., 2006	77.420	79.150	0.454						
Baxa et al., 2010							2.160	2.020	0.066
Baxa et al., 2010							2.090	0.066	1.900
Beckett et al., 2009- (1)	69.300	70.800	8.300	68.300	68.200	3.900	2.790	2.710	0.091
Beckett et al., 2009- (2)	69.300	71.000	8.300	68.300	68.200	3.900	2.790	2.720	0.091
Beckett et al., 2009- (3)	69.300	68.800	8.300	68.300	67.600	3.900	2.790	2.660	0.091
Beckett et al., 2009- (4)	53.200	60.600	1.500	56.000	62.400	1.500	1.810	1.940	0.048
Beckett et al., 2009- (5)	53.200	58.200	1.500	56.000	57.900	1.500	1.810	1.810	0.048
Beckett et al., 2009- (6)	53.200	58.400	1.500	56.000	57.000	1.500	1.810	1.810	0.048
Elam et al., 2009- (1)	52.610	53.610	1.818	62.870	62.720	2.810	2.040	2.010	0.011
Elam et al., 2009- (2)	52.610	52.600	1.818	62.870	61.670	2.810	2.040	2.020	0.011
Elam et al., 2009- (3)	52.610	52.790	1.818	62.870	61.100	2.810	2.040	2.000	0.011
Garmyn et al., 2011- (1)							2.400	2.100	0.120
Garmyn et al., 2010- (2)							2.030	2.020	0.038
Hilton et al., 2009	65.000	64.000	3.200	67.000	71.000	3.800	1.890	1.710	0.070
Holland et al., 2010	71.400	71.600	2.710	66.700	67.700	2.320	2.320	2.320	0.100
Kellermeir et al., 2009	45.940	43.210	3.253	54.690	1.991	1.991	2.150	1.990	0.108
Kellermeir et al., 2009	43.130	44.510	3.253	43.130	1.991	1.991	2.080	2.030	0.108
Lawrence et al., 2011- (1)									
Lawrence et al., 2011- (2)	84.700	91.800	6.500						
Luque et al., 2010									
Montgomery et al., 2009a-(1)	65.000	65.000	3.100	70.000	71.000	3.100	3.030	2.080	0.090

Author	Lean maturity score (0 to >200)			Overall maturity score (0 to >200)			Kidney, pelvic & heart fat (%)		
	Control	ZH	SEM	Control	ZH	SEM	Control	ZH	SEM
Montgomery et al., 2009a-(2)	68.000	66.000	3.100	71.000	72.000	3.100	2.040	2.000	0.090
Montgomery et al., 2009a-(3)	71.000	65.000	5.000	76.000	72.000	2.500	2.050	2.040	0.070
Montgomery et al., 2009a-(4)	68.000	63.000	5.000	74.000	72.000	2.500	2.040	2.090	0.070
Montgomery et al., 2009b							2.000	1.900	0.029
Neill et al., 2008-(1)	183.000	188.000	34.100	390.000	367.000	38.500	1.500	1.500	0.090
Neill et al., 2008-(2)	196.000	235.000	34.100	340.000	414.000	38.500	1.500	1.600	0.090
Parr et al., 2010									
Robles-Estrada et al., 2009							2.410	2.630	0.130
Scramlin et al., 2010	161.800	167.100	3.290	164.100	166.400	2.140	2.410	2.300	0.040
Vasconcelos et al., 2008- (1)	49.700	52.600	2.670	50.700	55.200	2.760	2.190	2.130	0.042
Vasconcelos et al., 2008- (2)	49.700	53.700	2.670	50.700	56.400	2.760	2.190	2.080	0.042
Vasconcelos et al., 2008- (3)	49.700	48.700	2.670	50.700	50.900	2.760	2.190	2.050	0.042
Rathmann et al., 2012							1.930	1.900	0.010
Rodas-Gonzales et al., 2012							3.310	3.400	0.220
Romero et al., 2012									
Strydom et al., 2009							1.380	1.330	0.108
Peterson, 2011							1.960	1.910	0.040

Table 7. Aging, selected muscle, cooking method, and Warner –Bratzler shear force and cooking loss

Author	Experimental unit	Aging	Selected muscle	Cooking method	No of animals		No of pens		No of muscles		Warner –Bratzler shear force (kg)			Cooking loss (%)		
					Control	ZH	Control	ZH	Control	ZH	Control	ZH	SE	Control	ZH	SE
Avendano-Reyes et al., 2006	Animal	5 & 14	Longissimus muscle		17	17	6	6	17	17	4.397	5.113	0.136			
Brooks et al., 2010- (1)	Pen	7	Strip loin	Grilled, 71^{oC}					30	30	3.080	3.580	0.130			
Brooks et al., 2010- (2)	Pen	7	Strip loin	Grilled, 71^{oC}					30	30	3.080	3.770	0.130			
Brooks et al., 2010- (3)	Pen	7	Strip loin	Grilled, 71^{oC}					30	30	3.080	3.630	0.130			
Brooks et al., 2010- (4)	Pen	14	Strip loin	Grilled, 71^{oC}					30	30	2.880	3.420	0.130			
Brooks et al., 2010- (5)	Pen	14	Strip loin	Grilled, 71^{oC}					30	30	2.880	3.500	0.130			
Brooks et al., 2010- (6)	Pen	14	Strip loin	Grilled, 71^{oC}					30	30	2.880	3.300	0.130			
Brooks et al., 2010- (7)	Pen	21	Strip loin	Grilled, 71^{oC}					30	30	2.840	2.990	0.130			
Brooks et al., 2010- (8)	Pen	21	Strip loin	Grilled, 71^{oC}					30	30	2.840	3.230	0.130			
Brooks et al., 2010- (9)	Pen	21	Strip loin	Grilled, 71^{oC}					30	30	2.840	3.010	0.130			
Garmyn et al., 2011- (1)	Subprimal	7	Longissimus lumborum	Grilled, 71^{oC}			7	7	77	77	2.430	3.580	0.260	10.600	12.500	0.400
Garmyn et al., 2011- (2)	Subprimal	14	Longissimus lumborum	Grilled, 71^{oC}			7	7	77	77	2.550	3.590	0.220	13.600	14.800	0.500
Garmyn et al., 2011- (3)	Subprimal	21	Longissimus lumborm	Grilled, 71^{oC}			7	7	77	77	2.500	3.290	0.200	15.100	17.300	1.100
Garmyn et al., 2011- (4)	Subprimal	28	Longissimus lumborum	Grilled, 71^{oC}			7	7	77	77	1.870	2.580	0.290	10.400	12.400	0.900
Garmyn et al., 2011- (5)	Subprimal	35	Longissimus lumborum	Grilled, 71^{oC}			7	7	77	77	2.600	2.890	0.170	11.600	12.100	1.200
Garmyn et al., 2010- (6)	Carcass side		Longissimus muscle	Oven, 68^{oC}	48	54			48	54	3.280	4.100	0.111	22.500	22.800	0.303
Hansen et al., 2011- (1)	Animal	7	Longissimus lumborum	Oven-broiled, 70^{oC}	10	10			10	10	3.500	4.300	0.242			
Hansen et al., 2011- (2)	Animal	14	Longissimus lumborum	Oven-broiled, 70^{oC}	10	10			10	10	2.400	3.700	0.242			
Hilton et al., 2009- (1)	Pen	7	Longissimus muscle	Belt grilled, 71^{oC}	50	50	10	10	50	50	3.630	4.940	0.170	15.460	16.500	0.620
Hilton et al., 2009- (2)	Pen	14	Longissimus muscle	Belt grilled, 71^{oC}	50	50	10	10	50	50	3.560	4.000	0.130			
Hilton et al., 2009- (3)	Pen	21	Longissimus muscle	Belt grilled, 71^{oC}	50	50	10	10	50	50	3.200	3.470	0.110			
Holmer et al., 2009- (1)	Carcass		Longissimus lumborum	Digital grill, 71^{oC}	90	90	10	10	90	90	2.800	3.600	0.170			
Holmer et al., 2009- (2)	Carcass		Longissimus lumborum	Digital grill, 71^{oC}	90	90	10	10	90	90	2.800	4.000	0.170			
Kellermeir et al., 2009- (1)	Carcass	7	Longissimus muscle	Grilled, 71^{oC}	570	570	4	4	30	30	3.380	5.050	0.201	22.270	21.150	0.568

Author	Experimental unit	Aging	Selected muscle	Cooking method	No of animals		No of pens		No of muscles		Warner –Bratzler shear force (kg)			Cooking loss (%)		
					Control	ZH	Control	ZH	Control	ZH	Control	ZH	SE	Control	ZH	SE
Kellermeir et al., 2009- (2)	Carcass	14	Longissimus muscle	Grilled, 71^{oC}					30	30	2.830	4.120	0.156			
Kellermeir et al., 2009- (3)	Carcass	21	Longissimus muscle	Grilled, 71^{oC}					30	30	2.680	4.080	0.225			
Leheska et al., 2009- (1)	Pen	28	Longissimus muscle	Belt grilled, 71^{oC}	120	120	12	12	24	24	3.190	3.910	0.260	13.700	14.170	0.460
Leheska et al., 2009- (2)	Pen	28	Longissimus muscle	Belt grilled, 71^{oC}	120	120	12	12	24	24	3.260	3.980	0.260	14.420	14.260	0.460
Leheska et al., 2009- (3)	Pen	28	Longissimus muscle	Belt grilled, 71^{oC}	120	120	12	12	24	24	3.530	4.370	0.370	13.370	14.450	0.430
Leheska et al., 2009- (4)	Pen	28	Longissimus muscle	Belt grilled, 71^{oC}	120	120	12	12	24	24	3.280	4.050	0.370	14.500	14.020	0.430
Rathmann et al., 2009- (1)	Pen	7	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.540	4.940	0.230			
Rathmann et al., 2009-(2)	Pen	7	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.540	5.710	0.230			
Rathmann et al., 2009- (3)	Pen	7	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.540	5.850	0.230			
Rathmann et al., 2009- (4)	Pen	14	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.370	4.730	0.230			
Rathmann et al., 2009- (5)	Pen	14	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.370	5.220	0.230			
Rathmann et al., 2009- (6)	Pen	14	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.370	4.850	0.230			
Rathmann et al., 2009- (7)	Pen	21	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.120	4.050	0.230			
Rathmann et al., 2009- (8)	Pen	21	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.120	4.650	0.230			
Rathmann et al., 2009- (9)	Pen	21	Strip loin	Belt grilled, 71^{oC}	7	7	7	7	7	7	3.120	4.700	0.230			
Rathmann et al., 2012- (1)	Animal	7	Strip loin	Belt grilled, 71^{oC}	60	60	2	2	60	60	3.470	4.250	0.070			
Rathmann et al., 2012- (2)	Animal	7	Strip loin	Belt grilled, 71^{oC}	60	60	2	2	60	60	3.050	3.570	0.050			
Rathmann et al., 2012- (3)	Animal	7	Strip loin	Belt grilled, 71^{oC}	60	60	2	2	60	60	3.030	3.500	0.050			
Rodas-Gonzales et al., 2012 (1)	Animal	7			19	20	12	12	19	20	3.650	4.450	0.200			
Rodas-Gonzales et al., 2012 (2)	Animal	14			19	20	12	12	19	20	3.530	4.080	0.140			
Rodas-Gonzales et al., 2012 (3)	Animal	21			19	20	12	12	19	20	3.290	3.710	0.150			

Author	Experimental unit	Aging	Selected muscle	Cooking method	No of animals		No of pens		No of muscles		Warner –Bratzler shear force (kg)			Cooking loss (%)		
					Control	ZH	Control	ZH	Control	ZH	Control	ZH	SE	Control	ZH	SE
Rodas-Gonzales et al., 2012 (4)	Animal	28			19	20	12	12	19	20	2.950	3.500	0.110			
Hansen et al., 2012- (1)	Animal	7			10	10	1	1	10	10	3.500	4.300	0.242			
Hansen et al., 2012- (2)	Animal	14			10	10	1	1	10	10	2.400	3.700	0.242			
Strydom et al., 2009	Animal	2		Belt grilled, 71^{oC}	NA	NA					4.600	5.400	0.109			

Table 8. List of studies that did not meet the selection criteria, insufficient data or data provided were not relevant

No	Studies	Reasons for exclusion
1	Boler et al., 2009	Did not meet the selection criteria and data were not relevant
2	Brooks et al., 2009	Did not meet the selection criteria and data were not relevant
3	Claus et al., 2010	Insufficient data (data presented in figures not in the tables or text)
4	Cooprider et al., 2011	Review – not relevant
5	Delmore et al., 2010	Review article
6	Etherton 2009	Review article
7	Gunderson et al., 2009 a	Did not meet the selection criteria and data were not relevant
8	Haneklaus et al., 2011	Did not meet the selection criteria and data were not relevant
9	Lawrence et al., 2010	Did not meet the selection criteria and data were not relevant
10	Miller et al., 2012	Did not meet the selection criteria and data were not relevant
11	Rogers et al., 2010	Did not meet the selection criteria and data were not relevant
12	Shook et al., 2009	Data were not relevant (data of Holland et al., 2010 were re-analysed for this study)
13	Strydom et al., 2011	Did not meet the selection criteria and data were not relevant
14	Van Donkersgoed et al., 2011	There was no negative control (zilpaterol*vs*. ractopamine)
15	Dunshea et al., 2005	Review article
16	Brooks et al., 2009	Review article
17	Stephany 2001	Review article (book chapter)
18	Mersmann 1998	Review article
19	Gunderson et al., 2009 b	Did not meet the selection criteria and data were not relevant
20	Edrington et al., 2006	Did not meet the selection criteria and data were not relevant
21	Mehaffey et al., 2009	Did not meet the selection criteria and data were not relevant
22	Edrington et al., 2009	Did not meet the selection criteria and data were not relevant

Table 9. List of studies in different countries, breed and class of cattle, days on feed and period of feeding Ractopamine

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Ractopamine (days)
Abney et al., 2007 (1)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	103	28
Abney et al., 2007 (2)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	103	28
Abney et al., 2007 (3)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	110	35
Abney et al., 2007 (4)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	110	35
Abney et al., 2007 (5)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	117	42
Abney et al., 2007 (6)	USA	3x3 Factorial	Brangus, British & British x Continental breeds	Steers	117	42
Allen et al., 2009	USA	RCT	Holstein	Culled dairy cows	90	32
Avendano-Reyes et al., 2006	Mexico	RCT	Cross-bred (Charolais 50% andLimousin 30% and Zebu 20%)=45, & 9 Brangus	Steers	105	36
Bass et al., 2009 (1)	USA	RCT	Holstein	Steers	104	36
Bass et al., 2009 (2)	USA	RCT	Holstein	Steers	104	36
Bass et al., 2009 (3)	USA	RCT	Holstein	Steers	104	36
Bass et al., 2009 (4)	USA	RCT	Holstein	Steers	104	36
Boler et al., 2012 (1)	USA	RCT	Simmental x Angus cross-bred	Steers	117	28
Boler et al., 2012 (2)	USA	RCT	Simmental x Angus cross-bred	Steers	117	28
Bryant et al., 2010 (1)	USA	3x3 Factorial		Steers	140	28
Bryant et al., 2010 (2)	USA	3x3 Factorial		Steers	140	28
Bryant et al., 2010 (3)	USA	3x3 Factorial	Charolais-cross-bred	Heifers	120	29
Dijkhuis et al., 2008 (1)	USA	RCT	Beefmaster & Brangus	Culled beef cows	48	30
Dijkhuis et al., 2008 (2)	USA	RCT	Beefmaster & Brangus	Culled beef cows	48	30
Dijkhuis et al., 2008 (3)	USA	RCT	Beefmaster & Brangus	Culled beef cows	48	30
Griffin et al., 2009	USA	RCT	English-cross	Steers	113	28
Gruber et al., 2007	USA	RCT	English, Continental cross-bred, Brahman cross-bred calf-fed	Steers	102	28
Holmer et al., 2009 (1)	USA	RCT		Culled beef cows	57	35
Holmer et al., 2009 (1)	USA	RCT		Culled beef cows	57	35
Quinn et al., 2008 Exp 1 (1)	USA	RCT	Cross-bred	Heifers	90	28
Quinn et al., 2008 Exp 2 (2)	USA	RCT	Cross-bred	Heifers	90	28
Quinn et al., 2008 Exp 2 (3)	USA	RCT	Cross-bred	Heifers	42	28
Quinn et al., 2008 Exp 2 (4)	USA	RCT	Cross-bred	Heifers	42	42

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Ractopamine (days)
Sissom et al 2007 (1)	USA	2x2 Factorial	English x continental	Heifer calves	182	28
Sissom et al 2007 (2)	USA	2x2 Factorial	English x continental	Heifer calves	182	28
Sissom et al 2007 (3)	USA	2x3 Factorial	English x continental	Yearling heifers	129	28
Sissom et al 2007 (4)	USA	2x3 Factorial	English x continental	Yearling heifers	150	28
Sissom et al 2007 (5)	USA	2x3 Factorial	English x continental	Yearling heifers	170	28
Scramlin et al., 2010	USA	RCT	Continental-crossbred (1/2 and 1/4 Brahman)	Steers	71	33
Vogel et al., 2009 (1)	USA	RCT	Holstein	Calf-fed		31
Vogel et al., 2009 (2)	USA	RCT	Holstein	Calf-fed		31
Vogel et al., 2009 (3)	USA	RCT	Holstein	Yearling		33
Winterholler et al., 2008 (1)	USA	2x2 Factorial	English x continental	Steers		37
Winterholler et al., 2008 (2)	USA	2x2 Factorial	English x continental	Steers		37
Winterholler et al., 2008 (3)	USA	2x2 Factorial	English x continental	Steers		28
Winterholler et al., 2008 (4)	USA	2x2 Factorial	English x continental	Steers		28
Winterholler et al., 2007	USA	3x2 Factorial	English x continental	Steers	171	28
Walker et al., 2006 (1)	USA	2x3 Factorial	Mixed-breed predominantly continental-crossed	Heifers	49	28
Waker et al., 2006 (2)	USA	2x3 Factorial	Mixed-breed predominantly continental-crossed	Heifers	49	28
Walker et al., 2006 (3)	USA	2x3 Factorial	Mixed-breed predominantly continental-crossed	Heifers	49	28
Woerner et al., 2011 (1)	USA	4x2 Factorial	Charolais bulls to British cross-bred	Heifers & steers	166	28
Woerner et al., 2011 (2)	USA	4x2 Factorial	Charolais bulls to British cross-bred	Heifers & steers	166	28
Laudert et al., 2004 (1)	USA	RCT	English x continental	Steers	132	30
Laudert et al., 2004 (2)	USA	RCT	English x continental	Steers	132	30
Schroeder et al., 2003 (1)	USA	RCT	Simmental X (Angus X Hereford), Brangus X Angus, Angus, Hereford	Steers	167	30
Schroeder et al., 2003 (2)	USA	RCT	Simmental X (Angus X Hereford), Brangus X Angus, Angus, Hereford	Steers	167	30
Schroeder et al., 2003 (3)	USA	RCT	Simmental X (Angus X Hereford), Brangus X Angus, Angus, Hereford	Steers	167	30
Schroeder et al., 2005 (1)	USA	RCT		Heifers calves and yearling		30
Schroeder et al., 2005 (2)	USA	RCT		Heifers calves and yearling		30
Schroeder et al., 2005 (3)	USA	RCT		Heifers calves and yearling		30
Jennings, 2011	USA	3x2 Factorial	British & British x Continental breeds	Heifers	140	28
Glanc, 2013 (1)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28

Authors	Country	Study design	Breed of cattle	Class of cattle	Days on feed	Period of feeding Ractopamine (days)
Glanc, 2013 (2)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28
Glanc, 2013 (3)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28
Glanc, 2013 (4)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28
Glanc, 2013 (5)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28
Glanc, 2013 (6)	Canada	2x3x2 Factorial	British & British x Continental breeds	Heifers & steers		28
Talton, 2006	USA	2x2 Factorial	British	Heifers	138	31
Peterson, 2011	USA	3x4 Factorial	Cross-bred	Yearling heifers		28
Schluter (1991) (1)	USA	RCT	Angus, and crossed with Hereford and Brangus)	Steers		44
Schluter (1991) (2)	USA	RCT	Angus, and crossed with Hereford and Brangus)	Steers		44
Schluter (1991) (3)	USA	RCT	Angus, and crossed with Hereford and Brangus)	Steers		44
Strydom et al., 2011	South Africa			Steers	12	12

Table 10. Dose, feeding and housing systems, delivery method of Ractopamine

Authors	Dose	Delivery method of Ractopamine	Distance travelled to abattoir (km)	Withdrawal of Ractopamine before slaughter (days)	Feeding system	Housing
Abney et al., 2007 (1)	100	Mixed and delivered via load cells			Yes	Pen
Abney et al., 2007 (2)	200	Mixed and delivered via load cells			Yes	Pen
Abney et al., 2007 (3)	100	Mixed and delivered via load cells			Yes	Pen
Abney et al., 2007 (4)	200	Mixed and delivered via load cells			Yes	Pen
Abney et al., 2007 (5)	100	Mixed and delivered via load cells			Yes	Pen
Abney et al., 2007 (6)	200	Mixed and delivered via load cells			Yes	Pen
Allen et al., 2009	312	Mixed with ground corn			No	Individual pens
Avendano-Reyes et al., 2006	300	Mixed with minerals	5		Yes	Pen
Bass et al., 2009 (1)	200	Not provided			Not provided	Commercial feedlot
Bass et al., 2009 (2)	200	Not provided			Not provided	Commercial feedlot
Bass et al., 2009 (3)	200	Not provided			Not provided	Commercial feedlot
Bass et al., 2009 (4)	200	Not provided			Not provided	Commercial feedlot
Boler et al., 2012 (1)	200	Mixed with basal diet	874		Yes	Pen
Boler et al., 2012 (2)	300	Mixed with basal diet	874		Yes	Pen
Bryant et al., 2010 (1)	100	Mixed with ground corn	402		Yes	Pen
Bryant et al., 2010 (2)	200	Mixed with ground corn	402		Yes	Pen
Bryant et al., 2010 (3)	250	Mixed with ground corn	60		No	Pen
Dijkhuis et al., 2008 (1)	100	Control diet + RAC			Yes	Pen
Dijkhuis et al., 2008 (2)	200	Control diet + RAC			Yes	Pen
Dijkhuis et al., 2008 (3)	300	Control diet + RAC			Yes	Pen
Griffin et al., 2009	200	Mixed with diet			Yes	Pen
Gruber et al., 2007	200	Mixed with ground corn			Yes	Pen
Holmer et al., 2009 (1)	200	Mixed with concentrate			Yes	Pen
Holmer et al., 2009 (1)	200	Mixed with concentrate			Yes	Pen
Quinn et al., 2008 Exp 1 (1)	200	In Premix			Yes	Pen
Quinn et al., 2008 Exp 2 (2)	200	In Premix			Yes	Pen
Quinn et al., 2008 Exp 2 (3)	200	In Premix			Yes	Pen
Quinn et al., 2008 Exp 2 (4)	200	In Premix			Yes	Pen
Sissom et al 2007 (1)	200	Mixed with basal diet	200		Yes	Pen

Authors	Dose	Delivery method of Ractopamine	Distance travelled to abattoir (km)	Withdrawal of Ractopamine before slaughter (days)	Feeding system	Housing
Sissom et al 2007 (2)	200	Mixed with basal diet	200		Yes	Pen
Sissom et al 2007 (3)	200	Mixed with basal diet	113		Yes	Pen
Sissom et al 2007 (4)	200	Mixed with basal diet	113		Yes	Pen
Sissom et al 2007 (5)	200	Mixed with basal diet	113		Yes	Pen
Scramlin et al., 2010	200	Type-B protein and mineral supplements			Yes	Pen
Vogel et al., 2009 (1)	200				Yes	Pen
Vogel et al., 2009 (2)	300				Yes	Pen
Vogel et al., 2009 (3)	200	Type-B medicated feed (SuperMix Opt1135)			Yes	Pen
Winterholler et al., 2008 (1)	200	Mixed with the diet	182		Yes	Pen
Winterholler et al., 2008 (2)	200	Mixed with ground corn	182		Yes	Pen
Winterholler et al., 2008 (3)	200	Mixed with the diet	182		Yes	Pen
Winterholler et al., 2008 (4)	200	Mixed with ground corn	182		Yes	Pen
Winterholler et al., 2007	200	Mixed with basal diet	113		Yes	Pen
Walker et al., 2006 (1)	200	Mixed with diet			No	Individual pen
Waker et al., 2006 (2)	200	Mixed with diet			No	Individual pen
Walker et al., 2006 (3)	200	Mixed with diet			No	Individual pen
Woerner et al., 2011 (1)	200	Type-B medicated ground corn supplement	150		Yes	
Woerner et al., 2011 (2)	200	Type-B medicated ground corn supplement	150		Yes	
Laudert et al., 2004 (1)	100	Mixed with the diet	32 to 499		Yes	Pen
Laudert et al., 2004 (2)	200	Mixed with the diet	32 to 499		Yes	Pen
Schroeder et al., 2003 (1)	100	Mixed with the diet			Yes	Pen
Schroeder et al., 2003 (2)	200	Mixed with the diet			Yes	Pen
Schroeder et al., 2003 (3)	300	Mixed with the diet			Yes	Pen
Schroeder et al., 2005 (1)	100	Mixed with the diet			Yes	Pen
Schroeder et al., 2005 (2)	200	Mixed with the diet			Yes	Pen
Schroeder et al., 2005 (3)	300	Mixed with the diet			Yes	Pen
Jennings, 2011	200	Premixed	112.7		Yes	Pen
Glanc, 2013 (1)	200	Mixed with diet			Individual	Pen
Glanc, 2013 (2)	200	Mixed with diet			Individual	Pen
Glanc, 2013 (3)	200	Mixed with diet			Individual	Pen
Glanc, 2013 (4)	200	Mixed with diet			Individual	Pen

Authors	Dose	Delivery method of Ractopamine	Distance travelled to abattoir (km)	Withdrawal of Ractopamine before slaughter (days)	Feeding system	Housing
Glanc, 2013 (5)	200	Mixed with diet			Individual	Pen
Glanc, 2013 (6)	200	Mixed with diet			Individual	Pen
Talton, 2006	150	Type-B protein supplement and corn			Yes	Pen
Peterson, 2011	200	Mixed with diet			Yes	Pen
Schluter (1991) (1)	100				Yes	Pen
Schluter (1991) (2)	200				Yes	Pen
Schluter (1991) (3)	300				Yes	Pen
Strydom et al 2011	100		3			

Table 11. Supplementation, vaccination, antibiotics, anti-parasitic treatments and growth implants

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Abney et al., 2007 (1)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Abney et al., 2007 (2)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Abney et al., 2007 (3)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Abney et al., 2007 (4)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Abney et al., 2007 (5)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Abney et al., 2007 (6)	Monensin and Tylosin	Titanium 5 & anti-clostridial (Vision 7 + SPUR)	Cydectin	Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 24mg estradiol)
Allen et al., 2009	Vitamins (A,E) and Monensin 80, Tylosin 40				
Avendano-Reyes et al., 2006	Vitamins (Se, Ve, Lapisa)	Express 5 HS & Caliber 7	Novox 50, PISA & Albendaphorte 10%, Salud Y	Synovex-C (100mg P4 & 10mg E2)	Synovex Plus (200mg TBA + 28mg E2)
Bass et al., 2009 (1)	Vitamins (A,E) and Monensin			E2 (43.7mg)	No implant
Bass et al., 2009 (2)	Vitamins (A,E) and Monensin			E2 (43.7mg)	EP (E2 20mg, P4 200mg)
Bass et al., 2009 (3)	Vitamins (A,E) and Monensin			E2 (43.7mg)	MT (16mg TBA, 80mg E2)
Bass et al., 2009 (4)	Vitamins (A,E) and Monensin			E2 (43.7mg)	HT (24mg TBA, 120mg E2)
Boler et al., 2012 (1)	Vitamins (AEDK), Tylosin, Monensin	Vista 3 SQ vaccine for IBR/BVD	Ivomec	Component TE-S	
Boler et al., 2012 (2)	Vitamins (AEDK), Tylosin, Monensin	Vista 3 SQ vaccine for IBR/BVD	Ivomec	Component TE-S	
Bryant et al., 2010 (1)	Urea, vitamins and monensin and Tylosin				
Bryant et al., 2010 (2)	Urea, vitamins and monensin and Tylosin			Revalor-S (120mg TBA, 24mg E17B)	
Bryant et al., 2010 (3)	MGA			Revalor-IS (80mg TBA, 16mg E17B)	Revalor-S (120mg TBA, 24mg E17B)
Dijkhuis et al., 2008 (1)					
Dijkhuis et al., 2008 (2)					
Dijkhuis et al., 2008 (3)					

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Griffin et al., 2009	Monensin&Tylosin	Vaccinated for pinkeye,		Revalor-G	SynovexChoice
Gruber et al., 2007	Monensin&Tylosin	Pyramid 4		Component ES (200mg P4 & 20mg E2)	Component T-ES (120mg TBA & 24mg E2)
Holmer et al., 2009 (1)					
Holmer et al., 2009 (1)					
Quinn et al., 2008 Exp 1 (1)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)			Revalor-H (140mg TBA, 14mg E2)	
Quinn et al., 2008 Exp 2 (2)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)				
Quinn et al., 2008 Exp 2 (3)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)				
Quinn et al., 2008 Exp 2 (4)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)				
Sissom et al., 2007 (1)	Monensin&Tylosin& MGA (Melengesterol 0.4mg/hd/d)			Revalor-200 (200mg TBA, 20mg E2)	
Sissom et al., 2007 (2)	Monensin&Tylosin& MGA (Melengesterol 0.4mg/hd/d)			Ravalor-IH (80mg TBA, 8mg E2)	Finaplix-H (200mg TBA)
Sissom et al., 2007 (3)	Monensin&Tylosin& MGA (Melengesterol 0.4mg/hd/d)			Ravalor-IH (80mg TBA, 8mg E2)	Revalor-200 (200mg TBA, 20mg E2) day 56
Sissom et al., 2007 (4)	Monensin&Tylosin& MGA (Melengesterol 0.4mg/hd/d)			Ravalor-IH (80mg TBA, 8mg E2)	Revalor-200 (200mg TBA, 20mg E2) day 56
Sissom et al., 2007 (5)	Monensin&Tylosin& MGA (Melengesterol 0.4mg/hd/d)			Ravalor-IH (80mg TBA, 8mg E2)	Revalor-200 (200mg TBA, 20mg E2) day 56
Scramlin et al., 2010	ADE, Tylosin, Monensin,	Elite [Clostridial species, IBR, BVD, Bovine Respiratory Syncytial Virus (BRSV)]	Internal and external parasites	Component E-S (20mg E2 & 200mg P4)	Component ES (120mg TBA and 24mg E2)
Vogel et al., 2009 (1)	Monensin, Tylosin			Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 20mg E2) & Synovex S (200mg P4 + 20mg E2)
Vogel et al., 2009 (2)	Monensin, Tylosin			Ralgro (36mg Zeranol)	Revalor S (120 mg TBA and 20mg E2) & Synovex S (200mg P4 + 20mg E2)
Vogel et al., 2009 (3)	Monensin, Tylosin		Ivemectin for Internal and external parasites		Synovex Choice (100mg TBA + 14mg E2)
Winterholler et al., 2008 (1)	Monensin, Tylosin, Vit & Mineral premix				Revalor- S (120mg TBA, 24mg E2)
Winterholler et al., 2008 (2)					
Winterholler et al., 2008 (3)	Monensin, Tylosin, Vit & Mineral premix				Revalor- S (120mg TBA, 24mg E2)
Winterholler et al., 2008 (4)					
Winterholler et al., 2007	Vitamins (ADE) monensin&Tylosin			Revalor-IS (80mg TBA & 16mg E2)	Revalor-S (120mg TBA, 24mg E2)
Walker et al., 2006 (1)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)			Revalor-H (140mg TBA & 14mg E2)	

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
Waker et al., 2006 (2)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)			Revalor-H (140mg TBA & 14mg E2)	
Walker et al., 2006 (3)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)			Revalor-H (140mg TBA & 14mg E2)	
Woerner et al., 2011 (1)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)				Revalor-S (120mg TBA, 24mg E2) & Revalor-H (140mg TBA & 14mg E2) day 63
Woerner et al., 2011 (2)	Monensin&Tylosin& MGA (Melengesterol 0.5mg/hd/d)			Revalor-IS (80mg TBA & 16mg E2) & Revalor-IH (80mg TBA & 8mg E2) day 0	Revalor-S (120mg TBA, 24mg E2) & Revalor-H (140mg TBA & 14mg E2) day 63
Laudert et al., 2004 (1)				Ravlor-S, Ravlor-IS, Ralgro, Component ES (different imaplants used at each site)	Component TE-S, Revalor-IS, Revalor S (different imaplants used at each site, 2 used none)
Laudert et al., 2004 (2)				Ravlor-S, Ravlor-IS, Ralgro, Component ES (different imaplants used at each site)	Component TE-S, Revalor-IS, Revalor S (different imaplants used at each site, 2 used none)
Schroeder et al., 2003 (1)		Yes (details not provided)	Yes (Details not provided)		Estrogenic implant
Schroeder et al., 2003 (2)		Yes (details not provided)	Yes (Details not provided)		Estrogenic implant
Schroeder et al., 2003 (3)		Yes (details not provided)	Yes (Details not provided)		Estrogenic implant
Schroeder et al., 2005 (1)					
Schroeder et al., 2005 (2)					
Schroeder et al., 2005 (3)					
Jennings, 2011	Tylosin&Monensin	Titanium 3 (virus vaccine) & anti-clostridial (Vision 7 + SPUR)	Ivemectin for Internal and external parasites	Component TE-IH	Component TE-200
Glanc, 2013 (1)	Vitamins/Minerals/Monensin mix and Alfafa hay 8%				
Glanc, 2013 (2)	Vitamins/Minerals/Monensin mix and Alfafa hay 16%				
Glanc, 2013 (3)	Vitamins/Minerals/Monensin mix and Alfafa hay 24%				
Glanc, 2013 (4)	Vitamins/Minerals/Monensin mix and Corn silage 8%				
Glanc, 2013 (5)	Vitamins/Minerals/Monensin mix and Corn silage 16%				
Glanc, 2013 (6)	Vitamins/Minerals/Monensin mix and Corn silage 24%				
Talton, 2006			Ivermectin	Compontent TE-IH	
Peterson, 2011	Urea, vitamins and monensin and	Presponse S-Q &	Synanthic	Revalor-S	

Author	Supplement and rumen modifiers	Vaccination	Anti-parasitic treatments	Initial implantation	Terminal implantation
	Tylosin	Pyramid II Plus BVD & Promectin			
Schluter (1991) (1)	Tylosin	Vaccinated for IBR, BVD, PI3, BRSV and clostridium C & D toxoid			
Schluter (1991) (2)	Tylosin	Vaccinated for IBR, BVD, PI3, BRSV and clostridium C & D toxoid			
Schluter (1991) (3)	Tylosin	Vaccinated for IBR, BVD, PI3, BRSV and clostridium C & D toxoid			
Strydom et al 2011				Revalor-S	

Table 12. Experimental unit, number of cattle and pens per group, body weight, dry matter intake and G:F ratio in cattle fed Ractopamine

Author	Experimental unit	No of animals/ group		No of animal/ pen	No of pens/ group	Body weight (kg)			Average daily gain (kg/hd/d)			Dry matter intake (kg/hd/d)			G:F ratio		
		Control	RAC	3	3	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE
Abney et al., 2007 (1)	Pen	1	40	40	5	585.450	584.680	11.770	1.040	1.220	0.090	8.830	8.800	0.280	0.120	0.140	0.007
Abney et al., 2007 (2)	Pen	1	40	40	5	585.450	591.530	11.770	1.040	1.190	0.090	8.830	9.020	0.280	0.120	0.130	0.007
Abney et al., 2007 (3)	Pen	1	40	40	5	592.020	591.720	11.770	1.210	1.300	0.090	9.160	9.370	0.280	0.130	0.140	0.007
Abney et al., 2007 (4)	Pen	1	40	40	5	592.020	601.100	11.770	1.210	1.530	0.090	9.160	9.460	0.280	0.130	0.160	0.007
Abney et al., 2007 (5)	Pen	1	40	40	5	580.360	598.900	11.770	1.120	1.470	0.090	9.060	9.580	0.280	0.120	0.150	0.007
Abney et al., 2007 (6)	Pen	1	40	40	5	580.360	593.320	11.770	1.120	1.390	0.090	9.060	9.220	0.280	0.120	0.150	0.007
Allen et al., 2009	Individual pens	0	8	9	1	759.900	759.900	26.030	1.080	1.000	0.195	14.500	14.800	0.600	0.076	0.067	0.011
Avendano-Reyes et al., 2006	Pen	1	17	18	3	478.200	488.800	1.740	1.580	2.080	0.033	8.510	8.370	0.024	0.185	0.248	0.004
Bass et al., 2009 (1)	Commercial feedlot	Animal?	99	99		569.800	582.000		1.140	1.260							
Bass et al., 2009 (2)	Commercial feedlot	Animal?	99	99		590.500	583.300		1.340	1.270							
Bass et al., 2009 (3)	Commercial feedlot	Animal?	99	99		588.600	594.000		1.320	1.360							
Bass et al., 2009 (4)	Commercial feedlot	Animal?	99	99		584.800	592.100		1.280	1.360							
Boler et al., 2012 (1)	Pen	0	47	48	7 to 8	520.830	535.670	1.920	0.960	1.490	0.070	10.090	10.080	0.120			
Boler et al., 2012 (2)	Pen	0	47	48	7 to 8	520.830	535.400	1.920	0.960	1.480	0.070	10.090	9.760	0.120			
Bryant et al., 2010 (1)	Pen	1	54	54	9	573.500	577.100	10.100	0.990	1.250	0.091	9.370	9.320	0.225	0.105	0.133	0.008
Bryant et al., 2010 (2)	Pen	1	54	54	9	573.500	579.500	10.100	0.990	1.240	0.091	9.370	9.200	0.225	0.105	0.134	0.008
Bryant et al., 2010 (3)	Pen	0	24	24	1	500.800	510.900	10.200	0.610	0.980	0.086	7.710	7.780	0.162	0.078	0.125	0.011
Dijkhuis et al., 2008 (1)	Pen	Animal	12	12	12												
Dijkhuis et al., 2008 (2)	Pen	Animal	12	12	12												
Dijkhuis et al., 2008 (3)	Pen	Animal	12	12	12												
Griffin et al., 2009	Pen	Pen	?	?	?	642.000	643.000	2.000	1.840	1.850	0.090	13.070	13.090	0.080	0.140	0.141	0.006
Gruber et al., 2007	Pen	1	208	209	10	561.200	568.500	9.100	1.500	1.730	0.090	10.300	10.200	0.280	0.145	0.170	0.005
Holmer et al., 2009 (1)	Pen	1	19	19	5	516.100	651.000	21.270	0.610	2.000	0.207						
Holmer et al., 2009 (1)	Pen	1	19	19	5	660.700	651.000	21.270	1.900	2.000	0.207	13.890	15.320	0.868	0.144	0.135	0.015
Quinn et al., 2008 Exp 1 (1)	Pen	1	150	152	12 to 13	527.000	529.000	2.700	1.690	1.800	0.050	10.100	9.860	0.110	0.167	0.183	0.005
Quinn et al., 2008 Exp 2 (2)	Pen	1	57	56	5 to 6							8.200	8.200	0.120			
Quinn et al., 2008 Exp 2	Pen	1	57	57	5 to 6							8.200	7.700	0.120			

Author	Experimental unit	No of animals/ group		No of animal/ pen	No of pens/ group	Body weight (kg)			Average daily gain (kg/hd/d)			Dry matter intake (kg/hd/d)			G:F ratio		
		Control	RAC	3	3	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE
(3)																	
Quinn et al., 2008 Exp 2 (4)	Pen	1	57	55	5 to 6							8.200	8.200	0.120			
Sissom et al 2007 (1)	Pen	1	274	271	51				1.380	1.420	0.010	7.670	7.660	0.140	0.179	0.186	0.004
Sissom et al 2007 (2)	Pen	1	274	271	51				1.400	1.420	0.010	7.790	7.600	0.140	0.180	0.187	0.004
Sissom et al 2007 (3)	Pen	1	380	387	47				1.600	1.620	0.020	8.430	8.470	0.090	0.189	0.191	0.001
Sissom et al 2007 (4)	Pen	1	377	377	47				1.530	1.580	0.020	8.580	8.570	0.090	0.179	0.185	0.001
Sissom et al 2007 (5)	Pen	1	382	372	47				1.470	1.470	0.020	8.550	8.370	0.090	0.173	0.178	0.001
Scramlin et al., 2010	Pen	1	100	100	10	546.620	554.150	1.450	0.950	1.180	0.050	8.980	9.070	0.120	0.107	0.131	0.005
Vogel et al., 2009 (1)	Pen	1	638	628	30	585.800	593.800	2.900	1.370	1.610	0.060	9.360	9.590	0.190	0.145	0.168	0.010
Vogel et al., 2009 (2)	Pen	1	638	626	30	593.800	592.600	2.900	1.370	1.570	0.060	9.360	9.180	0.190	0.145	0.169	0.010
Vogel et al., 2009 (3)	Pen	1	91	91	6	605.800	613.800	5.200	1.500	1.780	0.060	10.700	11.180	0.060	0.140	0.160	0.005
Winterholler et al., 2008 (1)	Pen	1	30	30	10	562.000	574.000	0.680	0.620	0.940	0.090	9.100	10.200	0.690	0.070	0.090	0.010
Winterholler et al., 2008 (2)	Pen	1	30	30	10	536.000	539.000	0.680	0.530	0.670	0.090	8.670	7.050	0.690	0.060	0.090	0.010
Winterholler et al., 2008 (3)	Pen	0	8	8		590.000	632.000	13.050	1.360	1.990	0.200	8.940	10.240	0.780	0.150	0.200	0.020
Winterholler et al., 2008 (4)	Pen	0	7	8		584.000	547.000	13.050	1.460	0.590	0.200	8.580	7.130	0.780	0.170	0.090	0.020
Winterholler et al., 2007	Pen	1	1126	1126	91-97	584.000	595.000	3.000	1.560	1.630	0.010	8.870	8.930	0.040	0.176	0.183	0.001
Walker et al., 2006 (1)	Individual pen	0	12	12	1	515.100	535.200	4.500	1.370	2.060	0.160	8.550	9.140	0.350	0.157	0.222	0.013
Waker et al., 2006 (2)	Individual pen	0	12	12	1	519.800	527.600	4.500	1.530	1.800	0.160	8.530	8.890	0.350	0.178	0.201	0.013
Walker et al., 2006 (3)	Individual pen	0	12	12	1	527.800	524.900	4.500	1.810	1.710	0.160	9.010	8.290	0.350	0.198	0.206	0.013
Woerner et al., 2011 (1)		0	74	70		609.000	604.000	10.100	1.570	1.670	0.059						
Woerner et al., 2011 (2)		0	73	74		620.000	630.000	10.100	1.540	1.730	0.059						
Laudert et al., 2004 (1)	Pen	1	2413	2132	76	587.000	590.400	3.130	1.380	1.510	0.110	9.080	9.030	0.200	0.152	0.167	0.009
Laudert et al., 2004 (2)	Pen	1	2413	2419	55	587.000	593.500	3.130	1.380	1.510	0.110	9.080	9.040	0.200	0.152	0.179	0.009
Schroeder et al., 2003 (1)	Pen	1	215	219	8 to 10	576.000	582.800	20.880	1.270	1.490	0.150	9.870	9.990	0.490	0.126	0.147	0.009
Schroeder et al., 2003 (2)	Pen	1	215	219	8 to 10	576.000	583.210	20.880	1.270	1.520	0.150	9.870	9.870	0.490	0.126	0.152	0.009
Schroeder et al., 2003 (3)	Pen	1	215	219	8 to 10	576.000	585.930	20.880	1.270	1.600	0.150	9.870	9.910	0.490	0.126	0.159	0.009
Schroeder et al., 2005 (1)	Pen	1	215	215	7 to 10	528.300	531.340	15.830	1.240	1.340	0.120	9.380	9.410	0.370	0.133	0.142	0.008
Schroeder et al., 2005 (2)	Pen	1	215	215	7 to 10	528.300	534.930	15.830	1.240	1.460	0.120	9.380	9.530	0.370	0.133	0.153	0.008

Author	Experimental unit	No of animals/ group		No of animal/ pen	No of pens/ group	Body weight (kg)			Average daily gain (kg/hd/d)			Dry matter intake (kg/hd/d)			G:F ratio		
		Control	RAC	3	3	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE	Control	RAC	SE
Schroeder et al., 2005 (3)	Pen	1	215	215	7 to 10	528.300	537.560	15.830	1.240	1.500	0.120	9.380	9.390	0.370	0.133	0.159	0.008
Jennings, 2011	Pen	1	27	27	3	548.200	547.300	3.680	1.320	1.460	0.050	8.700	8.750	0.120	0.150	0.170	0.010
Glanc, 2013 (1)	Pen	0	11	11	9				1.780	2.040	0.070						
Glanc, 2013 (2)	Pen	0	11	11	9				1.710	1.930	0.070						
Glanc, 2013 (3)	Pen	0	11	11	9				1.810	1.680	0.070						
Glanc, 2013 (4)	Pen	0	11	11	9				1.770	1.830	0.070						
Glanc, 2013 (5)	Pen	0	11	11	9				1.800	1.720	0.070						
Glanc, 2013 (6)	Pen	0	11	11	9				1.650	1.800	0.070						
Talton, 2006	Pen	1	24	24	6	582.000	584.300	3.170	1.270	1.390	0.080	11.500	12.400	0.440	0.050	0.050	0.003
Peterson, 2011	Pen	1	36	36	9	593.100	599.800	2.680	0.670	0.910	0.100	9.160	9.260	0.160			
Schluter (1991) (1)	Pen	1	40	40	8	492.400	496.500	2.600	0.920	0.950	0.040						
Schluter (1991) (2)	Pen	1	40	40	8	492.400	503.000	2.600	0.920	1.150	0.040						
Schluter (1991) (3)	Pen	1	40	40	8	492.400	503.500	2.600	0.920	1.170	0.040						
Strydom et al 2011	Individual	0	12	12													

Table 13b. Carcass pH, hot carcass weight (HCW), longissimus muscle area (LMA) and carcass colour score

Author	Carcass pH			Hot carcass weight (kg)			Longissimus muscle area (cm)			Carcass colour score (scale 1 to 9)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Abney et al., 2007 (1)				359.630	362.220	7.730	86.335	89.789	1.727			
Abney et al., 2007 (2)				359.630	367.280	7.730	86.335	87.833	1.727			
Abney et al., 2007 (3)				366.900	365.740	7.730	87.630	87.274	1.727			
Abney et al., 2007 (4)				366.900	373.370	7.730	87.630	91.288	1.727			
Abney et al., 2007 (5)				360.200	370.850	7.730	87.528	88.646	1.727			
Abney et al., 2007 (6)				360.200	366.850	7.730	87.528	88.875	1.727			
Allen et al., 2009				416.300	414.600	15.500	75.500	82.000	6.330			
Avendano-Reyes et al., 2006	5.439	5.442	0.007	291.700	305.300	1.330	66.750	72.170	1.370			
Bass et al., 2009 (1)				347.600	355.100		69.000	71.600				
Bass et al., 2009 (2)				360.400	356.000		72.300	74.800				
Bass et al., 2009 (3)				359.300	364.600		75.500	78.100				
Bass et al., 2009 (4)				357.300	361.200		74.800	74.800				
Boler et al., 2012 (1)				324.560	337.780	1.240	80.400	83.910	0.980			
Boler et al., 2012 (2)				324.560	339.460	1.240	80.400	84.040	0.980			
Bryant et al., 2010 (1)				362.100	363.100	5.900	84.000	84.000	1.300			
Bryant et al., 2010 (2)				362.100	368.400	5.900	84.000	86.300	1.300			
Bryant et al., 2010 (3)				327.600	334.100	6.100	79.900	82.400	1.900			
Dijkhuis et al., 2008 (1)				275.700	258.100	6.050	27.900	26.700	0.790			
Dijkhuis et al., 2008 (2)				275.700	258.600	6.050	27.900	25.900	0.790			
Dijkhuis et al., 2008 (3)				275.700	268.000	6.200	27.900	28.200	0.810			
Griffin et al., 2009				405.000	405.000	1.000	90.970	91.030	0.770			
Gruber et al., 2007				359.300	364.800	4.900	81.700	84.000	1.100			

Author	Carcass pH			Hot carcass weight (kg)			Longissimus muscle area (cm)			Carcass colour score (scale 1 to 9)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Holmer et al., 2009 (1)	5.620	5.520	0.037	278.000	356.900	9.940	68.800	80.400	1.790			
Holmer et al., 2009 (1)	5.530	5.520	0.037	352.800	356.900	9.940	78.200	80.400	1.790			
Quinn et al., 2008 Exp 1 (1)				334.000	335.000	2.500	86.300	88.200	0.200			
Quinn et al., 2008 Exp 2 (2)				304.000	308.000	2.500	83.900	83.200	0.200			
Quinn et al., 2008 Exp 2 (3)				304.000	307.000	2.500	83.900	83.200	0.200			
Quinn et al., 2008 Exp 2 (4)				304.000	312.000	2.500	83.900	83.900	0.200			
Sissom et al 2007 (1)				343.000	349.000	2.000	93.300	95.700	0.800			
Sissom et al 2007 (2)				346.000	350.000	2.000	94.200	96.900	0.800			
Sissom et al 2007 (3)				313.000	315.000	2.000	91.200	93.500	0.100			
Sissom et al 2007 (4)				329.000	335.000	2.000	94.200	96.100	0.100			
Sissom et al 2007 (5)				348.000	347.000	2.000	95.500	94.200	0.100			
Scramlin et al., 2010	5.460	5.450	0.010	357.790	363.060	1.360	34.190	34.210	0.430			
Vogel et al., 2009 (1)				357.500	362.200	1.430	77.030	78.770	1.610			
Vogel et al., 2009 (2)				357.500	362.600	1.430	77.030	79.810	1.610			
Vogel et al., 2009 (3)				346.700	352.200	2.610	71.930	73.550	0.980			
Winterholler et al., 2008 (1)				358.000	368.000	5.000	85.290	93.160	2.520			
Winterholler et al., 2008 (2)				341.000	341.000	5.000	84.770	86.580	2.520			
Winterholler et al., 2008 (3)				374.000	395.000	8.690	97.940	103.100	7.290			
Winterholler et al., 2008 (4)				365.000	339.000	8.690	99.870	83.030	7.290			
Winterholler et al., 2007				371.000	379.000	2.000	90.650	92.390	0.660			
Walker et al., 2006 (1)				318.000	327.800	3.200	91.500	86.100	3.500			
Waker et al., 2006 (2)				316.400	323.700	3.200	83.500	90.400	3.500			
Walker et al., 2006 (3)				319.300	322.900	3.200	81.600	91.300	3.500			
Woerner et al., 2011 (1)				370.000	371.000	5.300	88.100	88.400	1.070			
Woerner et al., 2011 (2)				381.000	387.000	5.300	91.200	94.400	1.070			

Author	Carcass pH			Hot carcass weight (kg)			Longissimus muscle area (cm)			Carcass colour score (scale 1 to 9)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Laudert et al., 2004 (1)				374.732	377.138	1.680	86.250	86.875	1.688			
Laudert et al., 2004 (2)				374.732	380.316	1.680	86.250	88.125	1.688			
Schroeder et al., 2003 (1)				342.044	344.586	13.166	75.000	76.875	2.688			
Schroeder et al., 2003 (2)				342.044	348.445	13.166	75.000	77.500	2.688			
Schroeder et al., 2003 (3)				342.044	350.306	13.166	75.000	78.125	2.688			
Schroeder et al., 2005 (1)				315.480	316.290	6.490	81.270	81.920	2.770			
Schroeder et al., 2005 (2)				315.480	318.330	6.490	81.270	81.920	2.770			
Schroeder et al., 2005 (3)				315.480	320.600	6.490	81.270	84.500	2.770			
Jennings, 2011				327.700	333.300	1.630	85.870	88.220	0.380	5.470	5.550	0.090
Glanc, 2013 (1)							26.900	22.600	0.930			
Glanc, 2013 (2)							25.300	25.100	0.930			
Glanc, 2013 (3)							23.800	25.000	0.930			
Glanc, 2013 (4)							24.400	25.500	0.930			
Glanc, 2013 (5)							25.400	28.800	0.930			
Glanc, 2013 (6)							24.500	23.300	0.930			
Talton, 2006	5.500	5.480	0.020	359.700	367.800	2.470	79.400	84.100	1.420			
Peterson, 2011				375.300	378.700	4.000	83.490	85.170	0.900			
Schluter (1991) (1)				302.000	305.000	2.110	78.800	79.200	1.030			
Schluter (1991) (2)				302.000	310.000	2.110	78.800	79.300	1.030			
Schluter (1991) (3)				302.000	310.000	2.110	78.800	81.000	1.030			
Strydom et al 2011				339.100	346.100	2.110	75.500	80.000	2.645			

Table 13c. Marbling score, fat thickness, carcass yield and dressing percentage

Author	Marbling score (300 to 500)			Fat thickness (cm)			Yield grade (scale 1 to 5)			Dressing (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Abney et al., 2007 (1)	380.560	391.250	11.300	1.200	1.150	0.070	2.780	2.590	0.110	61.440	61.980	0.330
Abney et al., 2007 (2)	380.560	408.750	11.300	1.200	1.240	0.070	2.780	2.800	0.110	61.440	62.070	0.330
Abney et al., 2007 (3)	395.120	401.750	11.300	1.230	1.180	0.070	2.800	2.760	0.110	62.010	61.790	0.330
Abney et al., 2007 (4)	395.120	390.120	11.300	1.230	1.190	0.070	2.800	2.620	0.110	62.010	62.100	0.330
Abney et al., 2007 (5)	393.750	411.440	11.300	1.230	1.210	0.070	2.740	2.770	0.110	62.070	61.910	0.330
Abney et al., 2007 (6)	393.750	398.880	11.300	1.230	1.210	0.070	2.740	2.720	0.110	62.070	61.810	0.330
Allen et al., 2009	539.000	522.000	60.000	0.740	0.850	0.133	3.000	3.200	0.200	54.800	54.600	1.130
Avendano-Reyes et al., 2006				1.650	1.560	0.058				61.000	62.480	0.217
Bass et al., 2009 (1)	579.800	619.200		0.760	0.720							
Bass et al., 2009 (2)	542.100	542.500		0.690	0.670							
Bass et al., 2009 (3)	520.900	518.800		0.630	0.650							
Bass et al., 2009 (4)	564.600	535.200		0.680	0.680							
Boler et al., 2012 (1)	471.400	453.500	14.570	1.350	1.350	0.050	2.820	2.740	0.080	62.270	63.060	0.300
Boler et al., 2012 (2)	471.400	443.700	14.570	1.350	1.400	0.050	2.820	2.810	0.080	62.270	63.390	0.300
Bryant et al., 2010 (1)	534.700	537.800	8.240	1.520	1.470	0.034	3.320	3.270	0.057	63.090	62.920	0.290
Bryant et al., 2010 (2)	534.700	531.400	8.240	1.520	1.480	0.034	3.320	3.210	0.057	63.090	63.550	0.290
Bryant et al., 2010 (3)	581.700	548.100	26.000	1.120	1.240	0.055	2.840	2.880	0.129	65.400	65.400	0.300
Dijkhuis et al., 2008 (1)	261.900	222.700	14.510				2.600	2.500	0.060	53.800	53.200	0.800
Dijkhuis et al., 2008 (2)	261.900	246.400	14.510				2.600	2.600	0.060	53.800	51.600	0.800
Dijkhuis et al., 2008 (3)	261.900	249.100	14.510				2.600	2.700	0.060	53.800	52.000	0.810
Griffin et al., 2009	574.800	573.500	32.200	1.190	1.190	0.100	2.860	2.840	0.110			
Gruber et al., 2007	487.000	477.000	5.200	1.320	1.290	0.020	3.180	3.080	0.060	64.000	64.200	0.260

Author	Marbling score (300 to 500)			Fat thickness (cm)			Yield grade (scale 1 to 5)			Dressing (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Holmer et al., 2009 (1)	438.000	551.000	26.800	0.400	1.300	0.180	1.900	3.000	0.300	55.600	58.400	1.030
Holmer et al., 2009 (1)	547.000	551.000	26.800	1.200	1.300	0.180	3.000	3.000	0.300	57.200	58.400	1.030
Quinn et al., 2008 Exp 1 (1)	380.000	373.000	7.000	0.790	0.760	0.030						
Quinn et al., 2008 Exp 2 (2)	438.000	431.000	13.000	0.910	0.990	0.020	2.090	2.120	0.100	63.800	63.900	0.500
Quinn et al., 2008 Exp 2 (3)	438.000	411.000	13.000	0.910	1.020	0.020	2.090	2.120	0.100	63.800	64.500	0.500
Quinn et al., 2008 Exp 2 (4)	438.000	427.000	13.000	0.910	1.090	0.020	2.090	2.310	0.100	63.800	65.200	0.500
Sissom et al 2007 (1)	425.000	409.000	8.000	1.240	1.140	0.030	2.610	2.450	0.080			
Sissom et al 2007 (2)	406.000	398.000	8.000	1.240	1.170	0.030	2.610	2.430	0.080			
Sissom et al 2007 (3)	477.000	472.000	6.000	1.190	1.220	0.030	2.130	2.010	0.070			
Sissom et al 2007 (4)	484.000	478.000	6.000	1.450	1.350	0.030	2.340	2.200	0.070			
Sissom et al 2007 (5)	501.000	506.000	6.000	1.520	1.520	0.030	2.500	2.540	0.070			
Scramlin et al., 2010	545.800	533.000	8.660	1.240	1.220	0.050	2.900	2.920	0.060	65.490	65.520	0.180
Vogel et al., 2009 (1)	514.800	497.700	20.700	0.660	0.640	0.030	2.770	2.710	0.080	61.220	61.150	0.510
Vogel et al., 2009 (2)	514.800	507.000	20.700	0.660	0.580	0.030	2.770	2.630	0.080	61.220	61.360	0.510
Vogel et al., 2009 (3)	556.100	549.200	12.600	0.520	0.480	0.030	2.130	2.000	0.100	58.320	59.070	0.010
Winterholler et al., 2008 (1)	383.000	349.000	9.000	1.070	0.910	0.050	2.400	2.000	0.080	63.700	64.100	0.400
Winterholler et al., 2008 (2)	358.000	342.000	9.000	0.840	0.860	0.050	2.100	2.000	0.080	63.700	63.300	0.400
Winterholler et al., 2008 (3)	362.000	410.000	31.800	1.070	1.130	0.210	2.300	2.300	0.520	63.400	62.500	0.880
Winterholler et al., 2008 (4)	395.000	458.000	31.800	1.020	1.240	0.210	2.100	2.900	0.520	62.500	61.800	0.880
Winterholler et al., 2007	492.000	496.000	3.000	1.470	1.490	0.030	2.800	2.800	0.040	63.330	63.620	0.140
Walker et al., 2006 (1)	338.000	344.000	22.000	0.690	0.740	0.090	1.730	2.130	0.200	61.700	61.400	0.530
Waker et al., 2006 (2)	390.000	338.000	22.000	0.660	0.850	0.090	2.050	2.000	0.200	60.900	61.500	0.530
Walker et al., 2006 (3)	346.000	348.000	22.000	0.760	0.760	0.090	2.310	1.810	0.200	60.500	61.500	0.530
Woerner et al., 2011 (1)	438.000	429.000	10.500				3.210	3.210	0.042			
Woerner et al., 2011 (2)	418.000	404.000	10.500				3.140	3.030	0.042			

Author	Marbling score (300 to 500)			Fat thickness (cm)			Yield grade (scale 1 to 5)			Dressing (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Laudert et al., 2004 (1)	503.700	503.600	6.400	1.275	1.250	0.100	2.870	2.850	0.140	63.850	63.870	0.240
Laudert et al., 2004 (2)	503.700	501.000	6.400	1.275	1.275	0.100	2.870	2.840	0.140	63.850	64.080	0.240
Schroeder et al., 2003 (1)	532.900	528.200	18.200	1.425	1.400	0.125	3.320	3.240	0.170			
Schroeder et al., 2003 (2)	532.900	530.700	18.200	1.425	1.400	0.125	3.320	3.220	0.170			
Schroeder et al., 2003 (3)	532.900	524.500	18.200	1.425	1.400	0.125	3.320	3.180	0.170			
Schroeder et al., 2005 (1)				1.600	1.600	0.180	3.100	3.100	0.220	62.200	62.000	0.700
Schroeder et al., 2005 (2)				1.600	1.600	0.180	3.100	3.100	0.220	62.200	62.000	0.700
Schroeder et al., 2005 (3)				1.600	1.570	0.180	3.100	3.000	0.220	62.200	62.100	0.700
Jennings, 2011	425.200	407.200	7.750	1.450	1.350	0.050	3.040	2.860	0.080	62.390	62.690	0.002
Glanc, 2013 (1)	419.900	500.100	26.380									
Glanc, 2013 (2)	516.800	407.000	26.380									
Glanc, 2013 (3)	455.700	410.200	26.380									
Glanc, 2013 (4)	452.700	436.900	26.380									
Glanc, 2013 (5)	415.100	428.100	26.380									
Glanc, 2013 (6)	462.200	455.400	26.380									
Talton, 2006	425.600	433.800	28.600	1.500	1.570	0.100	3.480	3.460	0.170	61.800	63.000	0.140
Peterson, 2011	431.000	411.380	5.530	1.270	1.190	0.030	3.120	3.010	0.040	63.360	63.210	0.440
Schluter (1991) (1)				0.930	0.970	0.470	2.600	2.700	0.080	61.300	61.400	0.250
Schluter (1991) (2)				0.930	0.940	0.470	2.600	2.800	0.080	61.300	61.500	0.250
Schluter (1991) (3)				0.930	0.990	0.470	2.600	2.700	0.080	61.300	61.400	0.250
Strydom et al	220.800	34.433	9.940	1.420	1.270	0.142	3.270	2.920	0.220	59.600	59.400	0.291

Table 13d.
Lean and overall maturity and 'kidney, pelvic and heart' fat percentage in control and Ractopamine treated cattle

Author	Lean maturity score (0 to >200)			Overall maturity score (0 to >200)			Kidney, pelvic & heart fat (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Abney et al., 2007 (1)							1.820	1.880	0.050
Abney et al., 2007 (2)							1.820	1.830	0.050
Abney et al., 2007 (3)							1.850	1.840	0.050
Abney et al., 2007 (4)							1.850	1.760	0.050
Abney et al., 2007 (5)							1.750	1.850	0.050
Abney et al., 2007 (6)							1.750	1.850	0.050
Allen et al., 2009	386.000	408.000	28.000				2.300	2.400	0.400
Avendano-Reyes et al., 2006									
Bass et al., 2009 (1)	125.700	131.300					2.630	2.620	
Bass et al., 2009 (2)	143.000	144.600					2.660	2.690	
Bass et al., 2009 (3)	151.000	149.600					2.620	2.530	
Bass et al., 2009 (4)	132.100	130.600					2.710	2.610	
Boler et al., 2012 (1)							2.210	2.090	0.080
Boler et al., 2012 (2)							2.210	2.150	0.080
Bryant et al., 2010 (1)	168.800	168.600	1.210	159.700	159.300	1.590	2.250	2.210	0.028
Bryant et al., 2010 (2)	168.800	168.900	1.210	159.700	160.600	1.590	2.250	2.250	0.028
Bryant et al., 2010 (3)	160.000	161.700	2.290	163.300	163.800	2.030	2.300	2.270	0.068
Dijkhuis et al., 2008 (1)	423.300	437.700	14.790						
Dijkhuis et al., 2008 (2)	423.300	419.600	14.790						
Dijkhuis et al., 2008 (3)	423.300	407.600	15.130						
Griffin et al., 2009									

Author	Lean maturity score (0 to >200)			Overall maturity score (0 to >200)			Kidney, pelvic & heart fat (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Gruber et al., 2007	157.900	158.900	2.600	158.800	159.000	1.500	2.120	2.120	0.030
Holmer et al., 2009 (1)	457.000	307.000	28.100	502.000	437.000	21.400	0.550	0.970	0.071
Holmer et al., 2009 (1)	394.000	307.000	28.100	464.000	437.000	21.400	0.990	0.970	0.071
Quinn et al., 2008 Exp 1 (1)							2.240	2.230	0.030
Quinn et al., 2008 Exp 2 (2)							2.690	2.560	0.060
Quinn et al., 2008 Exp 2 (3)							2.690	2.570	0.060
Quinn et al., 2008 Exp 2 (4)							2.690	2.660	0.060
Sissom et al 2007 (1)							1.970	2.000	0.040
Sissom et al 2007 (2)							2.010	2.030	0.040
Sissom et al 2007 (3)							1.900	1.890	0.020
Sissom et al 2007 (4)							1.840	1.850	0.020
Sissom et al 2007 (5)							1.790	1.710	0.020
Scramlin et al., 2010	161.800	167.300	3.290	164.100	166.400	2.140	2.410	2.400	0.040
Vogel et al., 2009 (1)	151.300	149.400	6.300	160.600	159.900	1.800	2.300	2.330	0.080
Vogel et al., 2009 (2)	151.300	151.800	6.300	160.600	160.100	1.800	2.300	2.320	0.080
Vogel et al., 2009 (3)							2.330	2.430	0.090
Winterholler et al., 2008 (1)							2.060	2.020	0.100
Winterholler et al., 2008 (2)							2.050	1.980	0.100
Winterholler et al., 2008 (3)							2.250	2.000	0.230
Winterholler et al., 2008 (4)							2.080	2.080	0.230
Winterholler et al., 2007							1.970	1.970	0.010
Walker et al., 2006 (1)							2.150	2.130	0.060
Waker et al., 2006 (2)							1.960	2.170	0.060
Walker et al., 2006 (3)							2.170	1.920	0.060
Woerner et al., 2011 (1)							2.140	2.170	0.078

Author	Lean maturity score (0 to >200)			Overall maturity score (0 to >200)			Kidney, pelvic & heart fat (%)		
	Control	RAC	SEM	Control	RAC	SEM	Control	RAC	SEM
Woerner et al., 2011 (2)							2.130	2.100	0.078
Laudert et al., 2004 (1)	160.700	161.100	3.700	166.000	167.000	3.000	1.950	1.940	0.820
Laudert et al., 2004 (2)	160.700	161.000	3.700	166.000	167.000	3.000	1.950	1.940	0.820
Schroeder et al., 2003 (1)							1.830	1.830	0.130
Schroeder et al., 2003 (2)							1.830	1.860	0.130
Schroeder et al., 2003 (3)							1.830	1.770	0.130
Schroeder et al., 2005 (1)							2.290	2.320	0.200
Schroeder et al., 2005 (2)							2.290	2.250	0.200
Schroeder et al., 2005 (3)							2.290	2.310	0.200
Jennings, 2011							3.170	3.050	0.080
Glanc, 2013 (1)									
Glanc, 2013 (2)									
Glanc, 2013 (3)									
Glanc, 2013 (4)									
Glanc, 2013 (5)									
Glanc, 2013 (6)									
Talton, 2006	181.900	183.100	6.080	181.900	184.500	0.690	2.080	2.060	0.160
Peterson, 2011							1.960	1.950	0.040
Schluter (1991) (1)							2.200	2.300	0.060
Schluter (1991) (2)							2.200	2.200	0.060
Schluter (1991) (3)							2.200	2.200	0.060
Strydom et al							1.380	1.290	0.108

Table 14. Aging, selected muscle, cooking method, and Warner –Bratzler shear force and cooking loss

Author	Experimental unit	Age	Selected muscle	Cooking method	No of animals		No of pens		No of muscles		Warner –Bratzler shear force (kg)			Cooking loss (%)		
					Control	RAC	Control	RAC	Control	RAC	Control	RAC	SE	Control	RAC	SE
Allen et al., 2009	Animal				8	9					4.320	4.510	0.347			
Avendano-Reyes et al., 2006	Pen				6	6					4.397	4.833	0.136			
Boler et al., 2012	Strip loin		Strip loin	Farberware Open Hearth grill - 70oc	6	6					2.280	2.420	0.090			
Boler et al., 2012	Strip loin		Strip loin	Farberware Open Hearth grill - 70oc	6	6					2.280	2.470	0.090			
Dijkhuis et al., 2008	Animal	14	Longissimus thoracis (ribeye)		1	1					3.800	4.500	0.330			
Dijkhuis et al., 2008	Animal	14	Longissimus thoracis (ribeye)		1	1					3.800	4.600	0.370			
Dijkhuis et al., 2008	Animal	14	Longissimus thoracis (ribeye)		1	1					3.800	4.500	0.350			
Gruber et al., 2008	Pen		Longissimus muscle	Electronic conveyer	21	21					4.220	4.220	0.060			
Quinn et al., 2008	Pen	14	Loins	DFG 102 Blodgett Oven-70oC	22	22					4.600	4.600	0.500	25	25	14
Scramlin et al., 2010	Strip loin	3	Strip loin	Electric clam shell grill- 66oC	10	10					4.660	5.360	0.200			
Scramlin et al., 2010	Strip loin	7	Strip loin	Electric clam shell grill- 66oC	10	10					4.150	4.630	0.200			
Scramlin et al., 2010	Strip loin	14	Strip loin	Electric clam shell grill- 66oC	10	10					3.550	3.780	0.200			
Scramlin et al., 2010	Strip loin	21	Strip loin	Electric clam shell grill- 66oC	10	10					3.050	3.280	0.200			
Woerner et al., 2011	Animal		Strip loin (LM)	Belt gril	74	70					3.480	3.720	0.062			
Woerner et al., 2011	Animal		Strip loin (LM)	Belt gril	73	74					3.600	3.830	0.062			
Jennings, 2011	Pen		Strip loin	Magi Belt Grill- 68-71oC	9	9					5.650	5.620	0.200			
Jennings, 2011	Pen		Strip loin	Magi Belt Grill- 68-71oC	9	9					4.790	4.920	0.140			

Author	Experimental unit	Age	Selected muscle	Cooking method	No of animals		No of pens		No of muscles		Warner –Bratzler shear force (kg)			Cooking loss (%)		
					Control	RAC	Control	RAC	Control	RAC	Control	RAC	SE	Control	RAC	SE
Jennings, 2011	Pen		Strip loin	Magi Belt Grill- 68-71oC	9	9					3.670	4.120	0.120			
Jennings, 2011	Pen		Strip loin	Magi Belt Grill- 68-71oC	9	9					3.630	3.620	0.100			
Glanc, 2013	Animal	14	Longissimus muscle (LM)	Garland Grill-70oC	1	1					3.940	4.130	0.069	22.4	23	0.22
Talton, 2006	Animal		Strip loin	Cooked ar 71oC										20.3	19.8	0.41
Strydom et al	Animal		M semitendinosis	Oven broiled	12	12					4.600	5.000	0.109			

Table 15. List of studies that did not meet the selection criteria, insufficient data or data provided were not relevant to ractopamine evaluation: to be completed

Studies	Reasons for exclusion
Beerman 2002	Review
Eisemann and Bristol	Data were not relevant
Gonzales et al., 2007	Data were not relevant
Gonzales et al., 2008	Data were not relevant
Gonzales et al., 2009	Data were not relevant
Li and Jiang 2012	Topic not relevant
Paddock et al 2011	Topic not relevant
Shelver and Smith 2002	Data were not relevant

Studies identified and information extracted

A comprehensive literature search was conducted by SBScibus using a number of 5 search engines to identify relevant peer-reviewed papers, theses and proceedings that were published between 2000 and 2012. The quality of papers was evaluated and documented by the reviewers and was considered in the analysis (Tables 1 to 14)

A series of selection criteria were developed by SBScibus, and selected papers were reviewed by 2 reviewers. A total of 52 studies on ZH, published between 2000 and 2012, was identified. Of these, 32 papers (with 83 sub-trials or comparisons on different outcomes) met the selection criteria. The required data and information from those studies that met the inclusion criteria were extracted and were tabulated and presented in Tables 1 to 8. The data included information on animal performance, carcass characteristics and meat quality. A total of 21 studies were excluded for various reasons (Table 8).

Similar search, extraction and reporting methods to those used for ZH were used for RAC. A comprehensive literature search was conducted on RAC and a total of 31 papers have been identified with 68 sub-trials or comparisons on different outcomes Contact with workers in the field provided valuable detail on studies and allowed re-analysis of some data. Again, two reviewers assessed the data and data were extracted and validated by two workers.

Tables 1 to 14 show that there were insufficient studies that reported some variables for meta-analytical evaluation.

Zilpaterol results

The results of the number of studies analysed for estimation of SMD, raw mean differences for variables, SMD, weighted mean differences, I^2 estimated heterogeneity and results of meta-regressions evaluating the effects of ZH are provided in Table 16. The forest plots and funnel plots for each variable are presented in Appendix 1.1. Overall, there was little evidence of missing studies in the funnel plots, however, there was substantial evidence of small study effects with these studies sometimes having quite large effects that differed from the larger studies.

Figures Appendix 2.1.1 and 2.1.4 show the difference in SMD and raw mean difference for pen fed (1) and individually fed (0) studies for LMA and for marbling, respectively. Figure 2.1.2 shows the relationship between period of feeding of ZH and SMD for LMA. Figures 2.1.7a and band 2.1.8 show the difference in SMD and raw mean difference for pen fed (1) and individually fed (0) studies for WBSF and the effect of aging on WBSF, respectively.

Ractopamine results

The results of the number of studies analysed for estimation of SMD, raw mean differences for variables, SMD, weighted mean differences, I^2 estimated heterogeneity and results of meta-regressions evaluating the effects of RAC are provided in Table 17. The forest plots and funnel plots for each variable are presented in Appendix 1.2. Similarly to ZH, there was little evidence of missing studies in the funnel plots and consequent publication bias, however, there was substantial evidence of small study effects with these studies sometimes having quite large effects that differed from the larger studies.

Significant meta-regression effects were identified for the period of feeding for fat thickness, and for the status of control animals for lean maturity score and KPH. Figures in Appendix 2.21 to 2.23 show the significant meta-regressions.

Table 16. Effects of zilpaterol on feedlot performance and carcase characteristics.

Outcome	Number of studies (n)	Raw mean difference 95% CI	Effect Size and 95% CI	Weighted mean difference and 95% CI	I^2 estimated hetero-geneity	Significant meta-regression effects
Final Body weight (kg)	31	6.562 4.229 to 8.895	0.449 0.277 to 0.621	8.150 5.627 to 10.674	0.0	
Dry Matter Intake (kg/d)	26	-0.160 -0.243 to -0.077	-0.470 -0.676 to -0.264	-0.118 -0.167 to -0.070	0.0	
Average Daily Gain (kg/d)	29	0.210 0.141 to 0.278	0.884 0.656 to 1.113	0.153 0.111 to 0.194	29.1 (0.0)[1]	
Gain:feed (kg/kg ratio)	28	0.024 0.017 to 0.031	1.374 1.034 to 1.715	0.024 0.018 to 0.030	54.5	
Carcase Measures						
Hot Carcase Weight (kg)	35	15.383 12.937 to 17.829	1.323 1.034 to.1.611	15.179 13.615 to 16.743	55.9	
pH	5	0.022 -0.033 to 0.077	0.102 -0.411 to 0.616	-0.002 -0.017 to 0.013	0.0	NA
Longissimus muscle area (cm^2)	35	8.147 7.115 to 9.180	2.302 1.898 to 2.705	8.006 7.052 to 8.959	70.8	Unit (0.022) period (0.165) Multivariate[2]
Objective measurement of 'redness' (Colour)	18	0.012 -0.122 to 0.098	0.098 -0.174 to 0.371	0.031 -0.004 to 0.066	15.0	
Fat thickness at the 12th rib (cm)	35	-0.106 -0.139 to -0.073	-0.697 -0.940 to -0.453	-0.119 -0.158 to -0.080	47.8	Fat of control(0.120) and period (0.186) Multivariate[2]
Standardised USDA marbling score	34	-18.814 -26.855 to -10.774	-0.861 -1.100 to -0.621	-14.389 -18.115 to -10.663	37.3	Unit (0.030) period (0.050) Multivariate[2]
USDA Yield Grading.	24	-0.402 -0.477 to -0.326	-1.357 -1.726 to -0.988	-0.403 -0.483 to -0.323	61.9	
Dressing Percentage (%)	27	1.657 1.319 to 1.996	2.205 1.669 to 2.741	1.706 1.510 to 1.902	71.5	
Lean Maturity Score	25	2.814 -0.602 to 6.230	0.264 0.060 to 0.468	2.061 1.104 to 3.019	0.5	Days on Feed (0.054)
Bone Maturity Score	23	2.983 -4.132 to 10.099	0.168 -0.046 to 0.383	1.298 -0.121 to 2.718	0.0	
Kidney, pelvic and Heart fat%	32	-0.178 -0.151 to -0.044	-0.437 -0.660 to -0.214	-0.062 -0.095to -0.030	27.4	KPH of control (P =.057)
Warner-Bratzler Shear Force (kg)	47	1.022 0.854 to 1.191	1.212 1.024 to 1.401	0.840 0.720 to 0.960	61	Age (0.001) unit (0.001) multivariate[2]

CI – Confidence interval.
[1] Sensitivity with removal of Avendano-Reyes et al
NA – insufficient studies to attempt
[2] Higgins and Thompson (2004) method

Table 17. Effects of ractopamine on feedlot performance and carcase characteristics.

Outcome	Number of studies (n)	Raw mean difference 95% CI	Effect Size and 95% CI	Weighted mean difference and 95% CI	I^2 estimated hetero-geneity%	Significant meta-regression effects < 0.05 (P)
Final Body weight (kg)	44	6.476 3.200 to 9.752	0.397 0.238 to 0.557	7.568 5.584 to 9.553	50	Body weight of control (0.01)
Dry Matter Intake (kg/d)	48	0.027 -0.116 to 0.170	0.020 -0.122 to 0.161	-0.003 -0.089 to 0.082	26.0	
Average Daily Gain (kg/d)	49	0.244 0.150 to 0.337	0.76 0.564 to 0.957	0.193 0.149 to 0.237	54.4	Average Daily Gain control (0.035)
Gain:feed (kg/kg ratio)	41	0.019 0.012 to 0.026	0.772 0.583 to 0.961	0.018 0.014 to 0.022	47.8	
Carcase Measures						
Hot Carcase Weight (kg)	54	7.376 3.475 to 11.277	0.47 0.312 to 0.628	6.182 4.551 to 7.812	46.5	
pH	5	-0.027 -0.079 to 0.024	-0.326 -0.873 to 0.220	-0.006 -0.023 to 0.011	0.0	NA
Longissimus muscle area (cm^2)	60	2.43 1.497 to 3.363	0.391 0.198 to 0.584	1.545 0.931 to 2.160	67.1	
Fat thickness at the 12th rib (cm)	45	0.029 -0.026 to 0.084	0.005 -0.171 to 0.182	-0.003 -0.035 to 0.028	43.1	Day on feed (0.012) Decreases smd
Standardised USDA marbling score	53	-2.471 -10.216 to 5.274	-0.108 -0.213 to -0.002	-5.144 -9.615 to -0.674	0.8	
USDA Yield Grade.	52	-0.022 -0.100 to 0.056	-0.118 -0.221 to -0.014	-0.055 -0.088 to -0.022	0.0	Period of ractopamine use (0.022) increase
Dressing Percentage (%)	40	0.503 0.221 to 0.784	0.131 0.000 to 0.262	0.275 0.110 to 0.440	66 $(0)^2$	
Lean Maturity Score	13	-18.636 -53.395 to 16.122	0.017 -0.186 to 0.220	0.436 -2.949 to 3.821	0.0	
Bone Maturity	12	-8.39 -23.963 to 7.183	0.018 -0.189 to 0.226	1.298 0.011 to 2.584	0	
Kidney, pelvic and Heart fat	53	-0.006 0.040 to 0.027	-0.04 -0.143 to 0.064	-0.011 -0.032 to 0.010	0.0	Kph of control (0.06) decrease
Warner-Bratzler Shear Force	17	0.305 0.188 to 0.421	0.429 0.267 to 0.592	0.203 0.122 to 0.284	0	

CI – Confidence interval.
Estimated mean difference
NA – insufficient studies to attempt
Jenning et al and Vogel 3 dropped due to implausible standard errors

5 Discussion

Methods Used

The methods of meta-analysis used in this study have been described and published previously (Lean et al., 2009; Lean et al., 2012; Rabiee et al., 2012). A critical consideration in this study was to ensure that appropriate estimates of evaluative units (eg pen, animal or carcase) were used for the analyses and that the estimates of standard deviation were also appropriate. Our decisions were influenced by advice received on design and analysis of pen studies (Tempelman 2009, Tempelman, pers com 2013). The advice received indicated that the analyses using SAS would report standard errors of the difference that were appropriate to providing estimates of standard deviation. Studies that did not clearly provide the unit of analysis were evaluated at the highest level of unit identified, ie pen. This may provide a conservative bias in the analysis. Similarly, only random effects models were used, a decision consistent with White and Thomas (2005) who concluded that it was appropriate to use these models when there was uncertainty in the evaluative units caused by clustering of observations.

The effect of reported and assessed evaluative unit was examined by testing of this in meta-regression. Only three outcomes, indicated that the evaluative unit significantly influenced the results of meta-regression, LMA, marbling and WBSF for ZH studies (Table 16). However, in all cases the raw mean difference, an unweighted measure, differed for the outcomes for the pen and individual animal studies, suggesting that there may be a biological reason the differences in effect. In all cases, also, the expected effect of ZH, i.e. increased LMA, lower marbling and increased WBSF was accentuated in the group fed animals. The lack of other significant findings in regard to unit of evaluation in the study overall suggest the possibility that whether cattle had access to individual feeders or were fed in pens influenced the LMA, marbling and WBSF for ZH treated cattle. We conclude that the evaluative units were probably correctly identified and, consequently, had little influence on results.

Zilpaterol discussion

The feedlot responses were significant and positive for the effects of ZH on final body weight and ADG, while DMI was significantly lower as was gain:feed in the studies. The results were relatively homogenous (I^2 <35), with the exception of the gain to feed, which had an I^2 of 54.5. The funnel plots for the feedlot variables did not indicate missing studies, with the possible exception of gain:feed (Figure Appendix 1.17). The SMD for these variables approached or exceeded 0.5 standard deviations and gain:feed was notable with an increased SMD of 1.4 standard deviations. These results are consistent with a number of the individual trials that are presented in Table 1 to 7 and presented in the forest plots in the Appendix Figures 1.11, 1.13. 1.15 and 1.17).

The effects of ZH on carcase data were also largely significant, with the exception of pH and colour and, in some cases, the effects were very substantial. The effect of ZH on the SMD for HCW, marbling, yield grade and dressing percentage all exceeded 1 standard deviation (Table 16 Figure Appendix 1.1). Of these, HCW, LMA and dressing percentage were positive for ZH use, but yield grade was not. The latter likely reflected the quite large negative effects on marbling (SMD = -.869), fat thickness (SMD = -0.712) and KPH percentage (SMD = -0.667), because yield grade is most influenced by thickness of fat, LMA and KPH (Table 1). The difference in effect of ZH treatment on HCW is nearly double the effect on final body weight, whether evaluated as SMD or WMD indicating a substantial partitioning of nutrients to muscle. Delmore et al., (2010) in a qualitative review of the effects of ZH, similarly noted the more marked effect of ZH on HCW than on body weight.

There was evidence of moderate to marked heterogeneity of results with HCW, LMA, fat thickness, marbling, yield grade, dressing percentage and KPH all having I^2 greater than 35 and most > 50 (Table 16). Investigation of the sources of this heterogeneity using meta-regression identified that significant heterogeneity in LMA was attributable to the period of feeding of ZH, further emphasising the causal basis of the effect. However, the unit of evaluation, in this case animal or pen indicated that the SMD of LMA was greater in the pen fed studies. This difference was evident in the raw, unweighted data, showing that the effect was not mediated through a difference in weighting of studies. It is therefore likely that this result and that for marbling in which the unit of measure was also a significant covariate and that similarly had a difference between pen and animal studies in the raw means reflect differences in expression of effect of ZH between pen fed animals and individually fed animals. The period of feeding of ZH was significant in increasing LMA and approached significance in reducing marbling, again indicating the biological significance of treatment. It is possible that the sensitivity to the ZH is increased under the more possibly stressful group fed conditions in which epinephrine levels may be higher. The plasma non-esterified fatty acid responses of cattle to under epinephrine stimulation increase with increased β-AA intake (Pethick et al., 2005).

The effect of ZH on WBSF was large being increased by SMD 1.2 and with a raw mean difference increase of more than 0.8 kg in WBSF. The result was influenced by aging of muscles which reduced the effect size of studies (Figure 2.1.9) and by the type of study design, whether the study was conducted at the animal level or the pen level. The implications drawn about the unit of evaluation for LMA and marbling are not as clear for WBSF, because animal was used as the unit of evaluation in some studies when animal or carcase was randomly selected within a group of cattle fed in pens. However, all studies were in the same direction, indicating an increase in WBSF. The heterogeneity identified, however, is only in degree of increase of WBSF, reflecting quite substantial differences in study design among the studies displayed in Figure 1.41.

Ractopamine

Feedlot performance

The final carcass weight data show that RAC significantly increased the weight of the cattle at slaughter (Table 17). A number of the studies were individually significant including the early studies of Schluter (1991). Similarly Avendano-Reyes et al., (2006), Walker et al 2006 and others found significant increases in weight for cattle at slaughter. One study excluded from further analysis (Winterholler et al 2008 Study 1) showed a marked and aberrantly large difference in effect and the responses without this study are summarised in Figure 2.11. There was a notable relative absence of studies that were negative for overall weight gain and the funnel plot indicated little evidence of missing studies (Figure 2.12), but results were heterogenous I^2 50% (Table 17, Figure 2.11). These findings are consistent with proposed actions of RAC in increasing weight gain of cattle. There were no significant covariates that influenced the response out of those studied.

This increase in weight gain was not mediated through increased DMI. The point direction was very close to a zero effect and the overall data showed a marked variation around the mean with some individual studies showing, significant increases or significant decrease in DMI. There was no evidence in this case of missing data from the funnel plot and none of the covariates were significant in explaining the effects of the DMI. Unsurprisingly, average daily gain during the period of feeding was significantly increased (Table 17) and the estimated effect size was quite large (0.77). Clearly the increase in ADG during the period of supplementation was substantial, however, some caution should be expressed in regard to this result as there is some evidence of missing data on the funnel plot (Figure 2.16). It appears that small negative studies may not be present in this particular data set. The covariates examined did not explain any of the variation in effect size. The gain:feed was significantly improved and quite similar in effect size to the response in regard to the ADG. This is unsurprising given the lack of significant increase in DMI observed. It clearly indicates that there are efficiency gains with treatment and the funnel plot was quite symmetric. It is possible, therefore that the funnel plots in the ADG data may be an artefact, reflecting the large number of investigations, of funnel plots in this study. Again none of the sources of variation investigated by meta-regression significantly influenced the gain to feed efficiency.

Carcase studies for ractopamine

The HCW was increased by supplementation and results were heterogeneous, but the I^2 was less than 50 (Table 17), indicating only moderate variation among study responses. Again with the HCW there is some possible evidence of a loss of small negative studies, but this should be viewed with caution as there are 4 studies with very large effect sizes, but very small numbers of pens. The increase in HCW had some covariates that approached significance, but when examined multivariate analysis none of these were significant ($P > .125$) and the most notable covariate that appeared to influence response was the HCW of the control.

The pH data were sparse and not significant. Evidence of repartitioning of nutrients was present in the carcase data. The SMD for LMA and dressing percentage was higher for the treated cattle and the SMD for marbling was significantly lower for the RAC treated cattle, as was the yield grade. These findings are consistent with the physiological action of RAC. These results, in combination indicate that the response was to increase muscle, as indicated by increased LMA and HCW, but to decrease lipid as indicated by the marbling scores, yield grade and KPH. The WBSF was also significantly increased by treatment. The carcase data were less heterogenous than the feedlot data with only the HCW and LMA I^2 approaching or exceeding 50, respectively.

The largest effect sizes for RAC treatment were for the ADG and Gain:feed, HCW and WBSF (Table 17). Meta-regression showed that conditions of the control at onset of study may have some effect on response for the lean maturity and KPH responses. Days on feed decreased the SMD for fat thickness at the 12^{th} rib and period of feeding of RAC increased the SMD for yield grade.

6 Conclusions

More than 30 papers were identified for both ZH and RAC and these contained more than 50 trial comparisons each. Data were extracted from more than 50 comparisons for both agents and analysed using meta-analysis and meta-regression. The SMD and WMD estimates of effect are more precise and robust than achieved by any single study of the effect of the β-AA on feedlot production and carcase quality.

Both agents markedly increased ADG, resulting in a higher final weight before slaughter for treated cattle and heavier HCW, dressing percentage and LMA. In particular, ZH dramatically increased outcomes in some cases by more than 2 standardised mean differences (SMD). The β-AA increased the efficiency of beef production, in that ZH and RAC increased ADG and did so without increasing DMI. In the case of ZH, DMI was lower in treated cattle by a standardised mean difference of 0.470.

For ZH the fat thickness, marbling and kidney, pelvic and heart fat percentage and USDSA yield grade were decreased by treatment. These effects were also large (approaching or exceeding a standardised mean difference (SMD) of 0.8) and marbling was markedly reduced. In general, the effects of RAC were similar, but less pronounced than ZH on feedlot efficiency. The effect of RAC treatment was not significant on fat thickness, marbling or kidney, pelvic and heart fat percentage. However, USDA yield grade was significantly decreased.

Treatment with ZH markedly increased WBSF by 1.2 standard deviations and more than 0.8 kg, while RAC increased WBSF by 0.43 standard deviations and 0.3 kg. In the case of ZH, the results were influenced by the unit of evaluation, ie pen or animal, cases and muscle. Reasons for this are not entirely clear, but significant differences existed in the raw means of the groups defined by unit of evaluation. These findings were consistent with similar observations of the effect of unit of evaluation for ZH studies on LMA and marbling. In all cases (MLA, marbling and WBSF), the pen studies showed a more pronounced effect of treatment than individual studies and the similarly observed effects in unweighted evaluations of the raw means of the effects suggest a biological, rather than statistical methods basis for the observation. These effects were not observed for the RAC trials. The ZH results for WBSF were also influenced by the aging of the muscles post-mortem. Increased aging reduced the effect size of the increase in WBSF. All ZH trials showed an increase in WBSF.This observation is consistent with part of the response to ZH being through lower protein degradation in the live animal which results in lower ageing in the muscles. As the muscles are aged for greater time the ZH effect becomes smaller.

These findings support the previously identified physiological roles of the β-AA and provide a strong evidence for producers and others to examine and consider the effects of ZH and RAC on beef cattle production. A large number of reviews and basic physiological studies have not clearly identified the mechanisms by which the actions of the specific β-AA are exerted (Beerman 2002; Dunshea et al., 2005; Mersmann 1998), however, this study clearly demonstrates that the repartitioning effects are rapid, marked and highly integrated.

Once these results have been critically reviewed by others, they can be immediately applied and used to formulate strategies to make best use of agents that markedly improve the efficiency of production. The adoption of these technologies will necessarily involve a consideration of the benefits in production costs and associated environmental benefits of improved efficiencies of resource use against the effects on meat tenderness.

This work has provided critically needed information on the effects of ZH and RAC on production, efficiency and meat quality. We were able meet our goals in providing more precise and robust estimates of the effects of the β-AA on efficiency of production and carcase quality measures. We identified using meta-regression that the method of feeding cattle may influence responses to ZH and identified that aging of steaks can reduce the effects of ZH on WBSF.

Acknowledgments

We are particularly grateful to Professor Mike Gaylean for provision of raw data. We also sincerely thank Professor Robert Tempelman for discussions on the unit of interest and study design.

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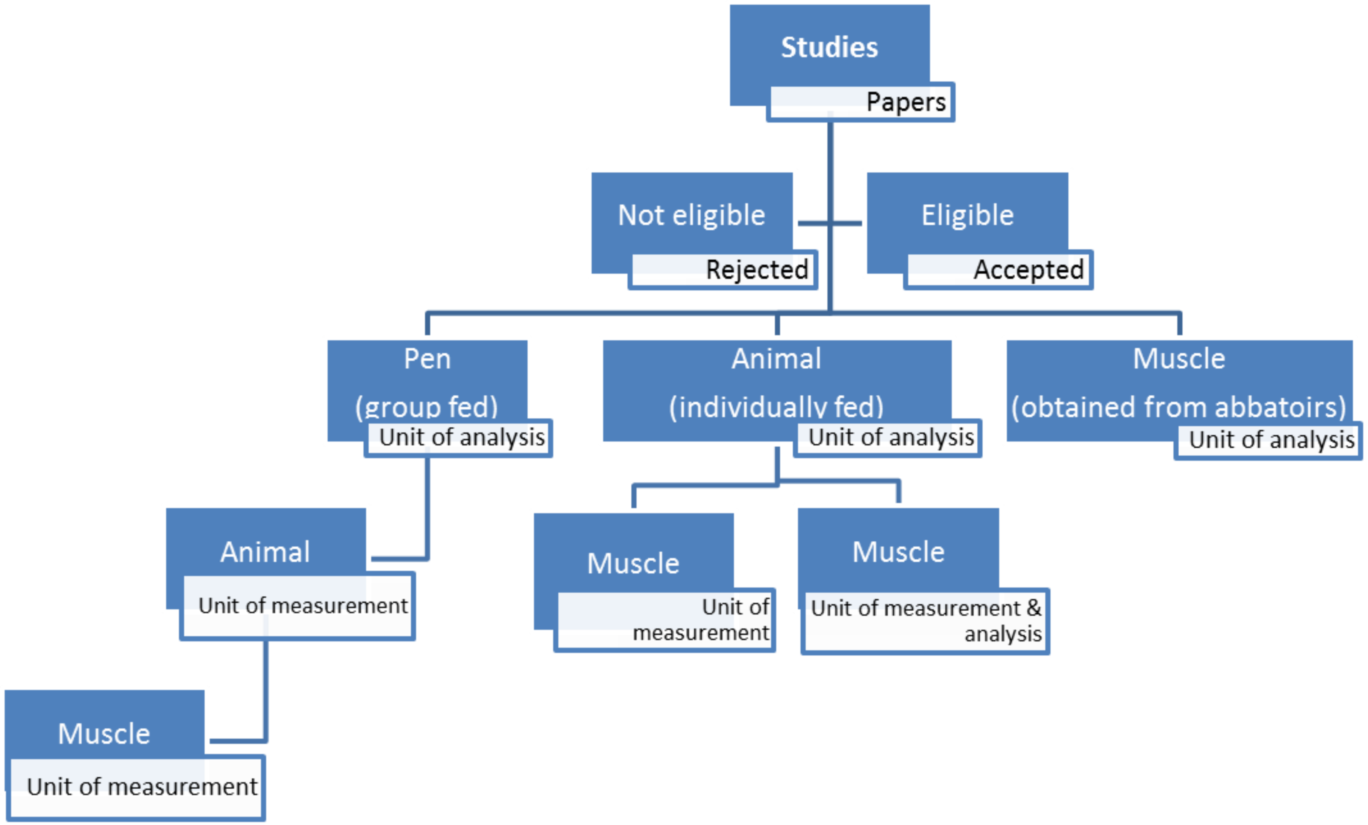
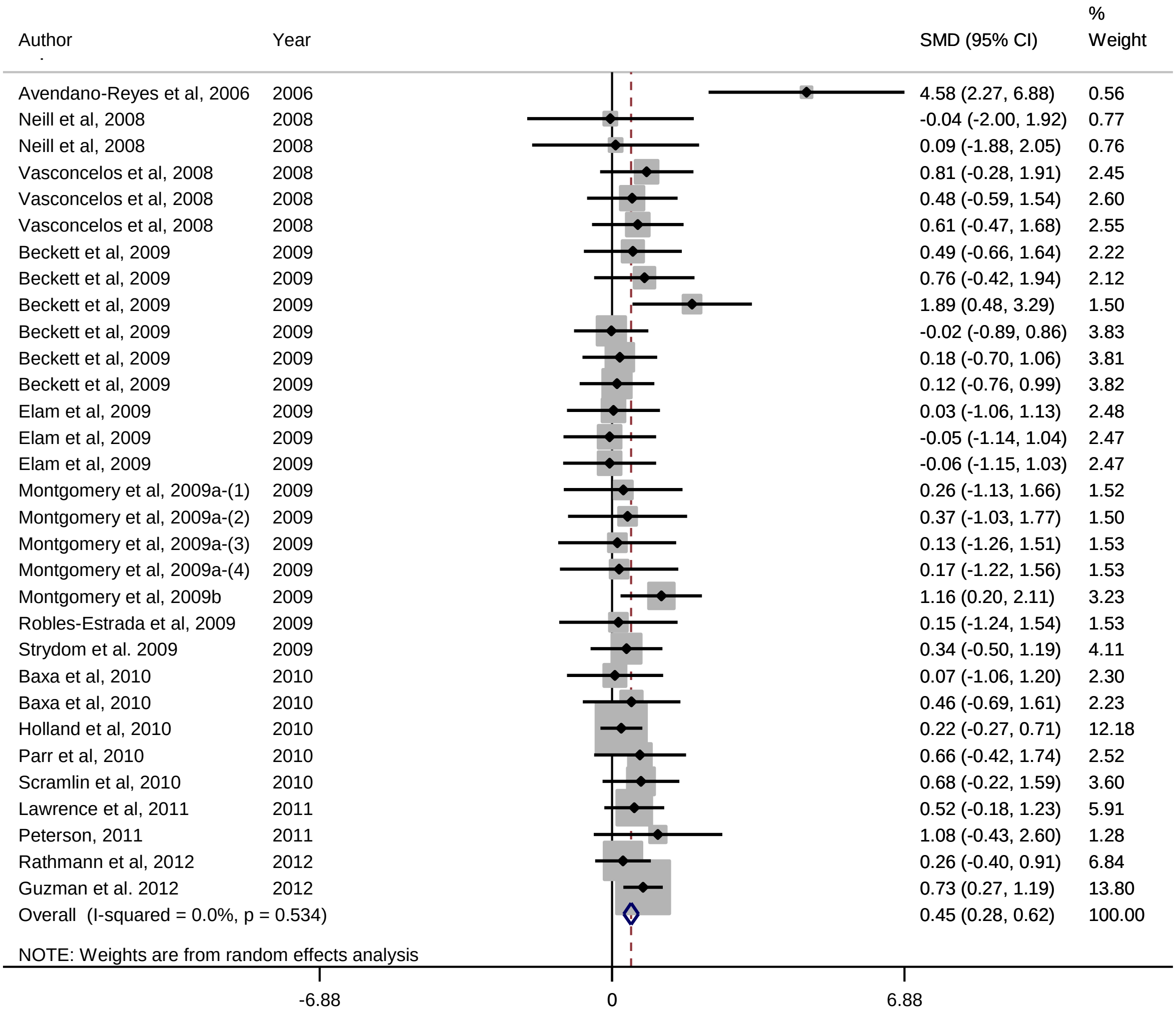


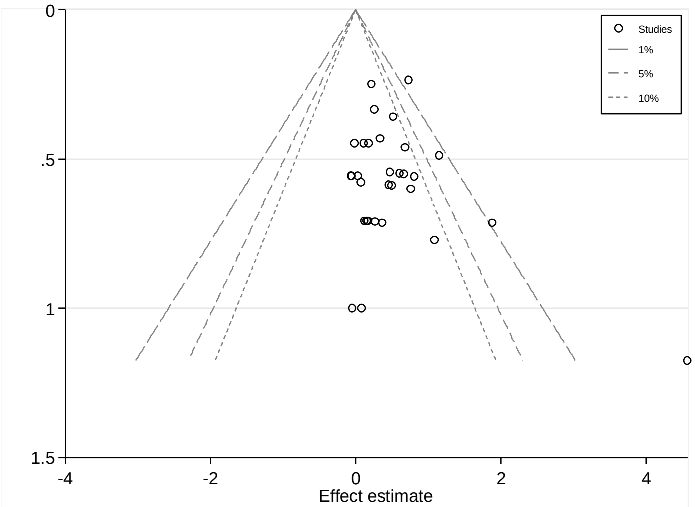
Figure 1. Flow chart of studies assessed for the effects of β-adrenergic against on cattle performance and carcass characteristics. The papers reviewed for the study differed in design, unit of measures and analysis.

8 Appendices

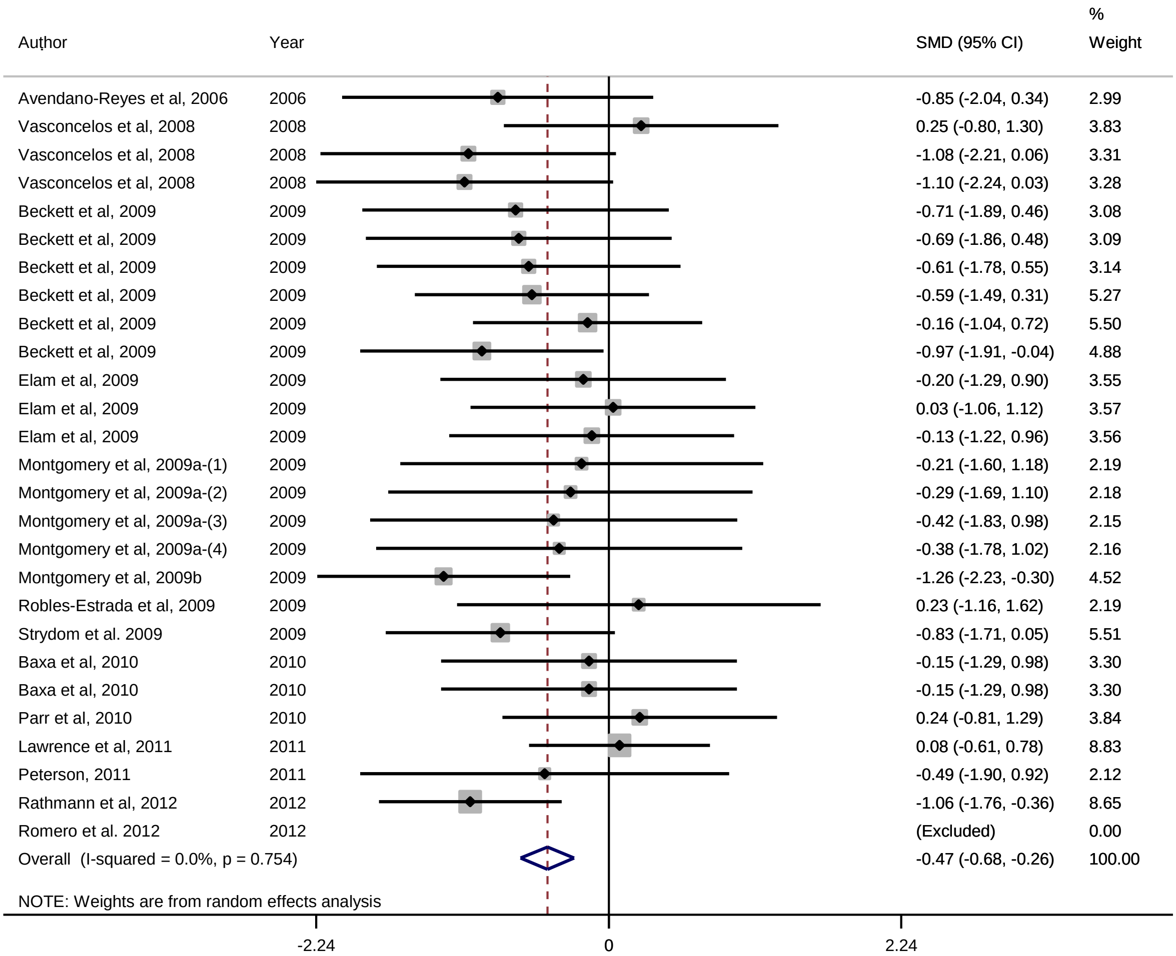
Appendix 1.11. Forest plot of body weight responses for Zilpaterol studies



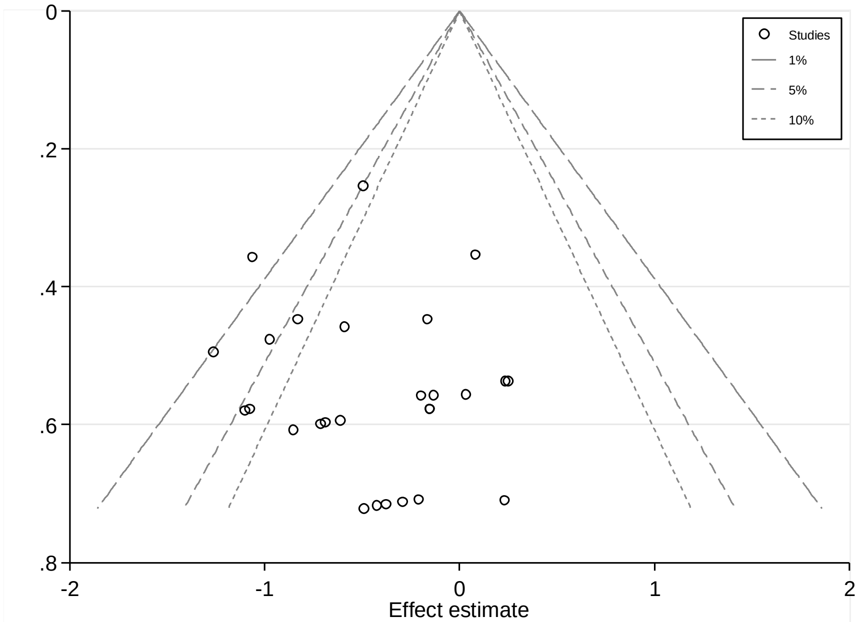
Appendix 1.12. Funnel plot of body weight responses for Zilpaterol studies



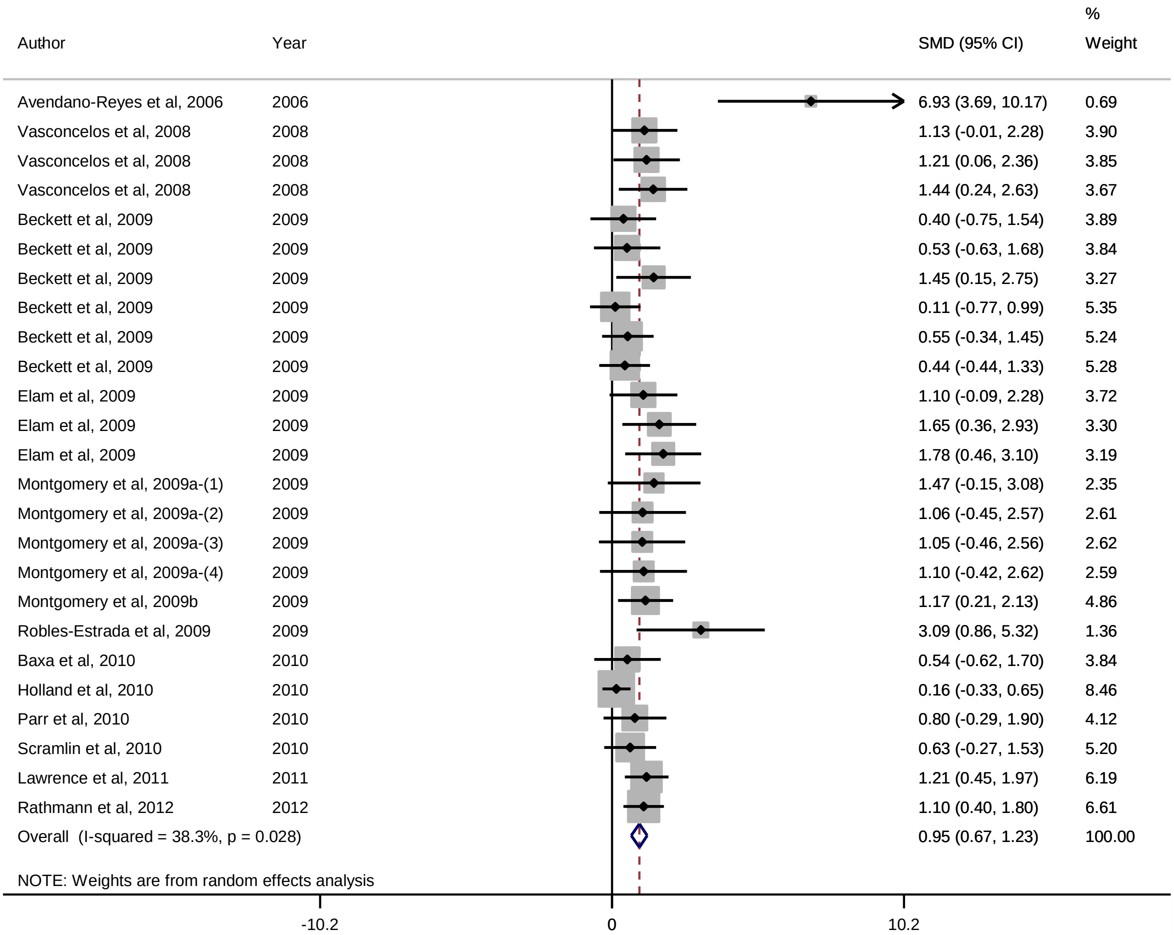
Appendix 1.13. Forest plot of Dry Matter Intake (kg/d) responses for Zilpaterol studies



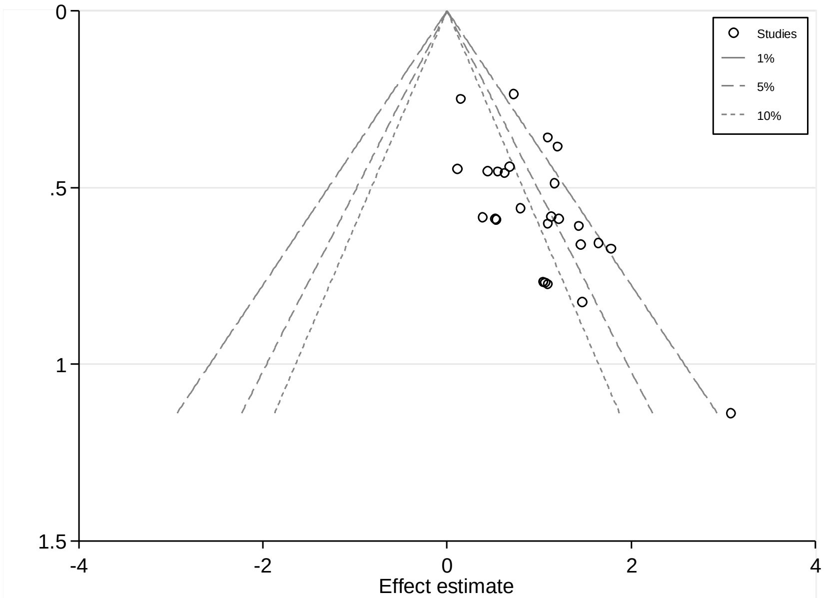
Appendix 1.14. Funnel plot of Dry Matter Intake (kg/d) responses for Zilpaterol studies



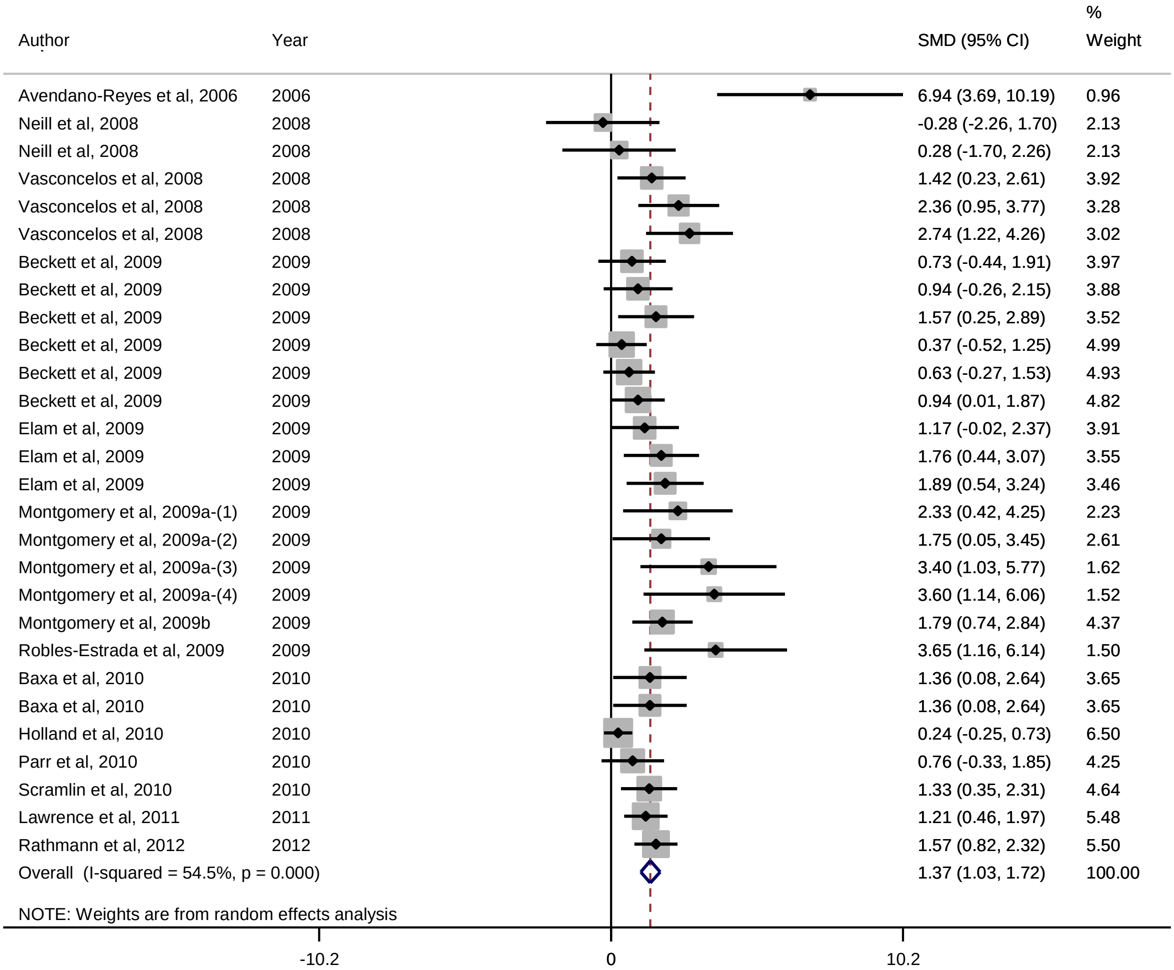
Appendix 1.15. Forest plot of Average Daily Gain (kg/d) responses for Zilpaterol studies



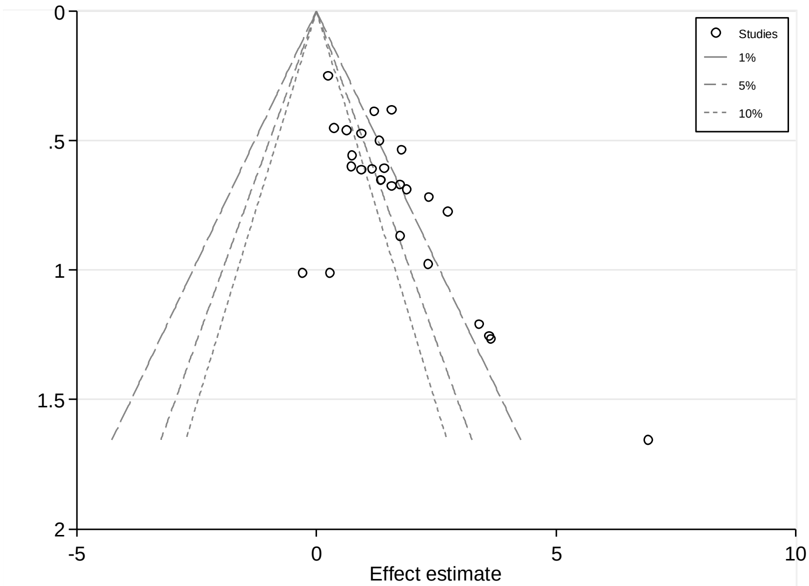
Appendix 1.16. Funnel plot of Average Daily Gain (kg/d) responses for Zilpaterol studies



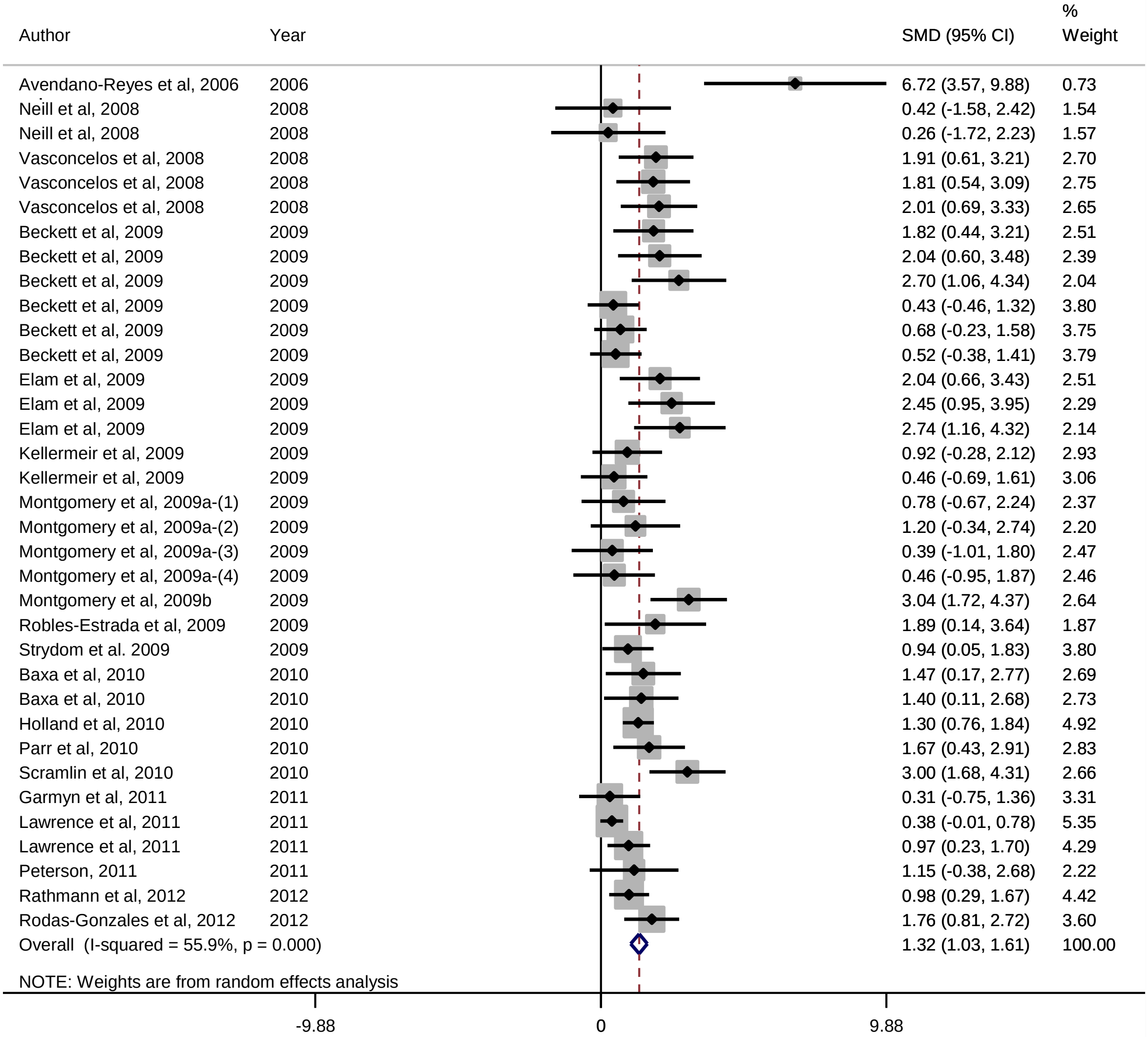
Appendix 1.17. Forest plot of Gain:feed (kg/kg ratio) responses for Zilpaterol studies



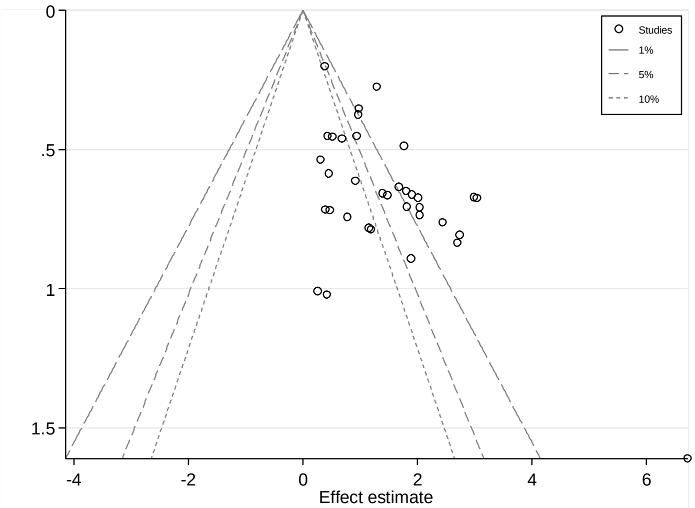
Appendix 1.18. Funnel plot of Gain:feed (kg/kg ratio) responses for Zilpaterol studies



Appendix 1.19. Forest plot of Hot Carcase Weight responses for Zilpaterol studies

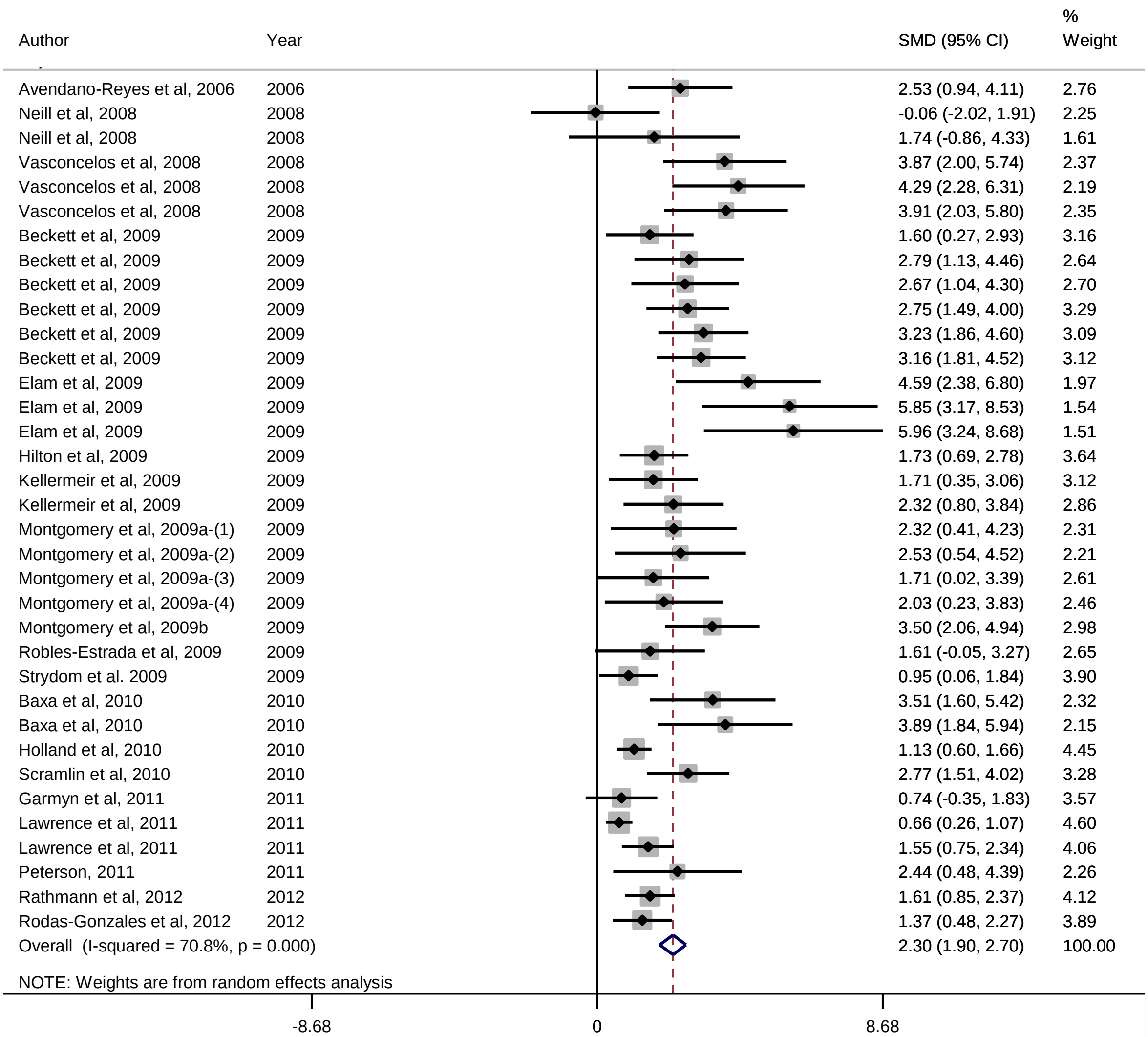


Appendix 1.20. Funnel plot of Hot Carcase Weight responses for Zilpaterol studies.

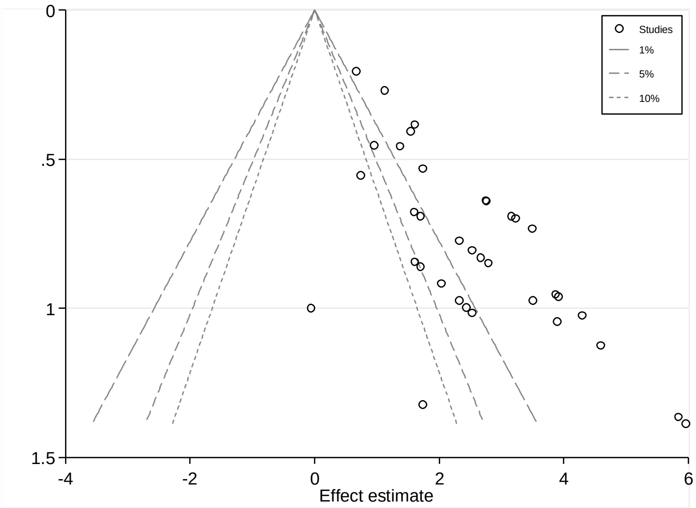


Appendix 1.21. Forest plot of PH responses for Zilpaterol studies. NA
Appendix 1.22. Funnel plot of PH responses for Zilpaterol studies. NA

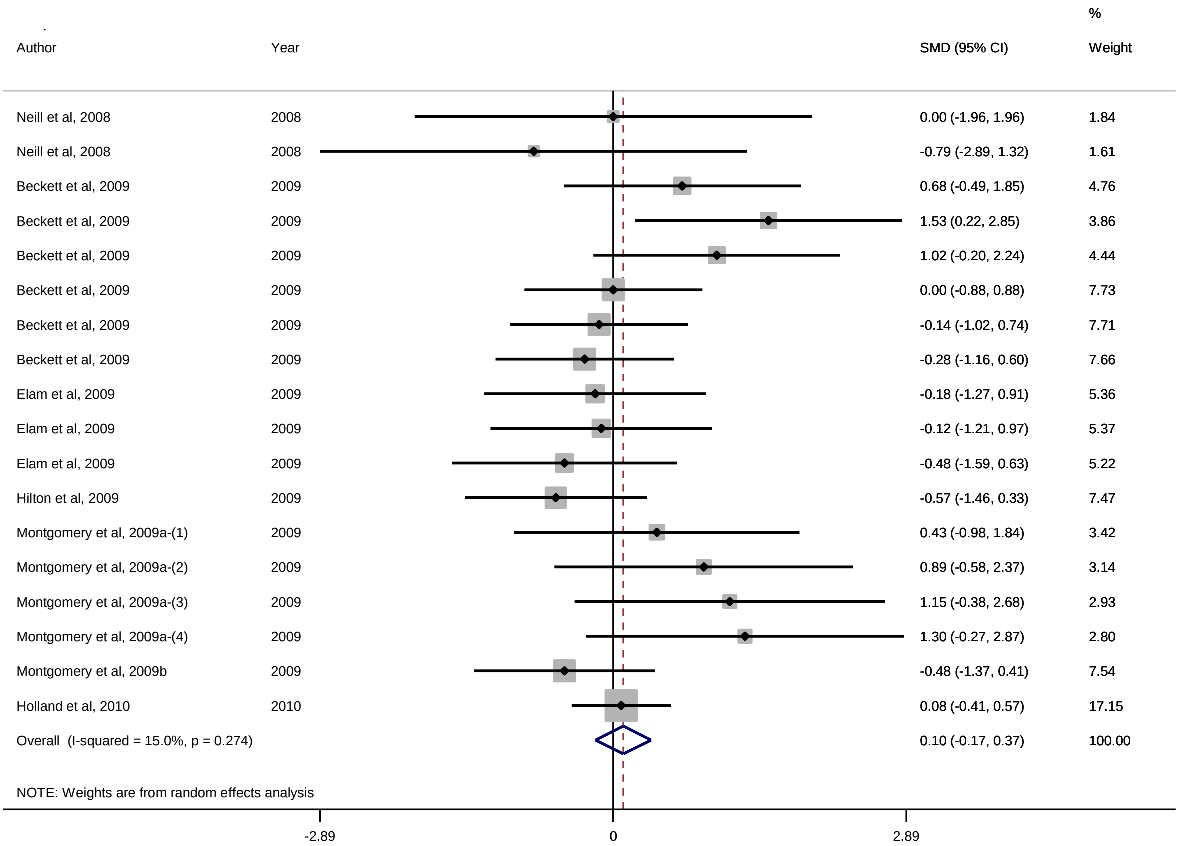
Appendix 1.23. Forest plot of Longissimus muscle area (cm2) responses for Zilpaterol studies



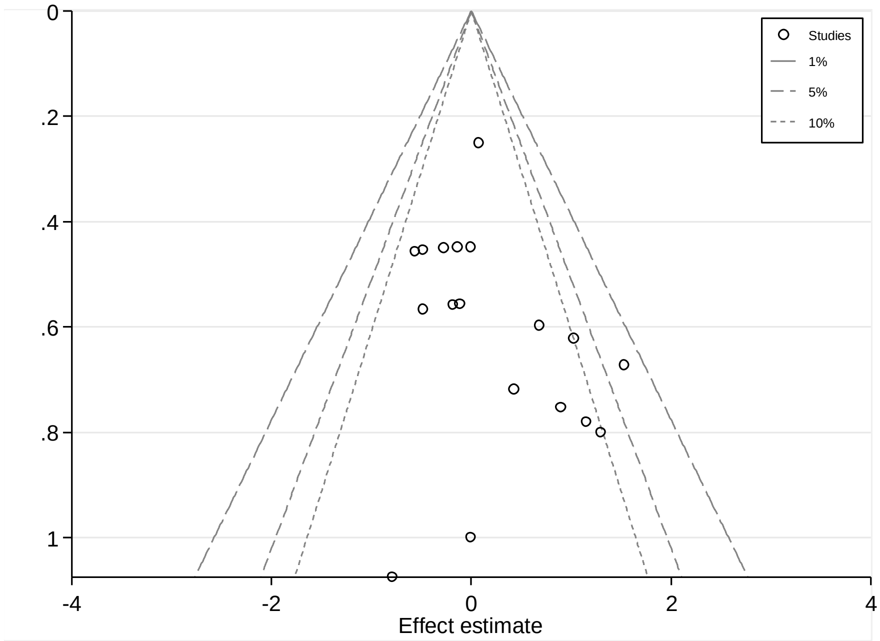
Appendix 1.24. Funnel plot of Longissimus muscle area (cm2) responses for Zilpaterol studies



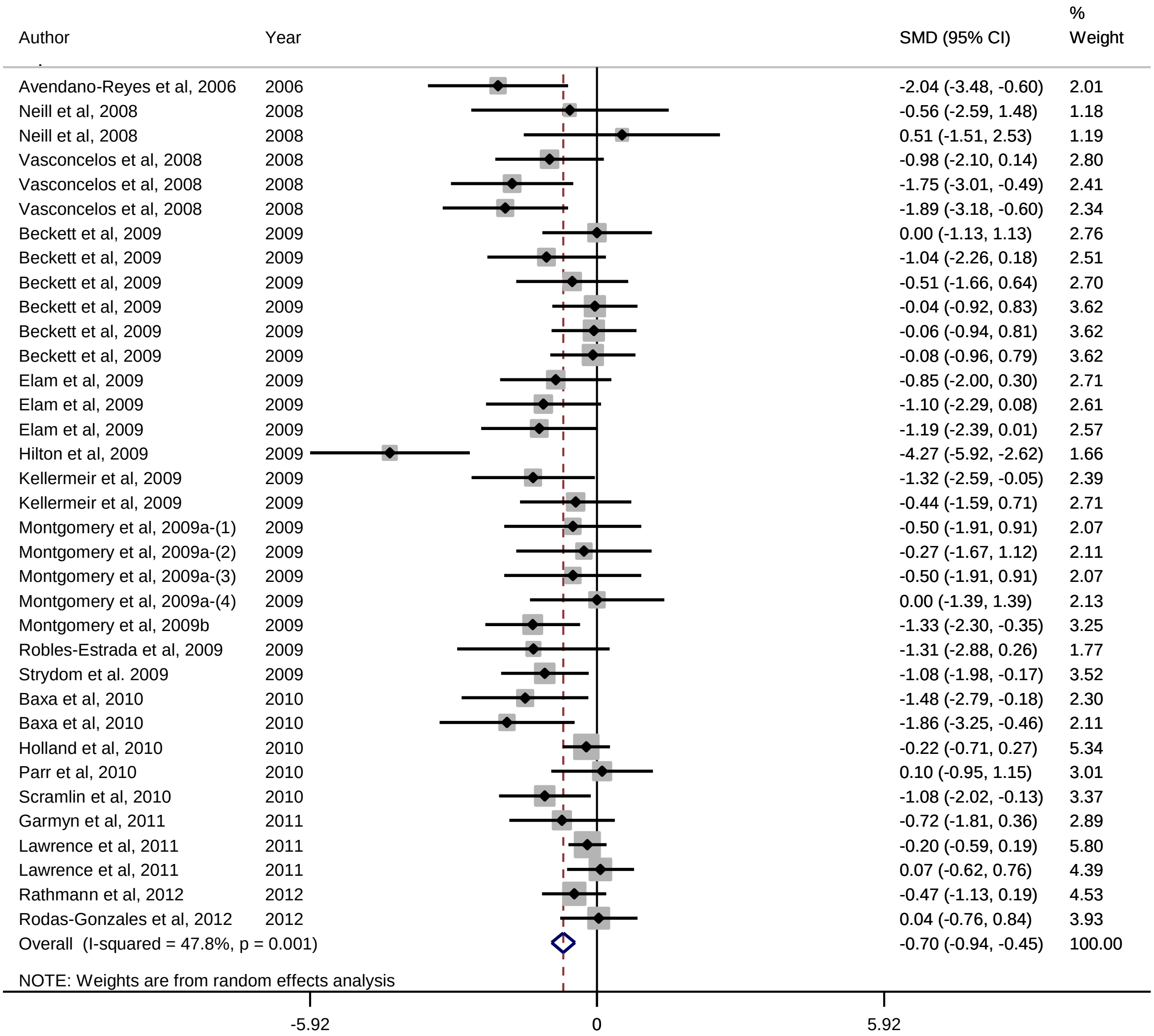
Appendix 1.25. Forest plot of objective measurement of 'redness' (Colour) responses for Zilpaterol studies



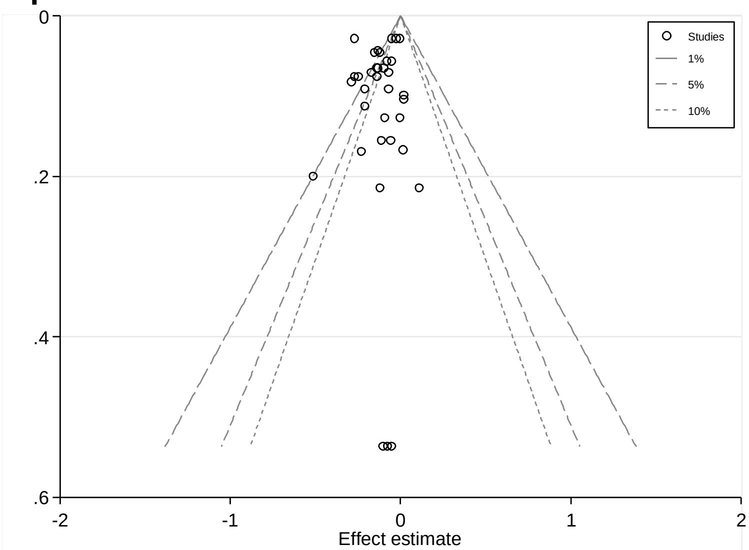
Appendix 1.26. Funnel plot of objective measurement of 'redness' (Colour) responses for Zilpaterol studies



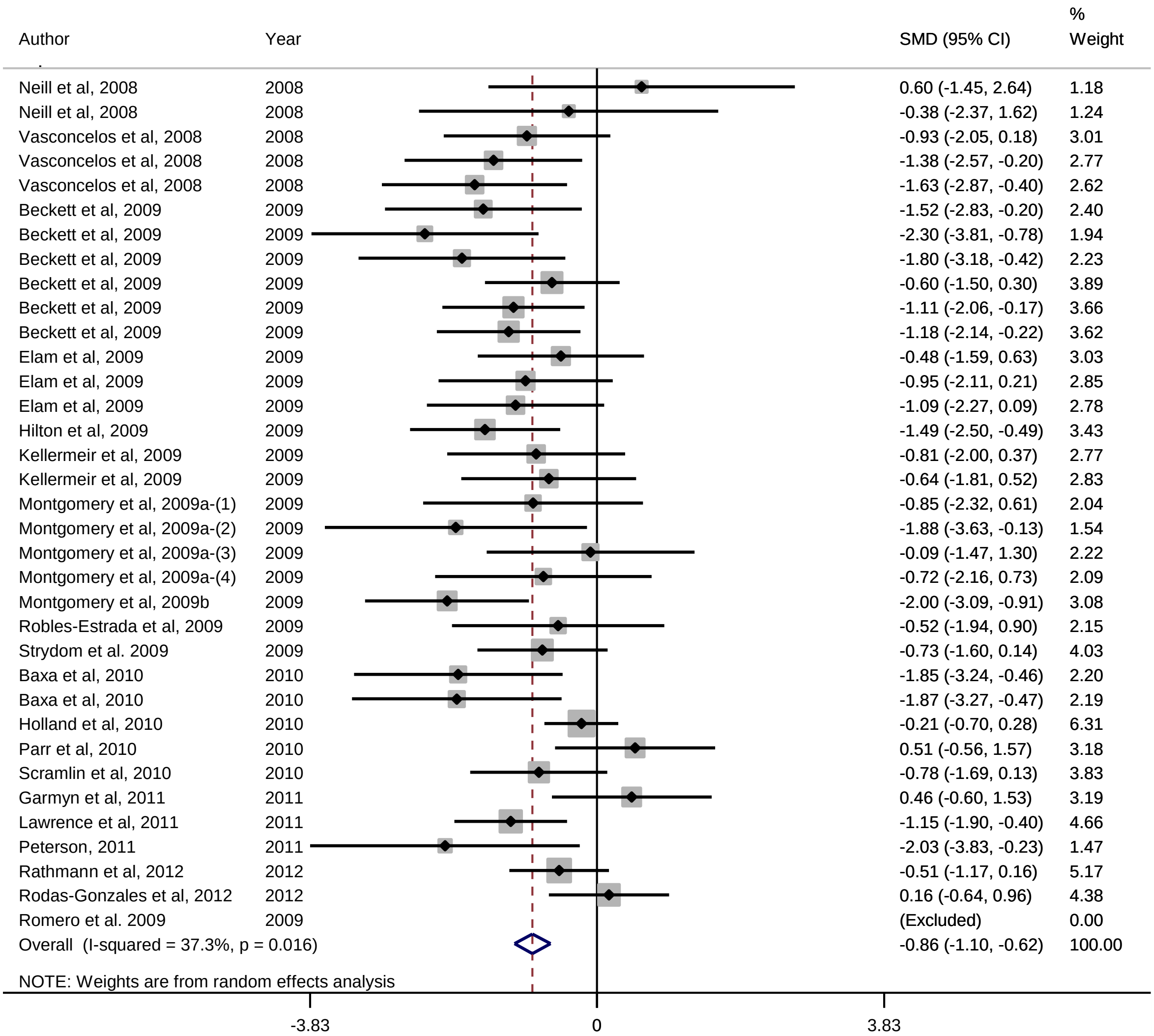
Appendix 1.27. Forest plot of Fat thickness at the 12th rib (cm) responses for Zilpaterol studies



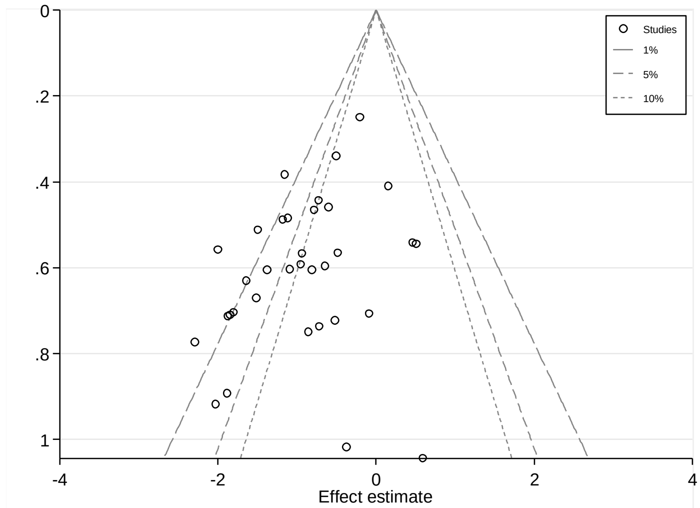
Appendix 1.28. Funnel plot of Fat thickness at the 12th rib (cm) responses for Zilpaterol studies



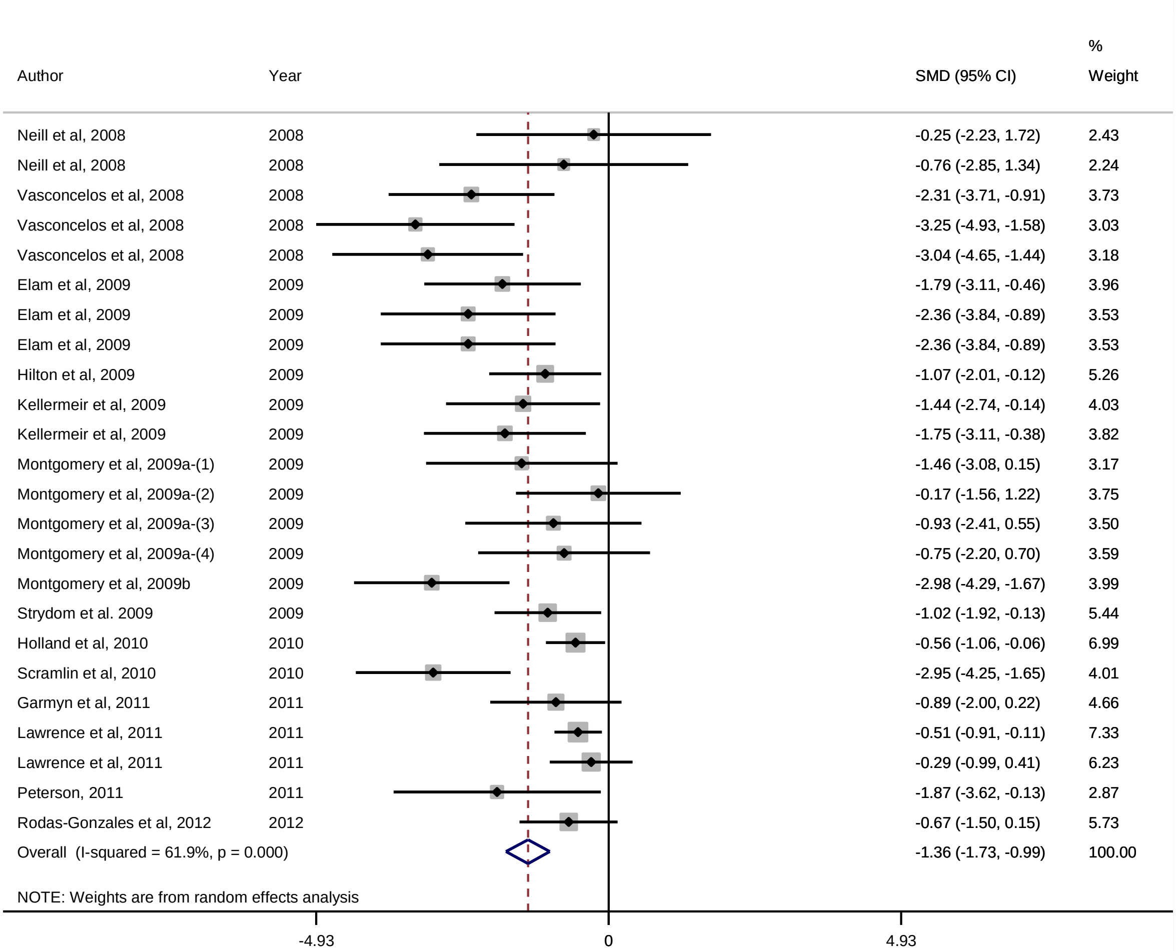
Appendix 1.29. Forest plot of Standardised USDA marbling score responses for Zilpaterol studies



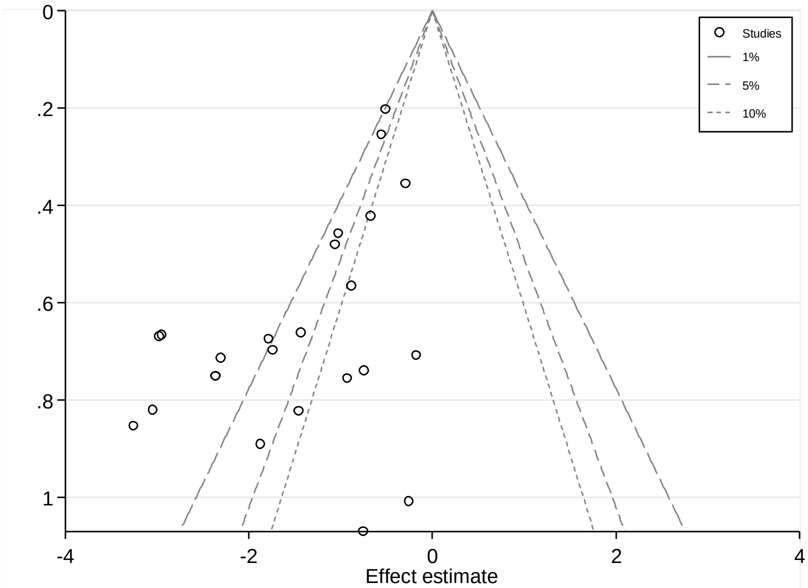
Appendix 1.30. Funnel plot of Standardised USDA marbling score responses for Zilpaterol studies



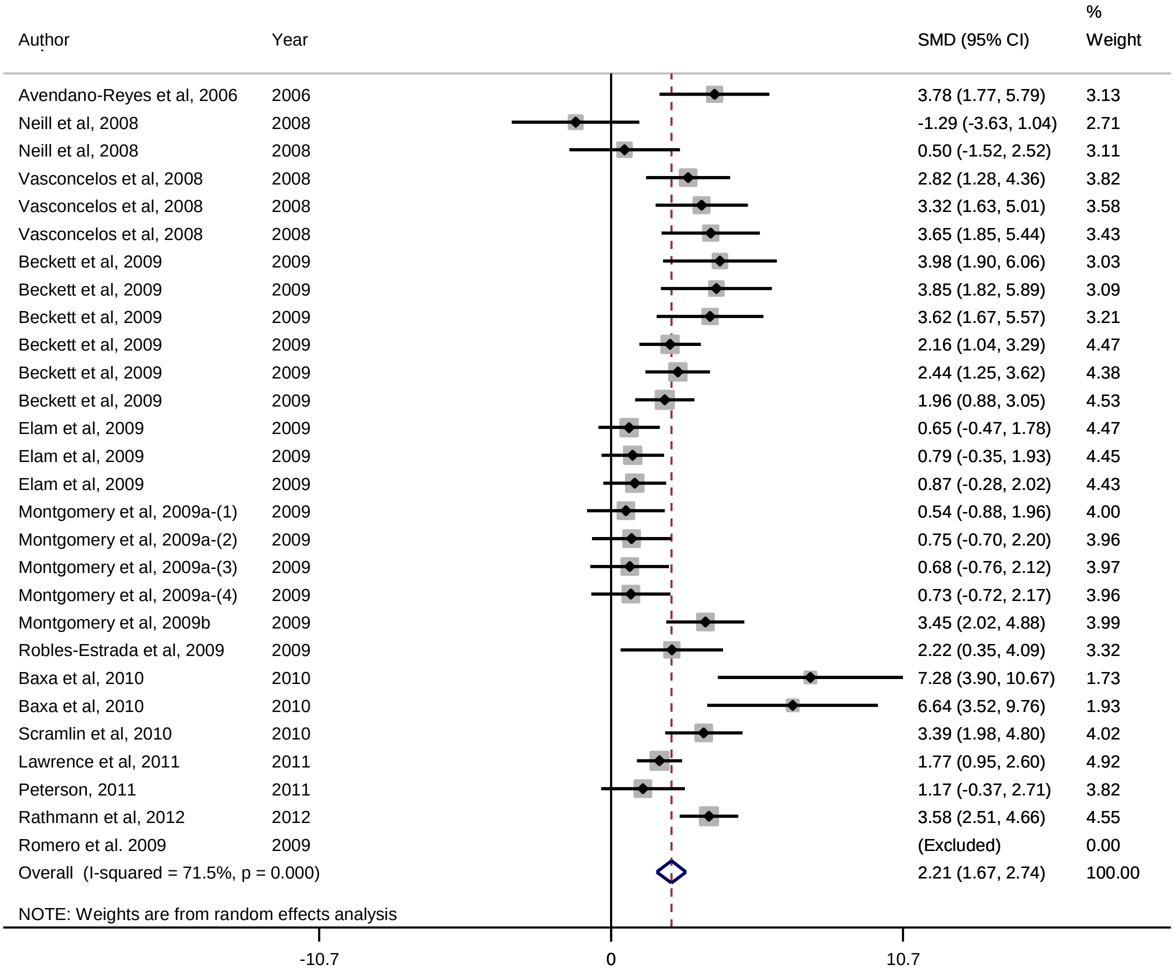
Appendix 1.31. Forest plot of USDA Yield Grading responses for Zilpaterol studies



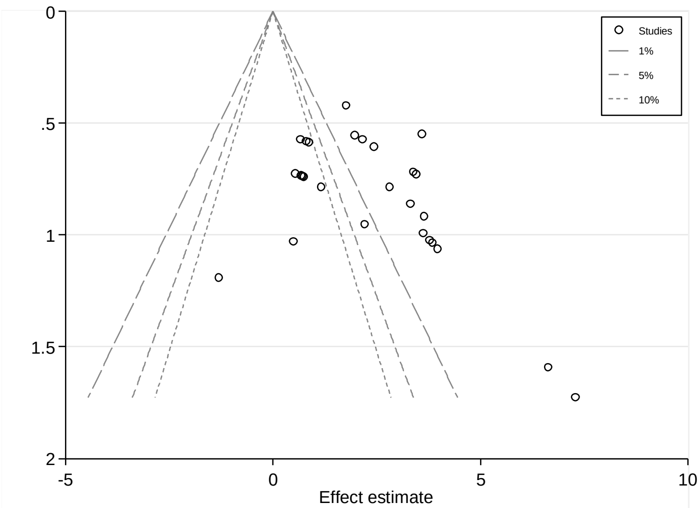
Appendix 1.32. Funnel plot of USDA Yield Grading responses for Zilpaterol studies



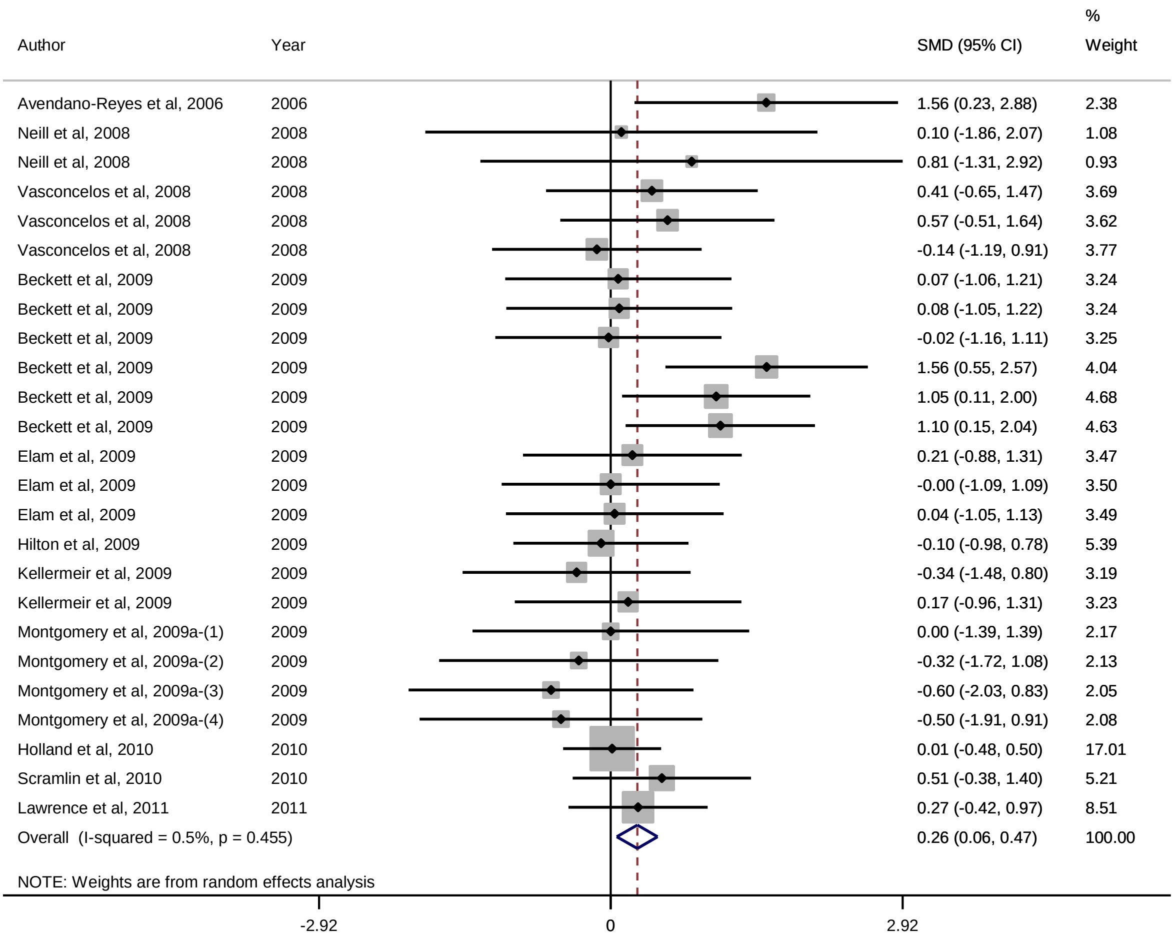
Appendix 1.33. Forest plot of Dressing Percentage (%).responses for Zilpaterol studies



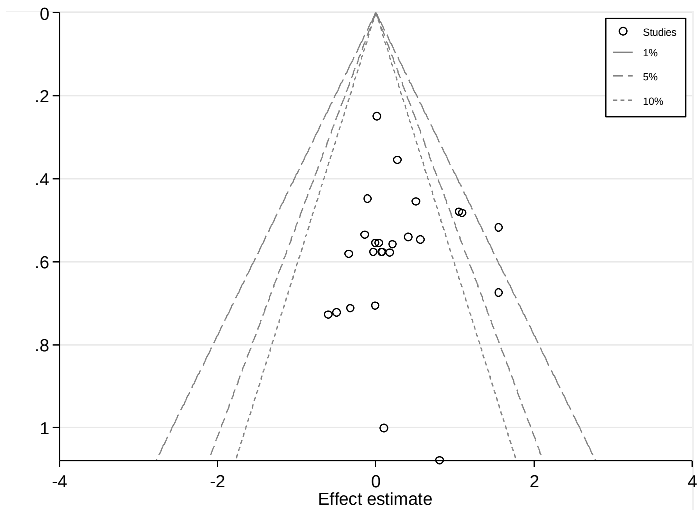
Appendix 1.34. Funnel plot of Dressing Percentage (%).responses for Zilpaterol studies



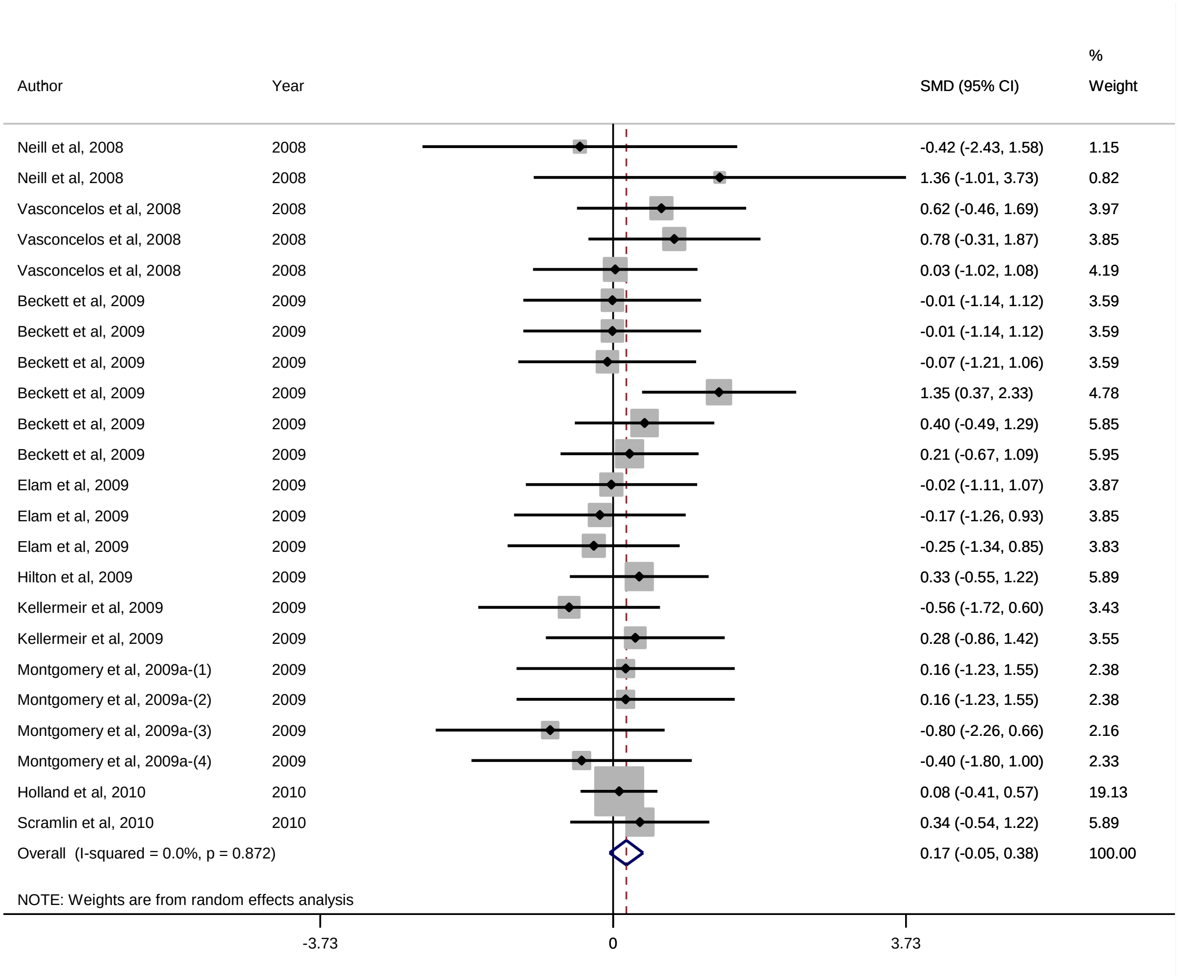
Appendix 1.35. Forest plot of Lean Maturity Score responses for Zilpaterol studies



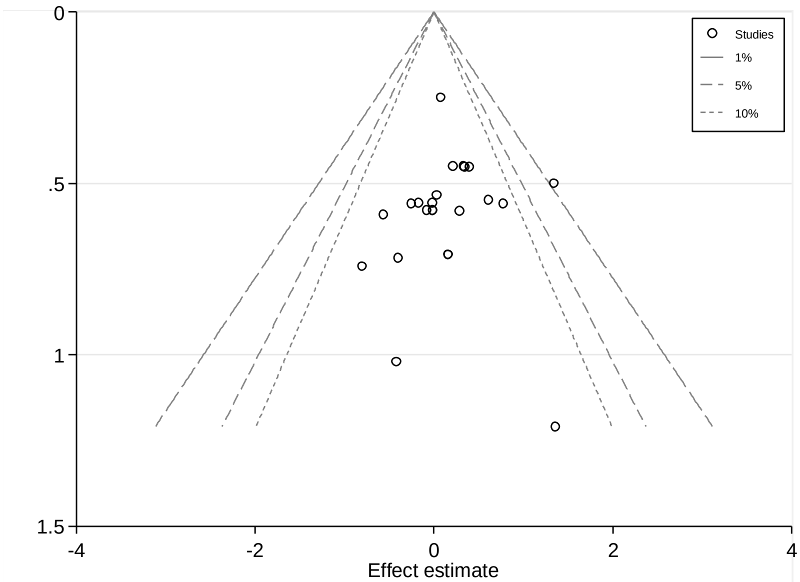
Appendix 1.36. Funnel plot of Lean Maturity Score responses for Zilpaterol studies



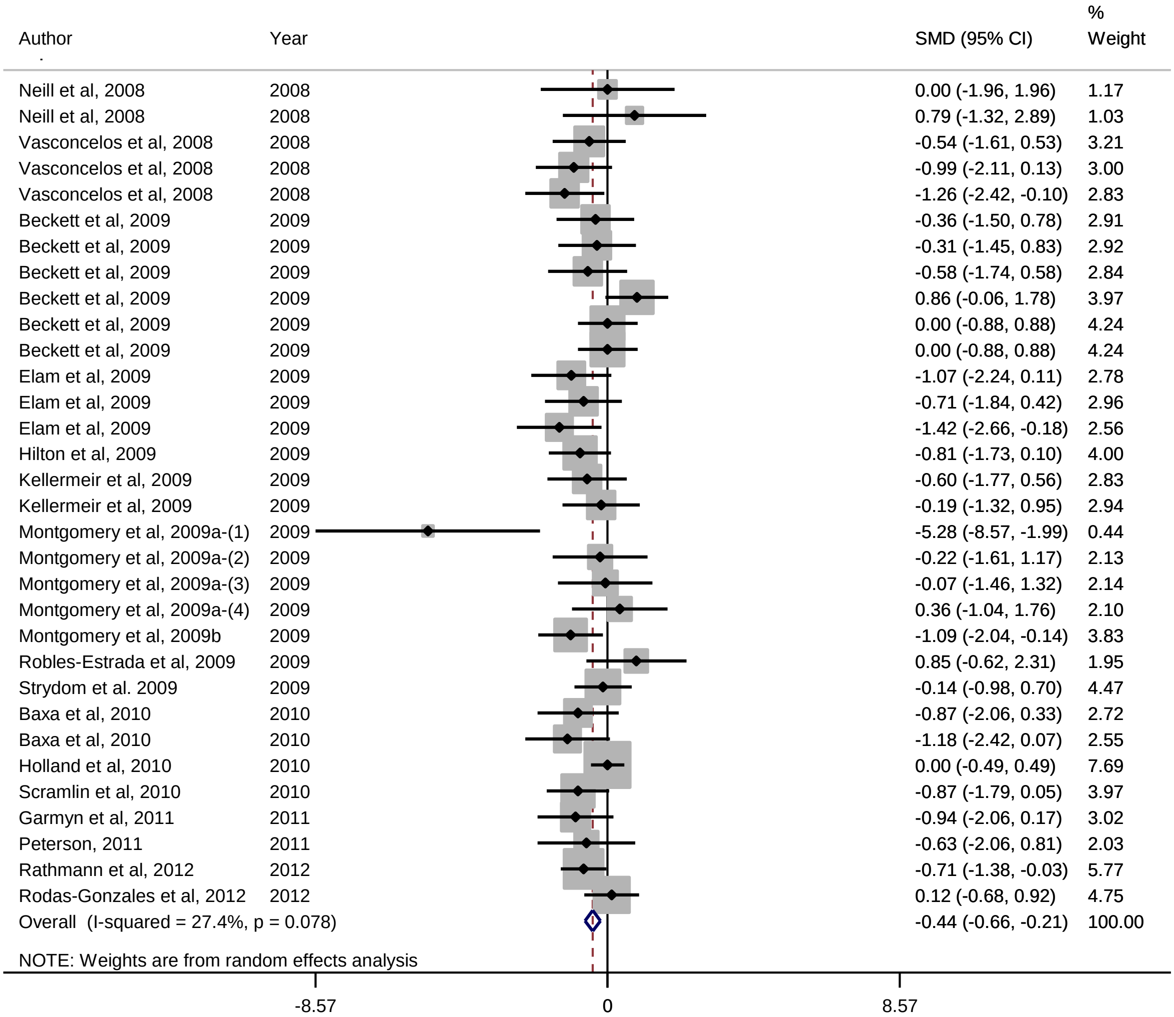
Appendix 1.37. Forest plot of Bone Maturity Score responses for Zilpaterol studies



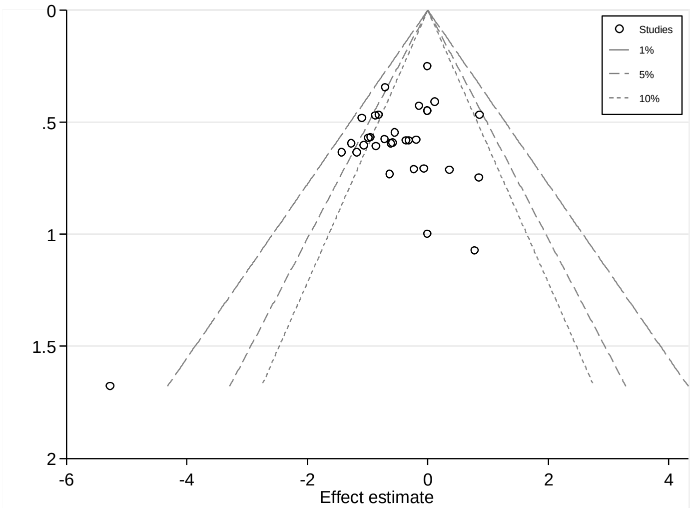
Appendix 1.38. Funnel plot of Bone Maturity Score responses for Zilpaterol studies



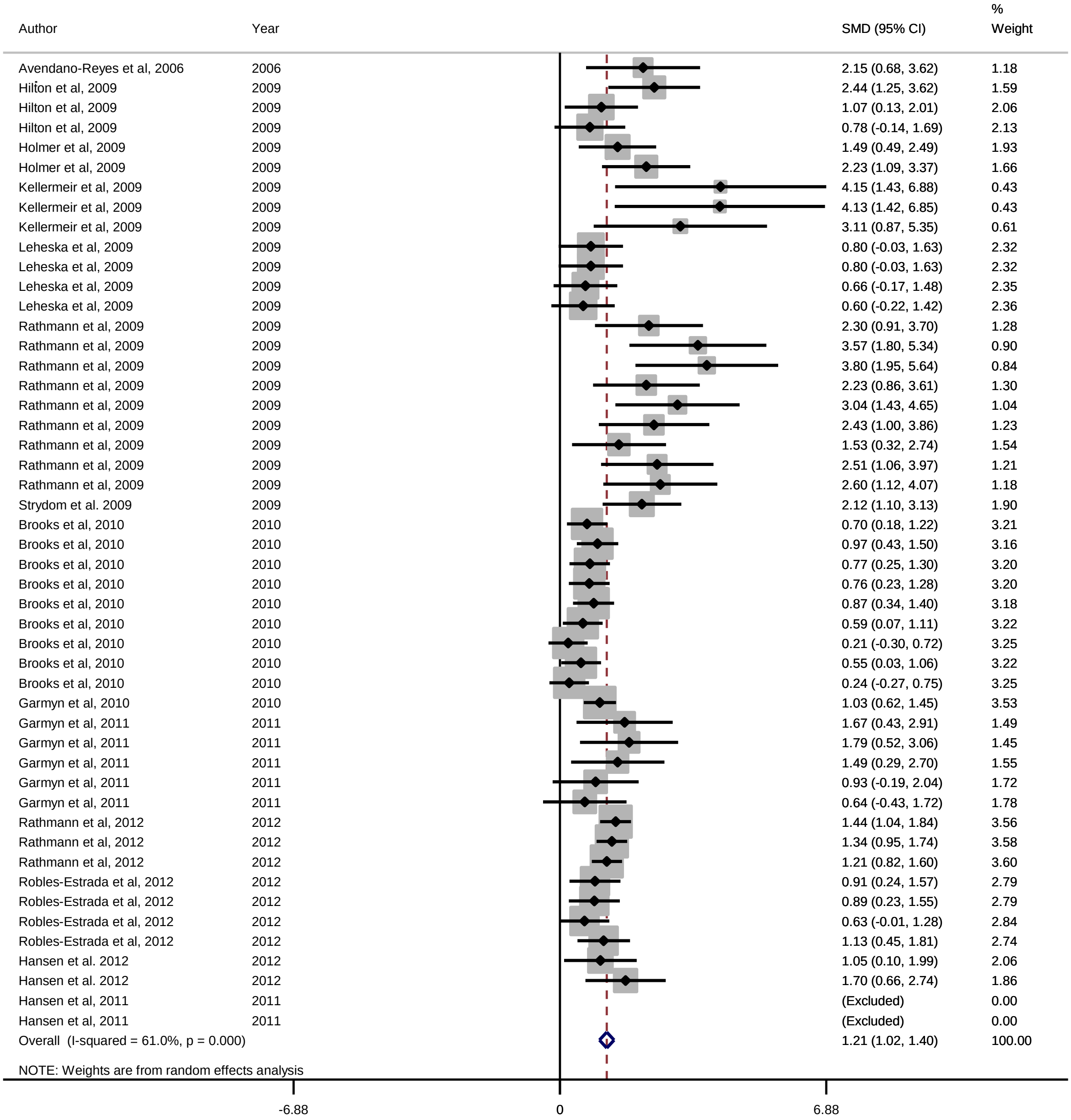
Appendix 1.39. Forest plot of Kidney, pelvic and Heart fat responses for Zilpaterol studies



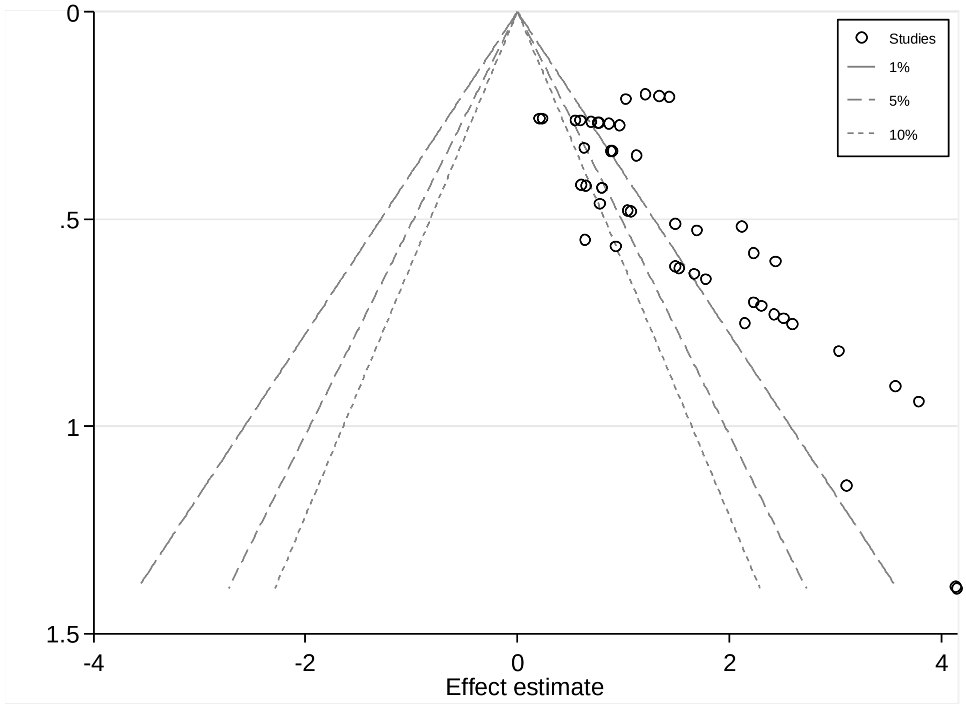
Appendix 1.40. Funnel plot of Kidney, pelvic and Heart fat responses for Zilpaterol studies



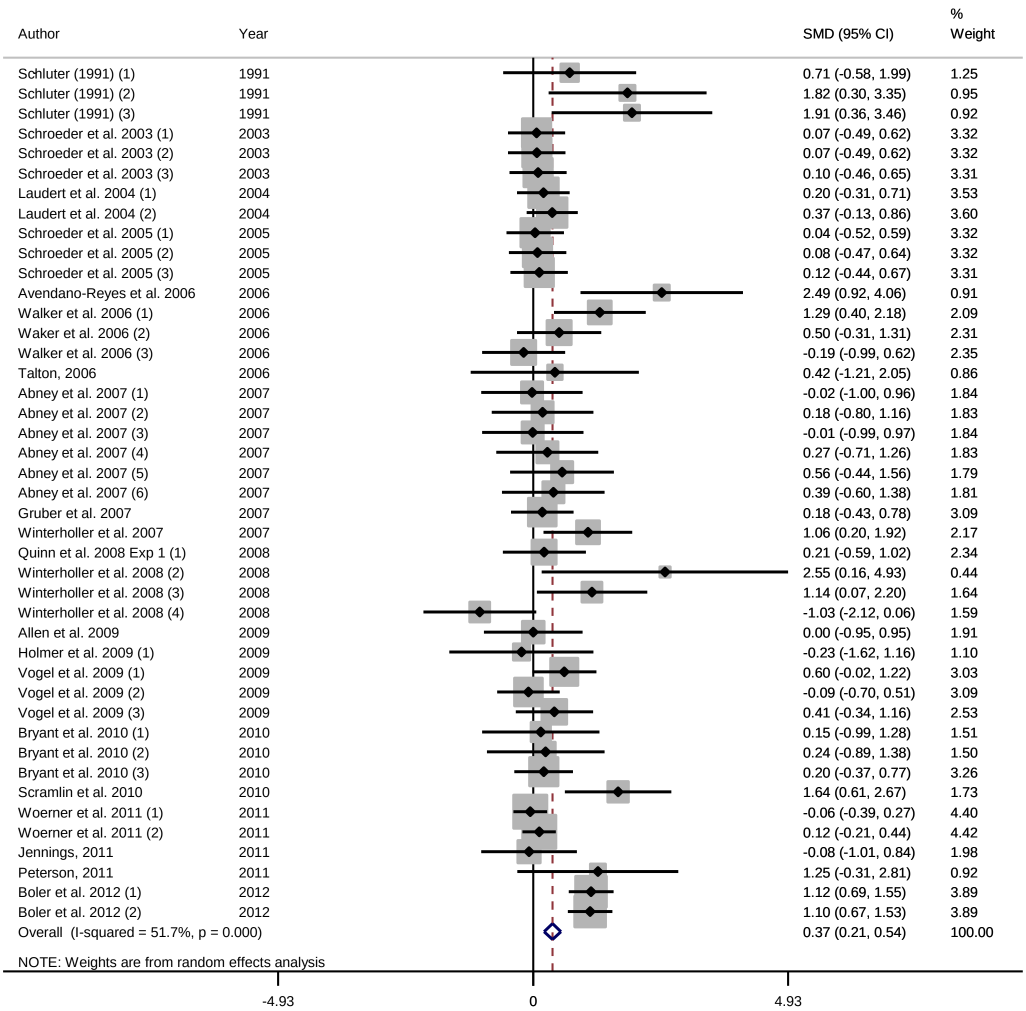
Appendix 1.41. Forest plot of Warner-Braetzler Shear Force responses for Zilpaterol studies



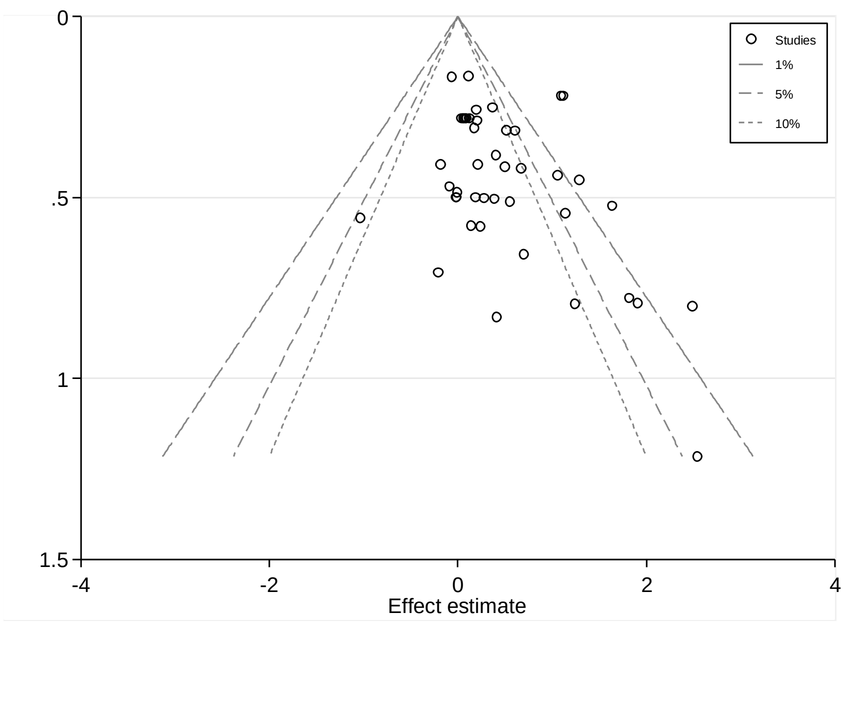
Appendix 1.42. Funnel plot of Warner-Braetzler Shear Force responses for Zilpaterol studies



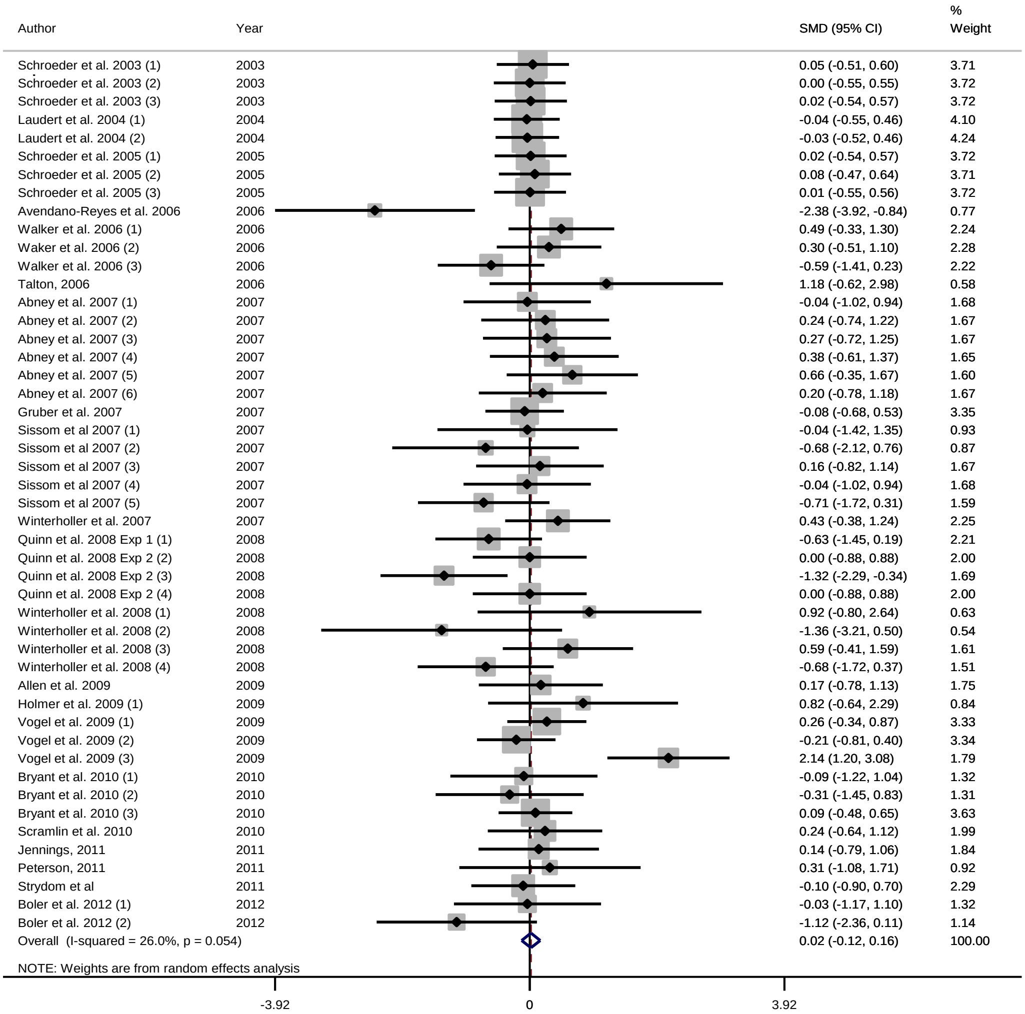
Appendix 2.11. Forest plot of body weight responses for ractopamine studies



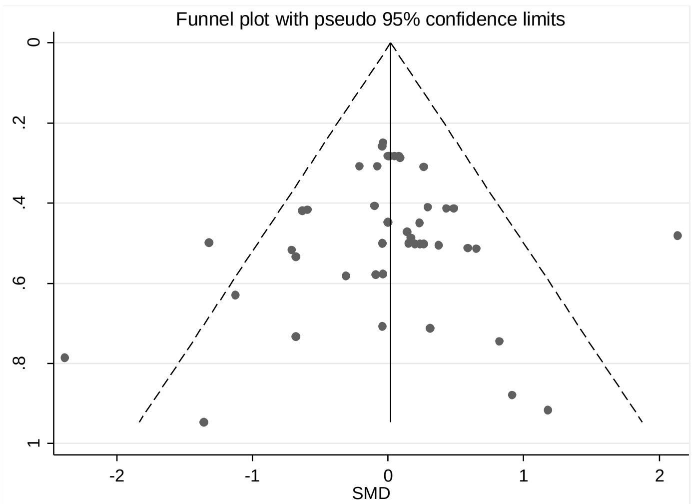
Appendix 2.12. Funnel plot of body weight responses for ractopamine studies



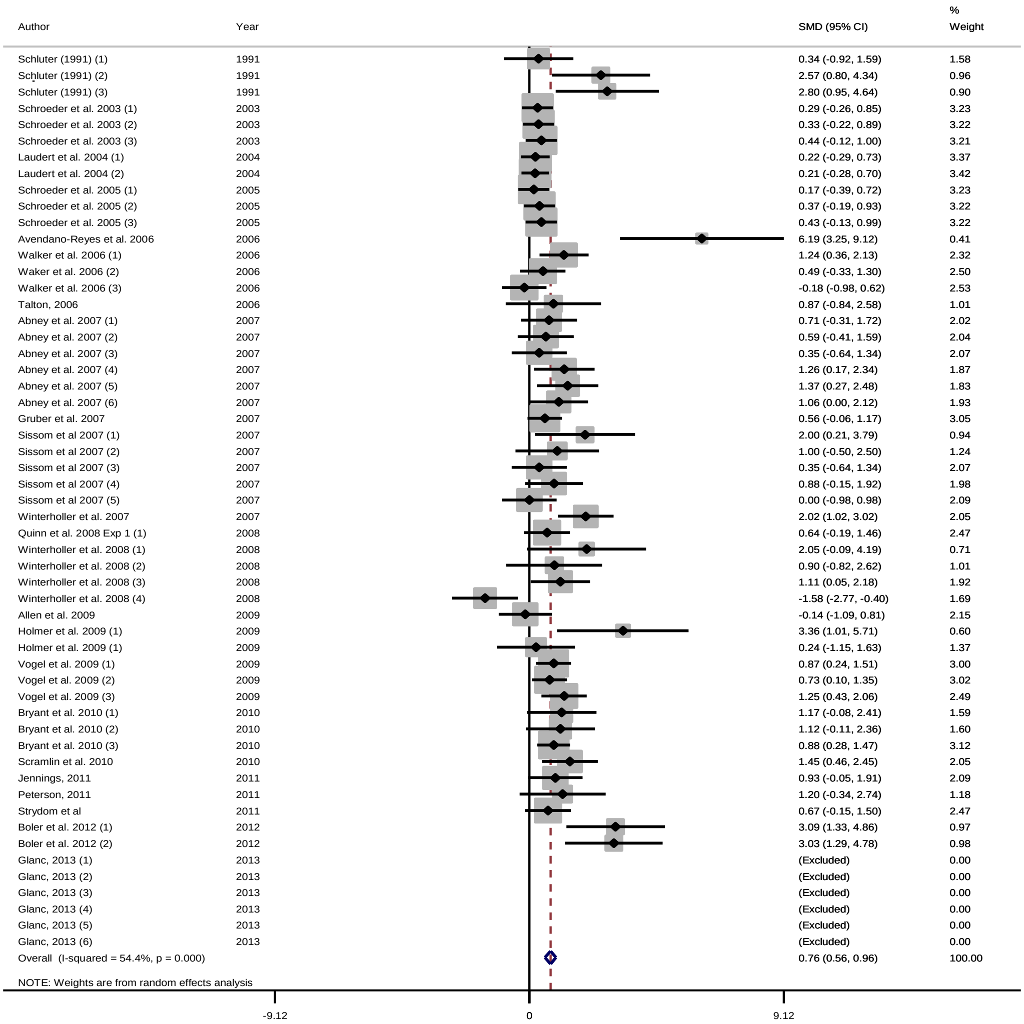
Appendix 2.13. Forest plot of dry matter intake responses for ractopamine studies



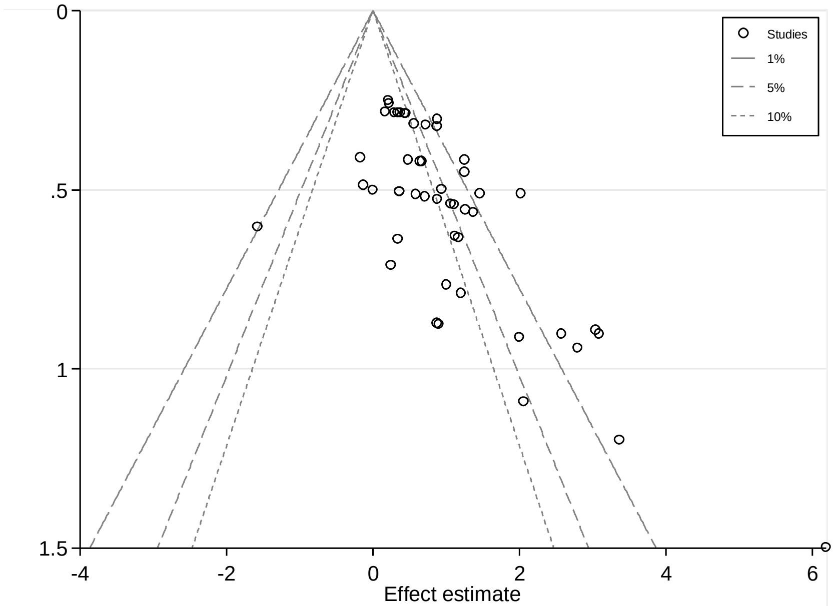
Appendix 2.14. Funnel plot of dry matter intake responses for ractopamine studies



Appendix 2.15.Forest plot of average daily gain for ractopamine studies



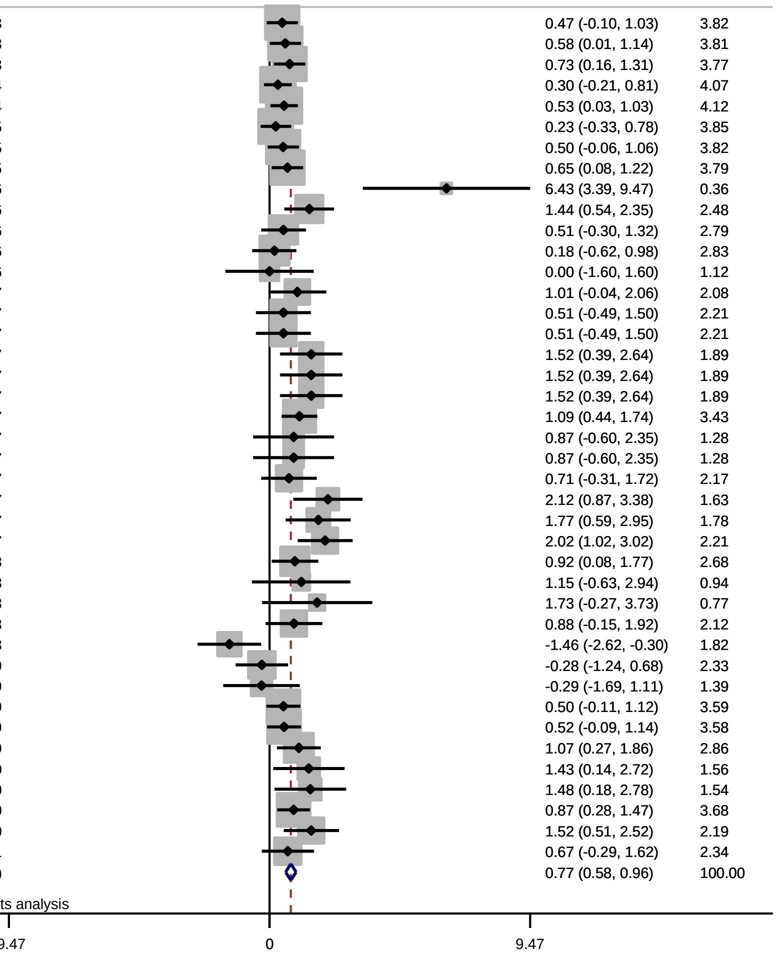
Appendix 2.16. Funnel plot of average daily gain for ractopamine studies



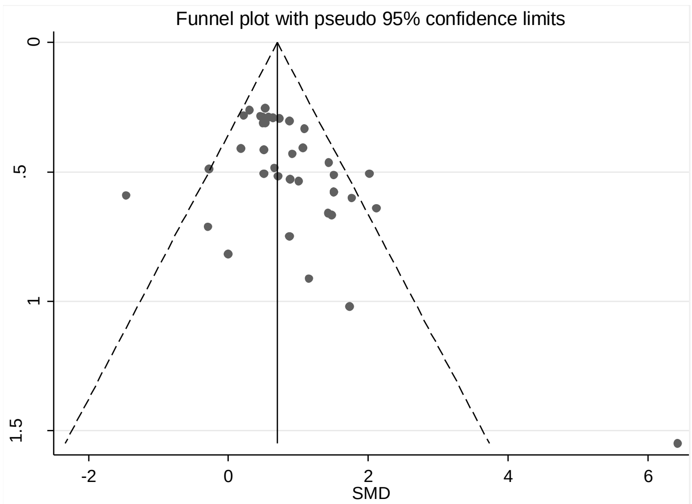
Appendix 2.17.Forest plot of gain to feed for ractopamine studies

Author	Year	SMD (95% CI)	% Weight
Schroeder et al. 2003 (1)	2003	0.47 (-0.10, 1.03)	3.82
Schroeder et al. 2003 (2)	2003	0.58 (0.01, 1.14)	3.81
Schroeder et al. 2003 (3)	2003	0.73 (0.16, 1.31)	3.77
Laudert et al. 2004 (1)	2004	0.30 (-0.21, 0.81)	4.07
Laudert et al. 2004 (2)	2004	0.53 (0.03, 1.03)	4.12
Schroeder et al. 2005 (1)	2005	0.23 (-0.33, 0.78)	3.85
Schroeder et al. 2005 (2)	2005	0.50 (-0.06, 1.06)	3.82
Schroeder et al. 2005 (3)	2005	0.65 (0.08, 1.22)	3.79
Avendano-Reyes et al. 2006	2006	6.43 (3.39, 9.47)	0.36
Walker et al. 2006 (1)	2006	1.44 (0.54, 2.35)	2.48
Waker et al. 2006 (2)	2006	0.51 (-0.30, 1.32)	2.79
Walker et al. 2006 (3)	2006	0.18 (-0.62, 0.98)	2.83
Talton, 2006	2006	0.00 (-1.60, 1.60)	1.12
Abney et al. 2007 (1)	2007	1.01 (-0.04, 2.06)	2.08
Abney et al. 2007 (2)	2007	0.51 (-0.49, 1.50)	2.21
Abney et al. 2007 (3)	2007	0.51 (-0.49, 1.50)	2.21
Abney et al. 2007 (4)	2007	1.52 (0.39, 2.64)	1.89
Abney et al. 2007 (5)	2007	1.52 (0.39, 2.64)	1.89
Abney et al. 2007 (6)	2007	1.52 (0.39, 2.64)	1.89
Gruber et al. 2007	2007	1.09 (0.44, 1.74)	3.43
Sissom et al 2007 (1)	2007	0.87 (-0.60, 2.35)	1.28
Sissom et al 2007 (2)	2007	0.87 (-0.60, 2.35)	1.28
Sissom et al 2007 (3)	2007	0.71 (-0.31, 1.72)	2.17
Sissom et al 2007 (4)	2007	2.12 (0.87, 3.38)	1.63
Sissom et al 2007 (5)	2007	1.77 (0.59, 2.95)	1.78
Winterholler et al. 2007	2007	2.02 (1.02, 3.02)	2.21
Quinn et al. 2008 Exp 1 (1)	2008	0.92 (0.08, 1.77)	2.68
Winterholler et al. 2008 (1)	2008	1.15 (-0.63, 2.94)	0.94
Winterholler et al. 2008 (2)	2008	1.73 (-0.27, 3.73)	0.77
Winterholler et al. 2008 (3)	2008	0.88 (-0.15, 1.92)	2.12
Winterholler et al. 2008 (4)	2008	-1.46 (-2.62, -0.30)	1.82
Allen et al. 2009	2009	-0.28 (-1.24, 0.68)	2.33
Holmer et al. 2009 (1)	2009	-0.29 (-1.69, 1.11)	1.39
Vogel et al. 2009 (1)	2009	0.50 (-0.11, 1.12)	3.59
Vogel et al. 2009 (2)	2009	0.52 (-0.09, 1.14)	3.58
Vogel et al. 2009 (3)	2009	1.07 (0.27, 1.86)	2.86
Bryant et al. 2010 (1)	2010	1.43 (0.14, 2.72)	1.56
Bryant et al. 2010 (2)	2010	1.48 (0.18, 2.78)	1.54
Bryant et al. 2010 (3)	2010	0.87 (0.28, 1.47)	3.68
Scramlin et al. 2010	2010	1.52 (0.51, 2.52)	2.19
Jennings, 2011	2011	0.67 (-0.29, 1.62)	2.34
Overall (I-squared = 47.8%, p = 0.000)		0.77 (0.58, 0.96)	100.00

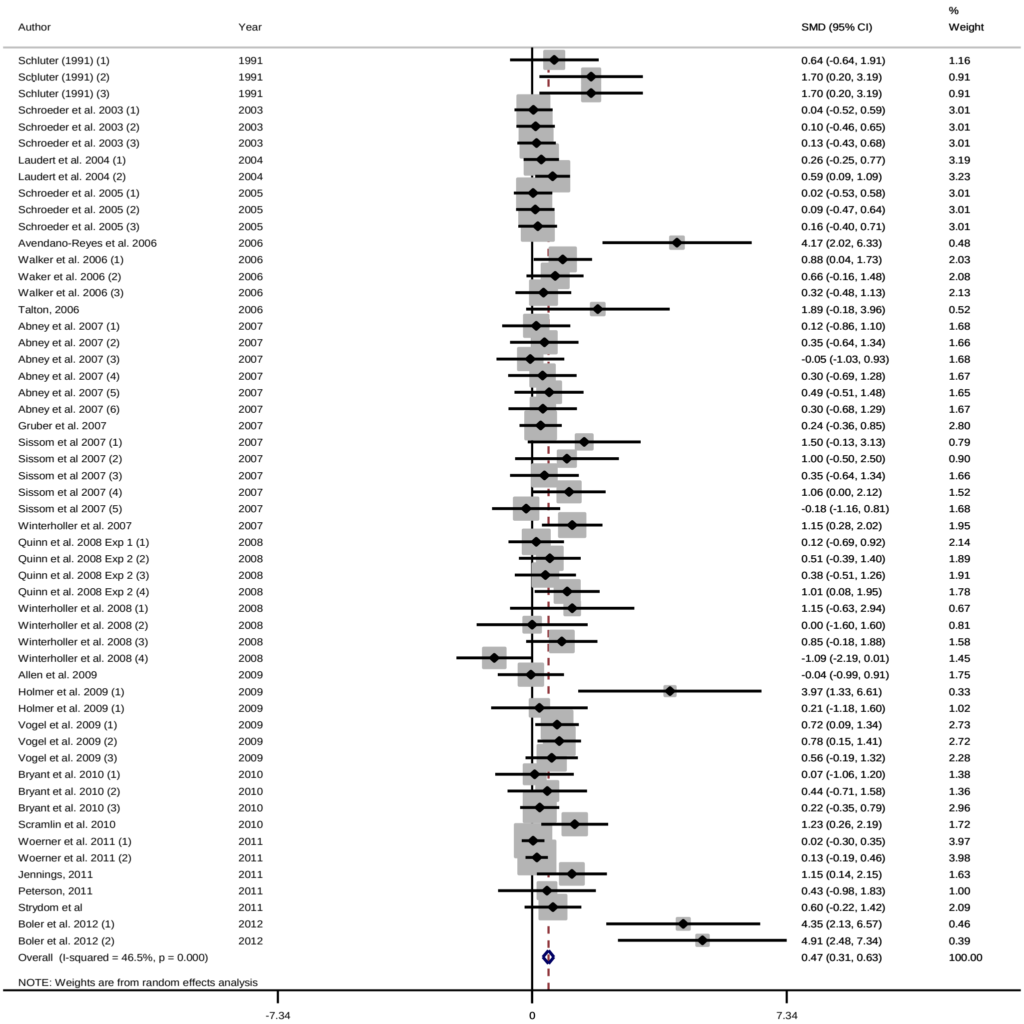
NOTE: Weights are from random effects analysis



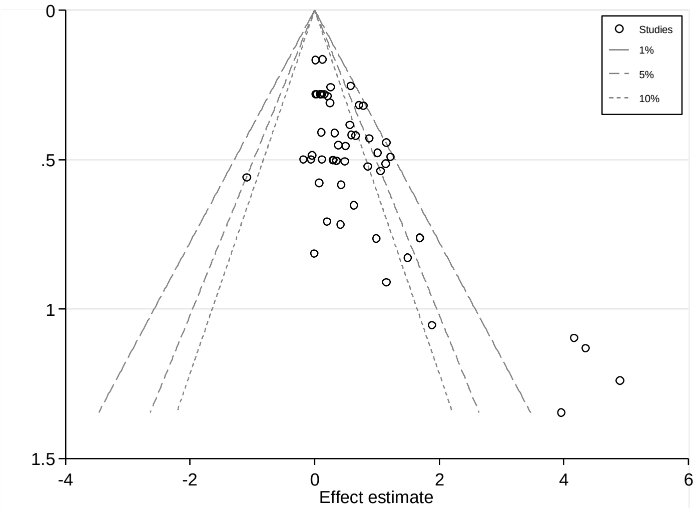
Appendix 2.18. Funnel plot of gain to feed for ractopamine studies



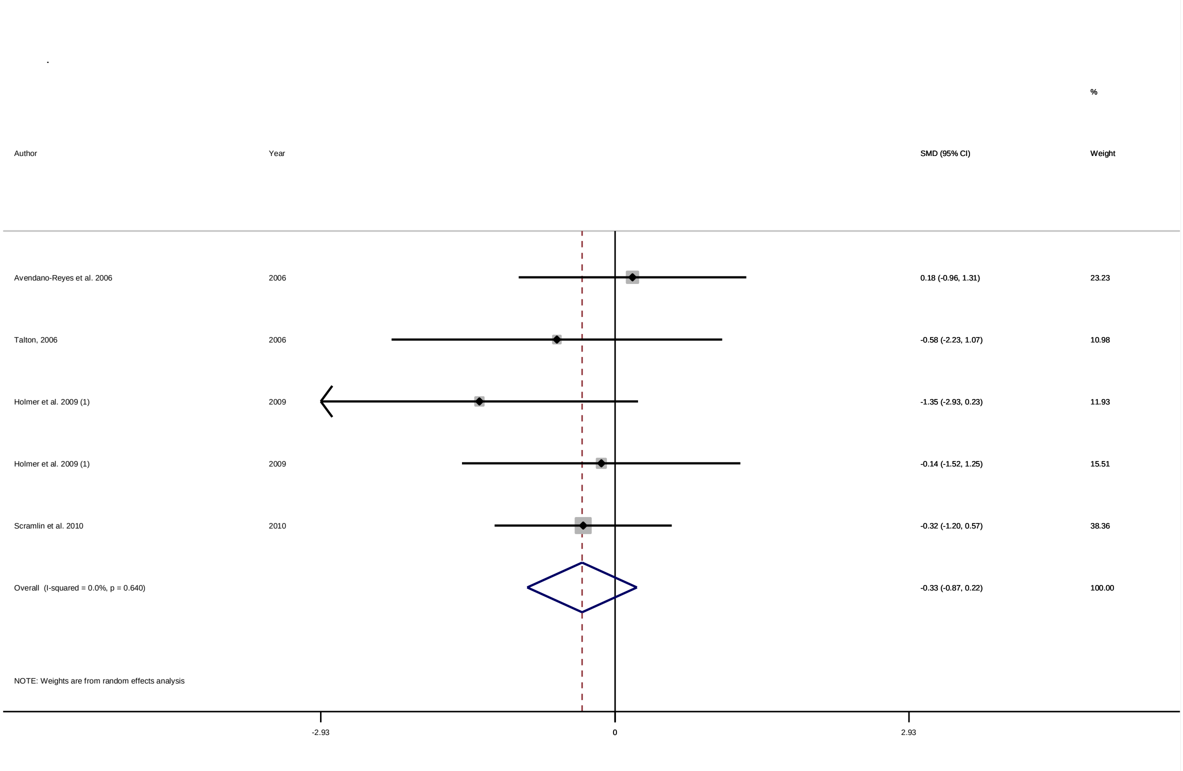
Appendix 2.19.Forest plot of hot carcass weight for ractopamine studies



Appendix 2.20. Funnel plot of hot carcass weight for ractopamine studies

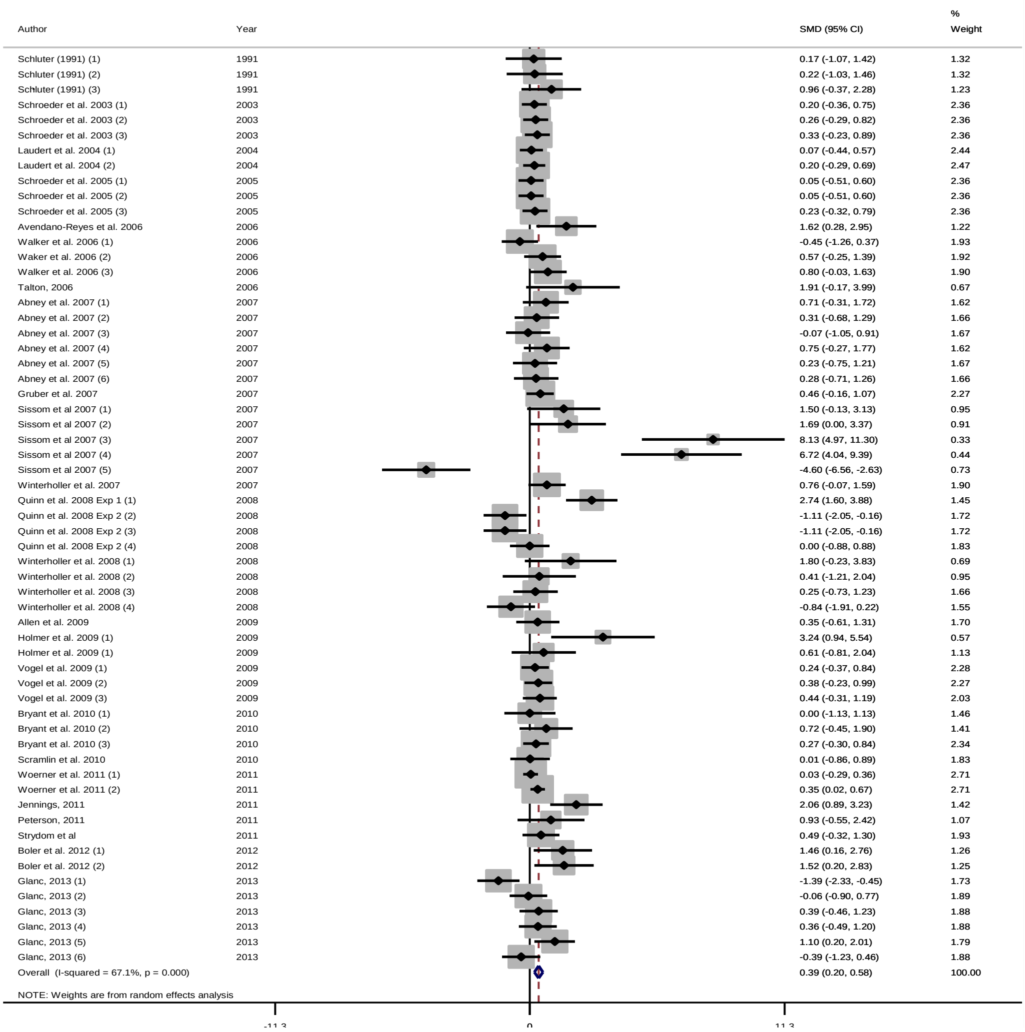


Appendix 2.21.Forest plot of PH for ractopamine studies

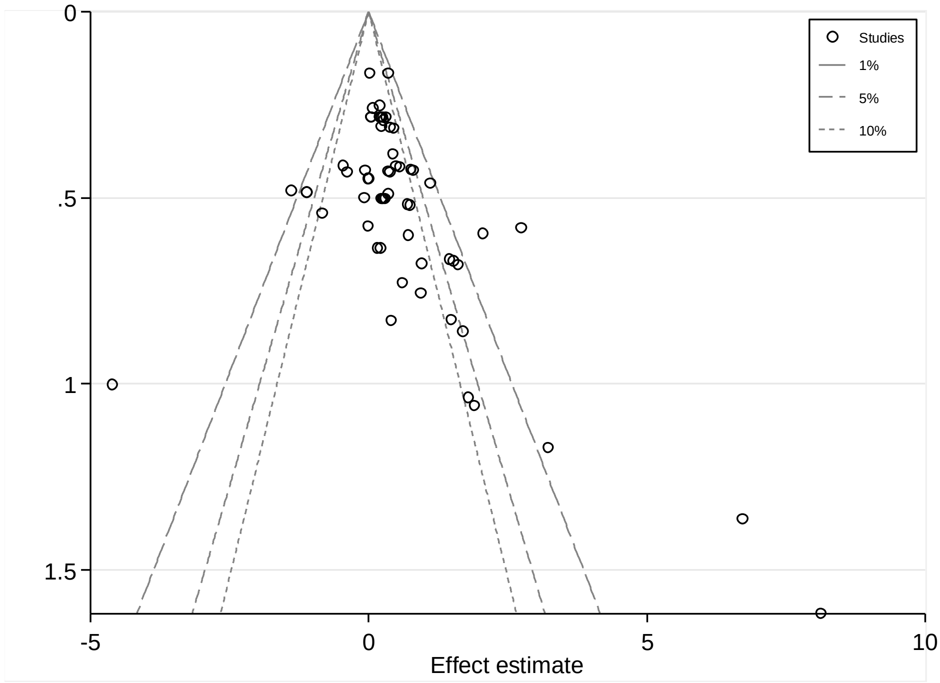


Appendix 2.22. Funnel plot of PH for ractopamine studies (Not available)

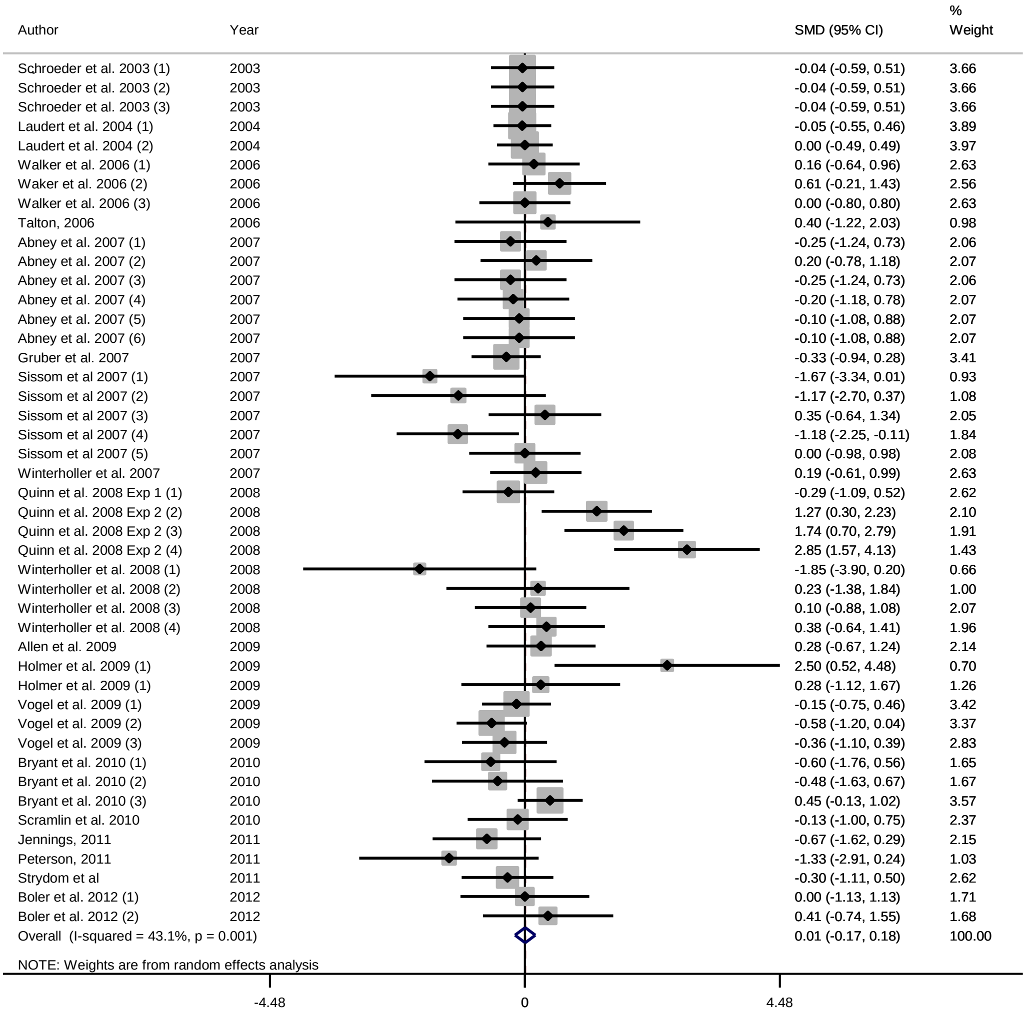
Appendix 2.23.Forest plot of longissimus muscle area (cm2)for Ractopamine studies



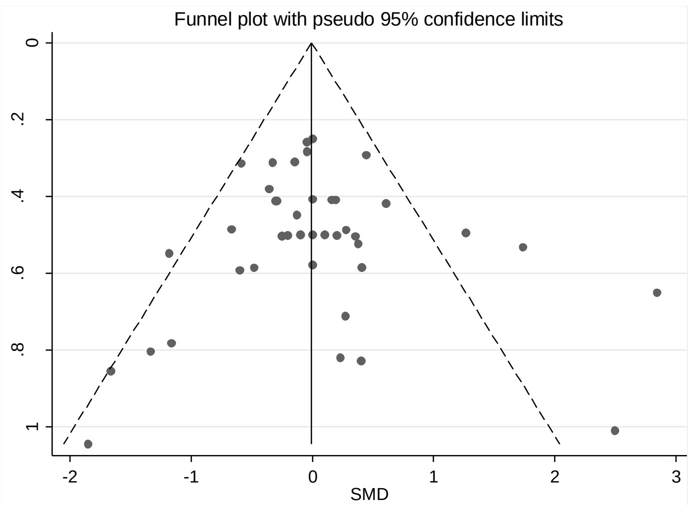
Appendix 2.24. Funnel plot of longissimus muscle area (cm2) for ractopamine studies



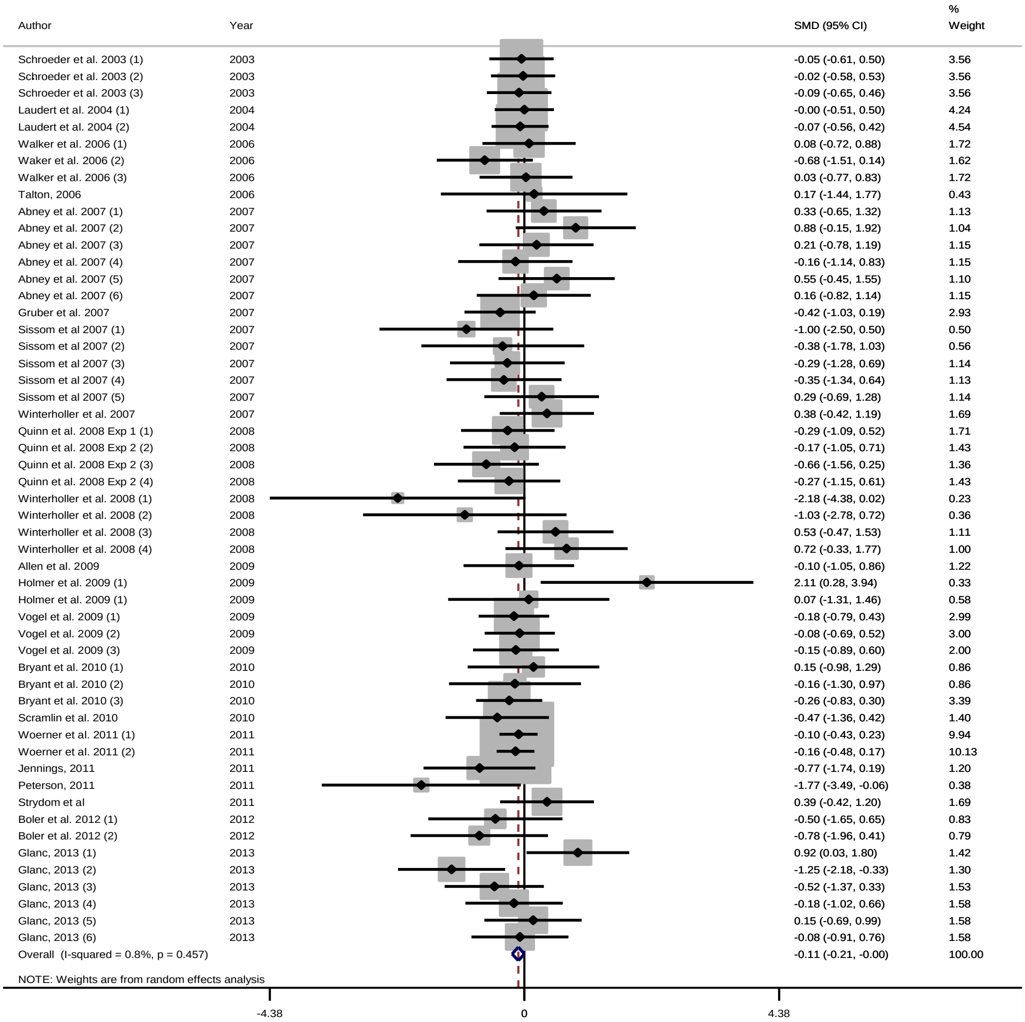
Appendix 2.25.Forest plot of Fat thickness at the 12th rib (cm) for Ractopamine studies



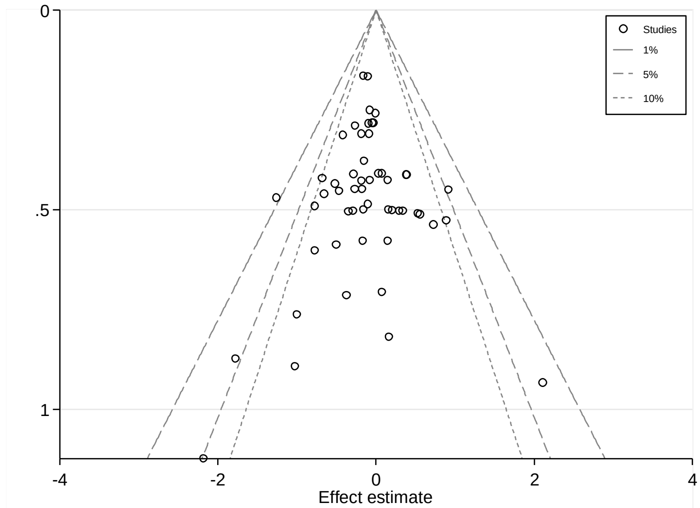
Appendix 2.26.Funnelplot of Fat thickness at the 12th rib (cm) for Ractopamine studies



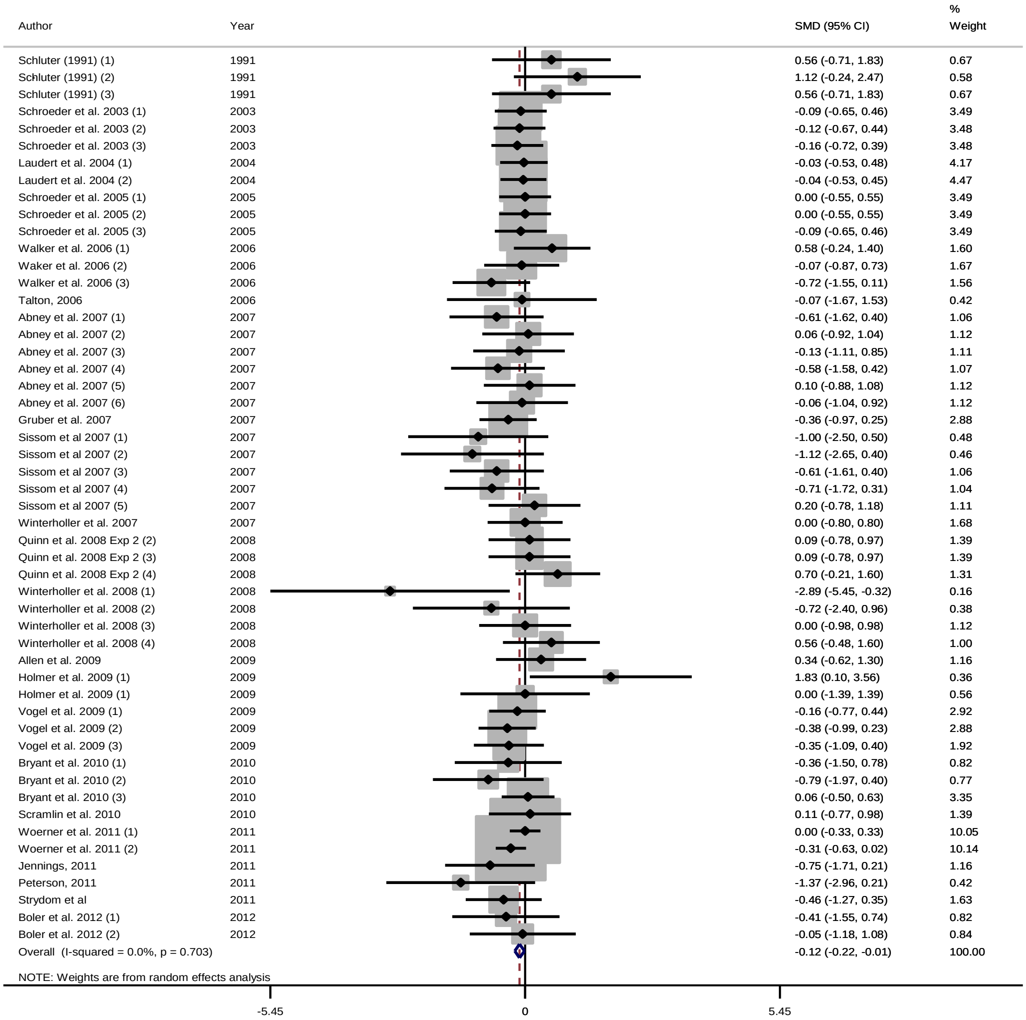
Appendix 2.27.Forest plot of Standardised USDA marbling score for Ractopamine studies



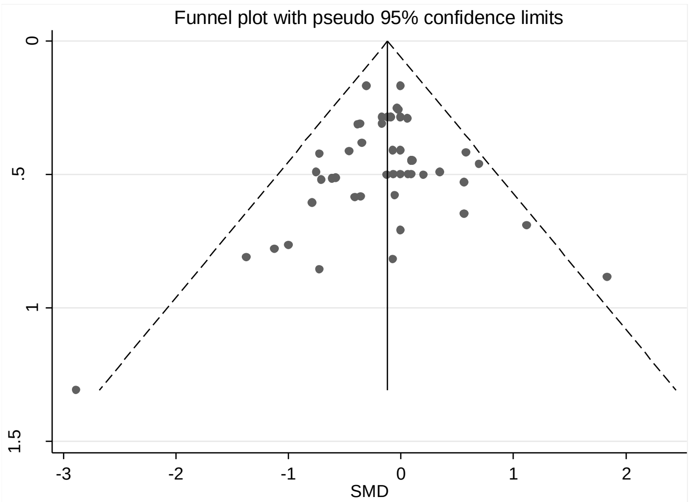
Appendix 2.28.Funnelplot of Standardised USDA marbling score for Ractopamine studies



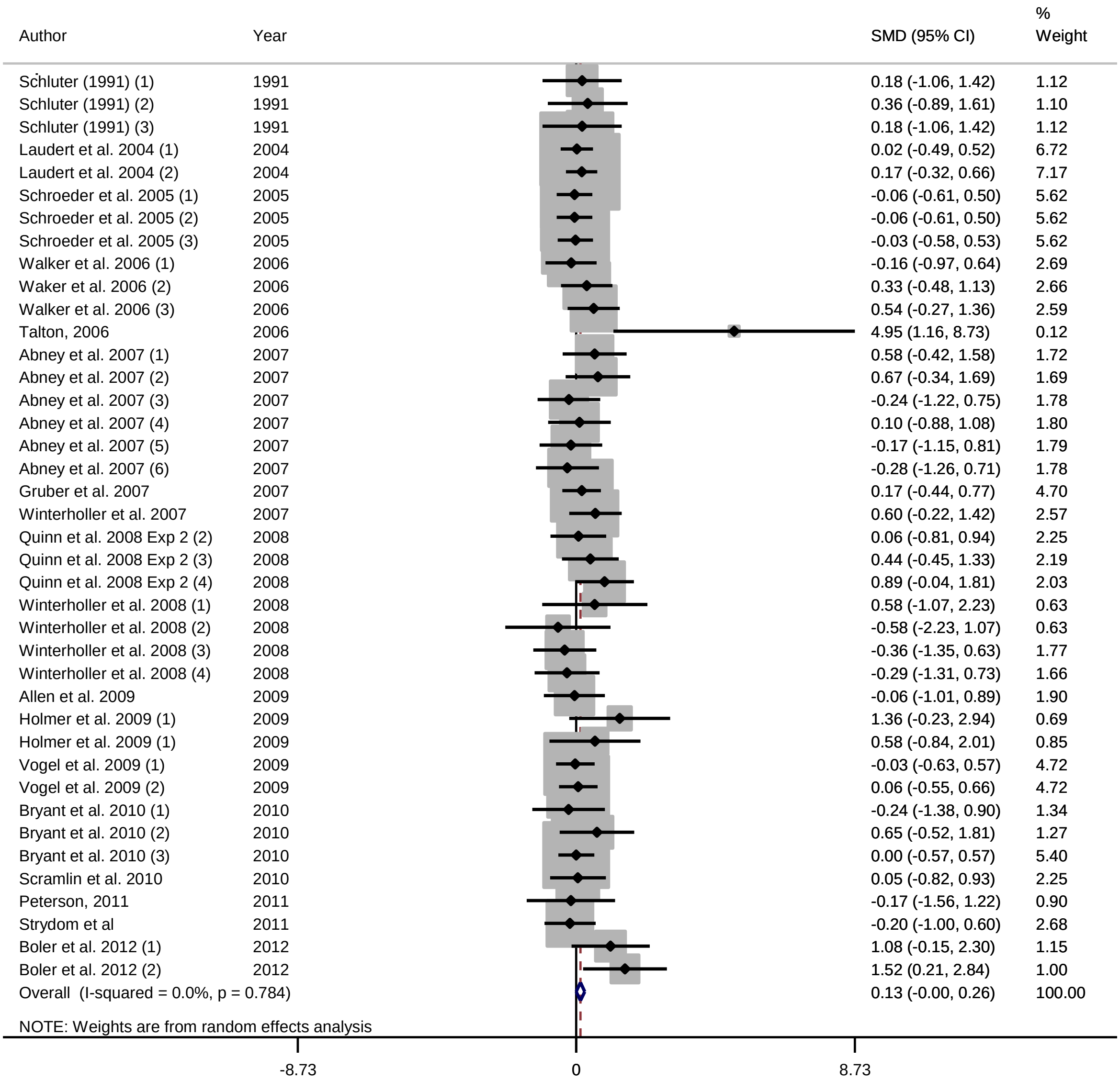
Appendix 2.29.Forest plot of USDA Yield Gradefor Ractopamine studies



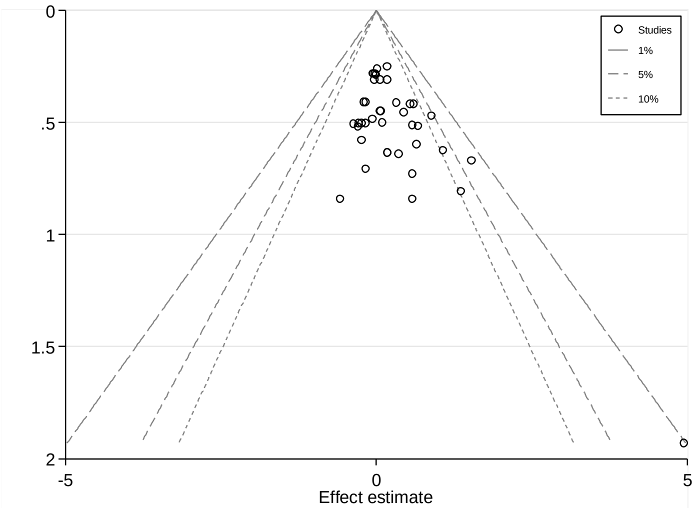
Appendix 2.30.Funnelplot of USDA Yield Gradefor Ractopamine studies



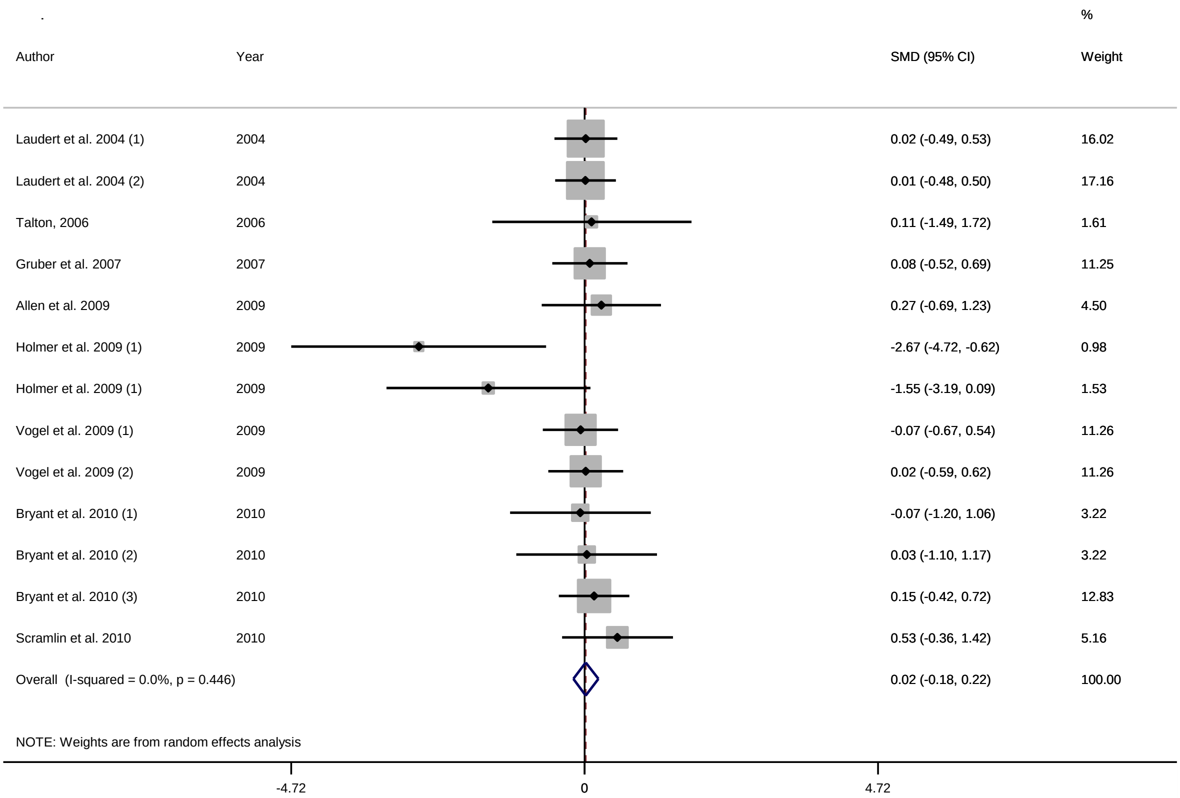
Appendix 2.31.Forest plot of Dressing Percentage (%)for Ractopamine studies



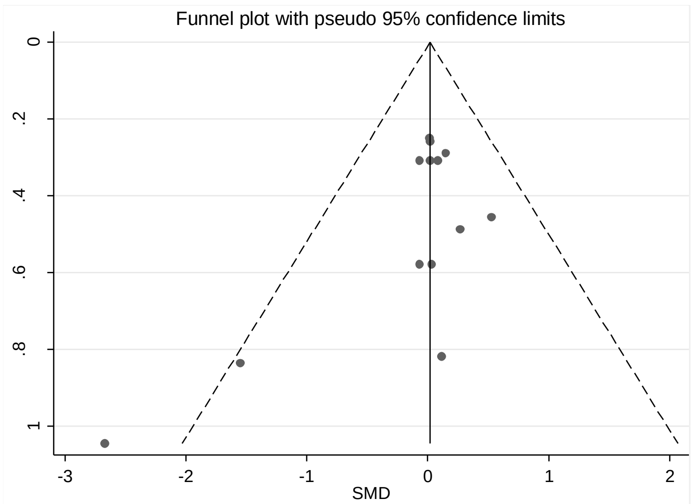
Appendix 2.32.Funnelplot of Dressing Percentage (%)for Ractopamine studies



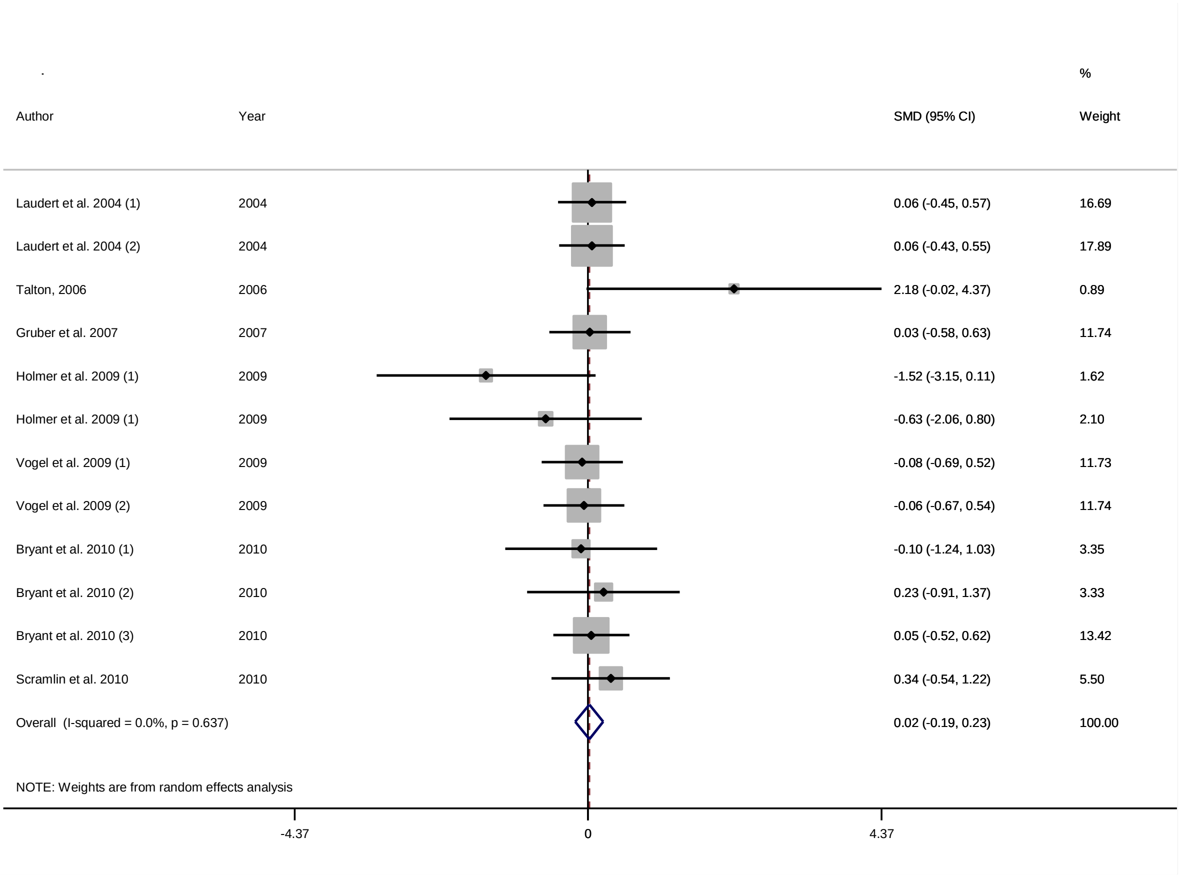
Appendix 2.33.Forest plot of Lean Maturity Score for Ractopamine studies



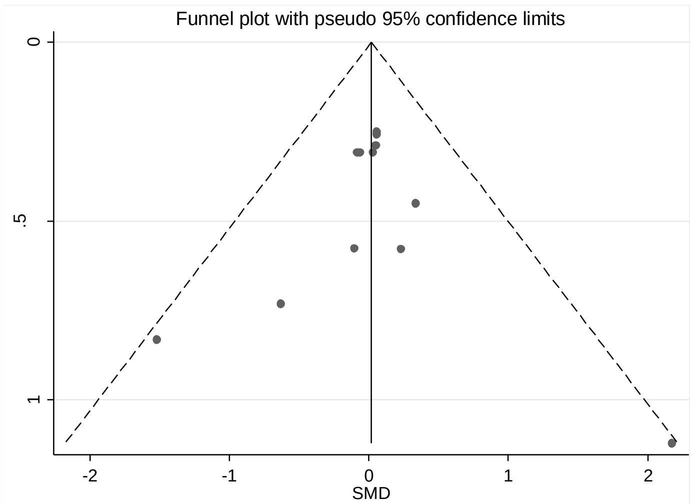
Appendix 2.34.Funnelplot of Lean Maturity Score for Ractopamine studies



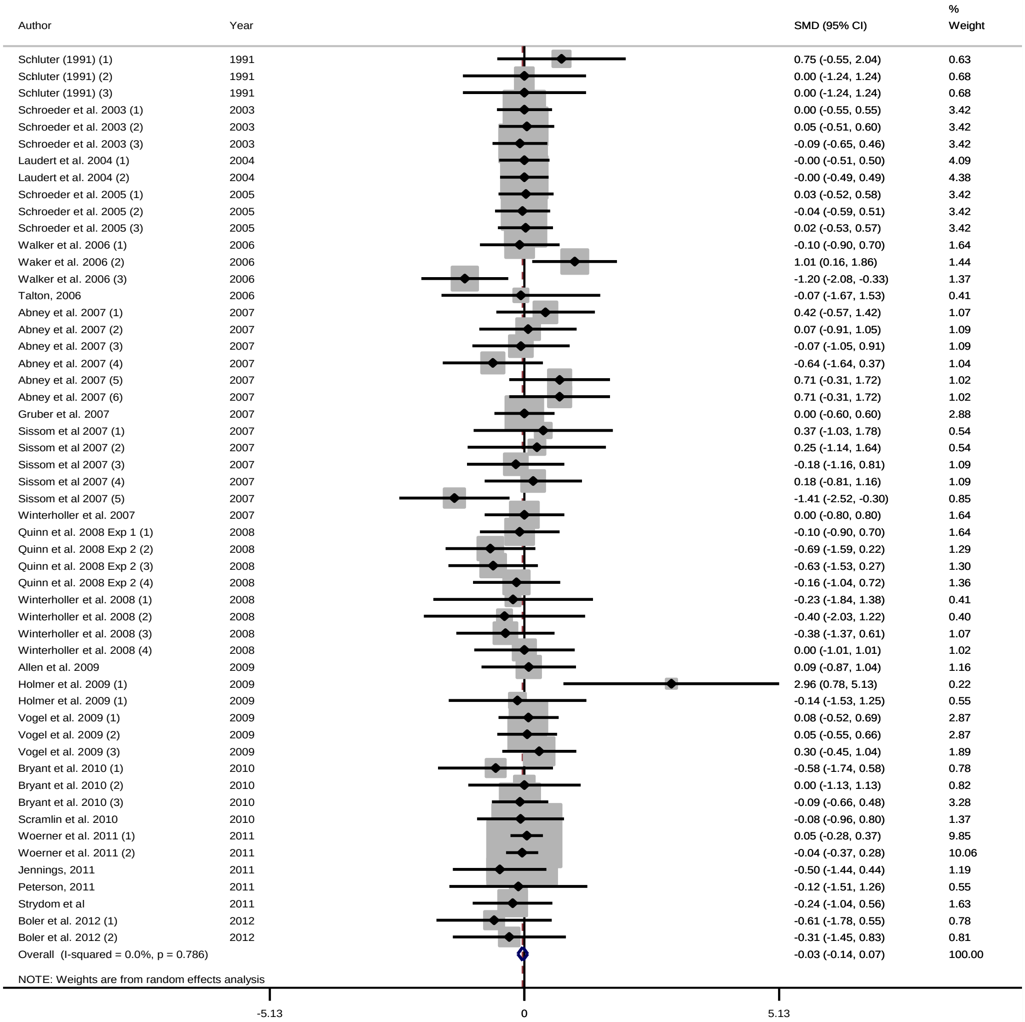
Appendix 2.35.Forestplot of bone maturity for Ractopamine studi



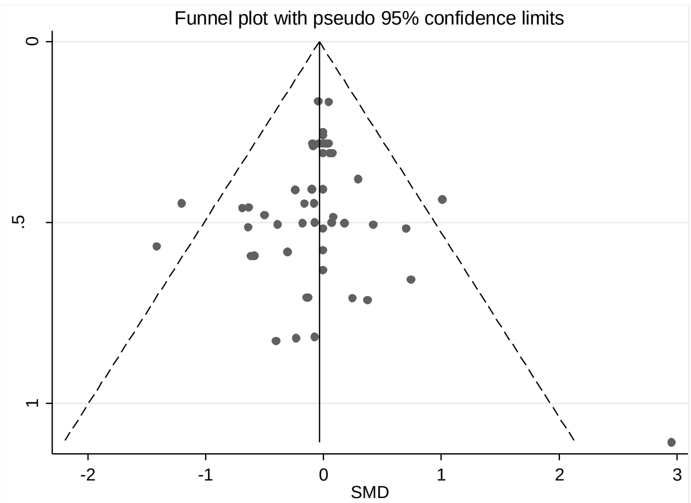
Appendix 2.36.Funnelplot of bone maturity for Ractopamine studies



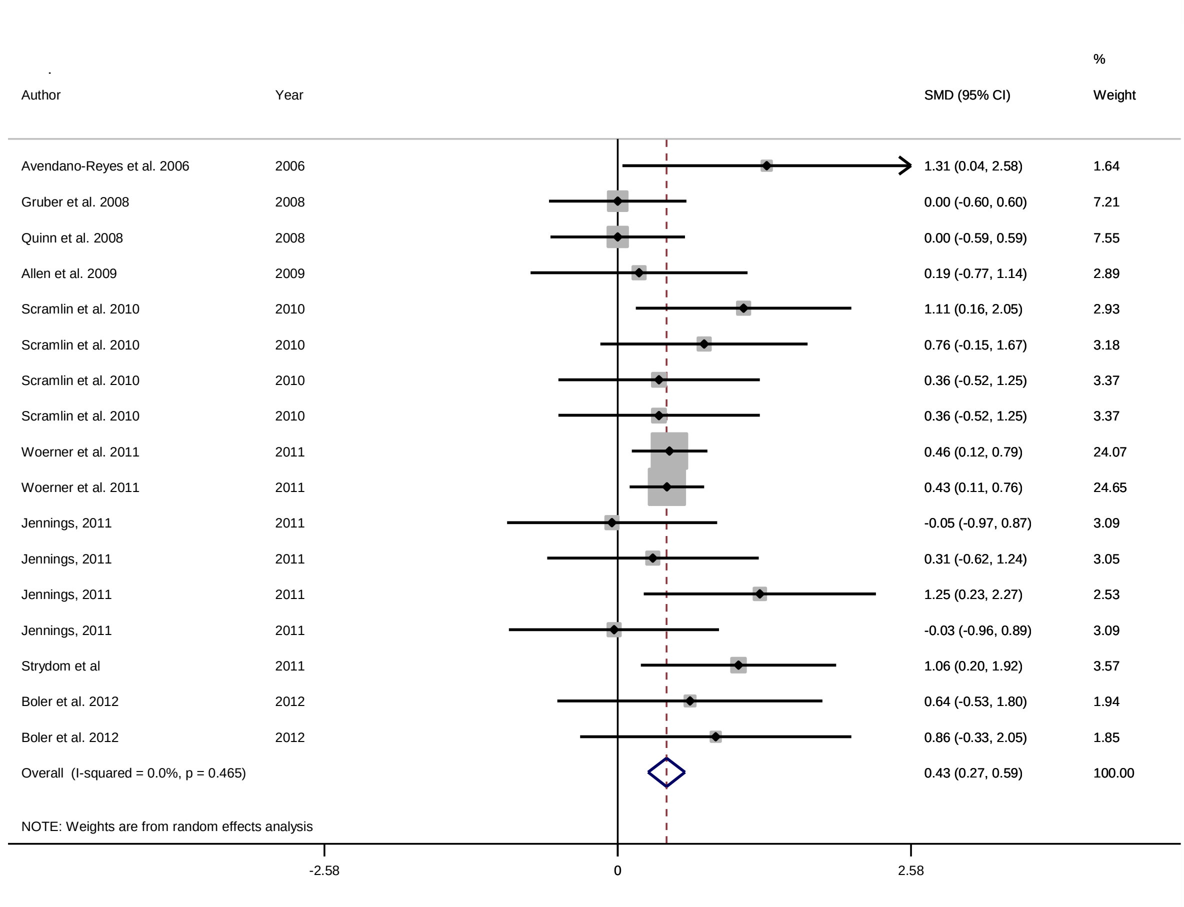
Appendix 2.37.Forestplot of Kidney, pelvic and Heart fat for Ractopamine studies



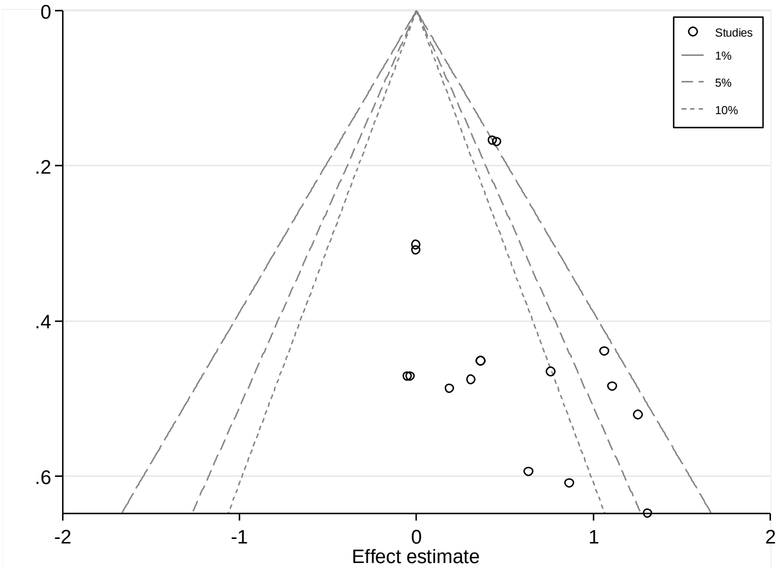
Appendix 2.38.Funnelplot of Kidney, pelvic and Heart fat for Ractopamine studies



Appendix 2.39.Forestplot of Warner-Braetzler Shear Force for Ractopamine studies



Appendix 2.40.Funnelplot of Warner-Braetzler Shear Force for Ractopamine studies



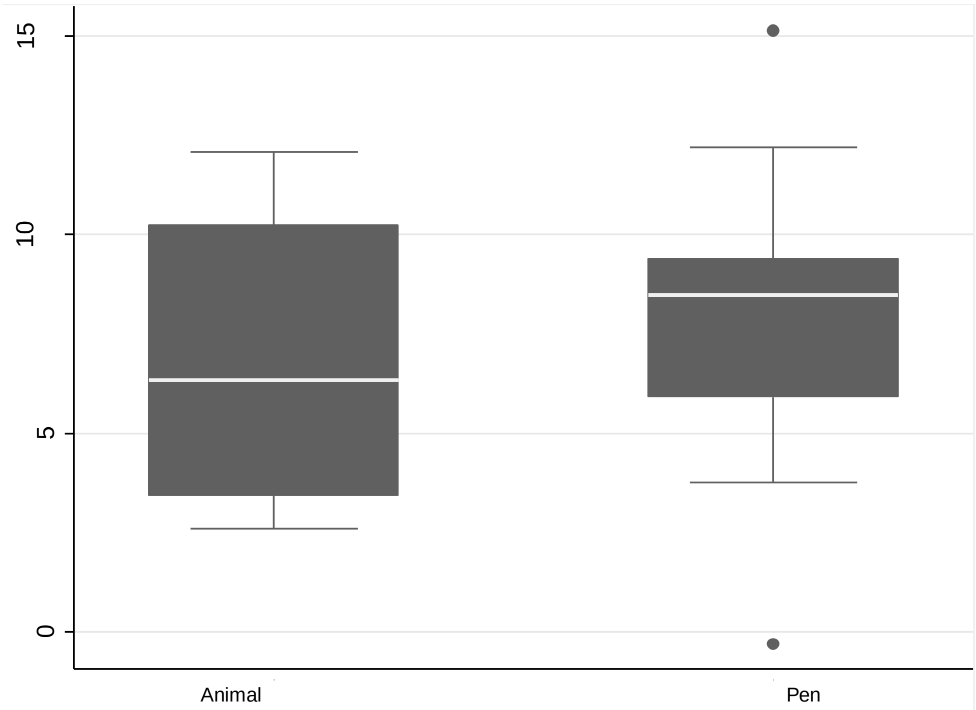


Figure 2.1.1 Raw mean differences for studies using animal or pen as the unit of interest for the effect of Zilpaterol on Longissimus Muscle Area (cm^2).

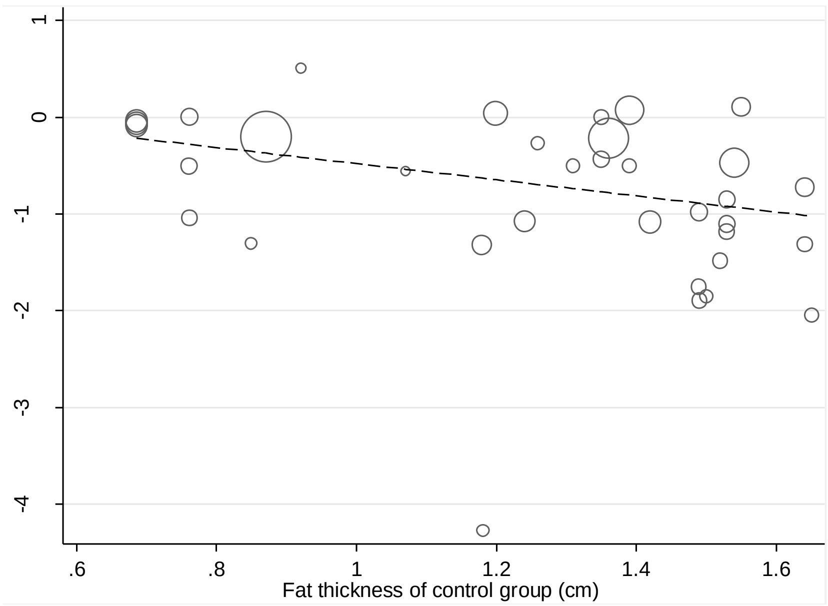


Figure 2.1.2 Effect of fat thickness for the control group on standardised mean difference of studies examining Zilpaterol and fat thickness

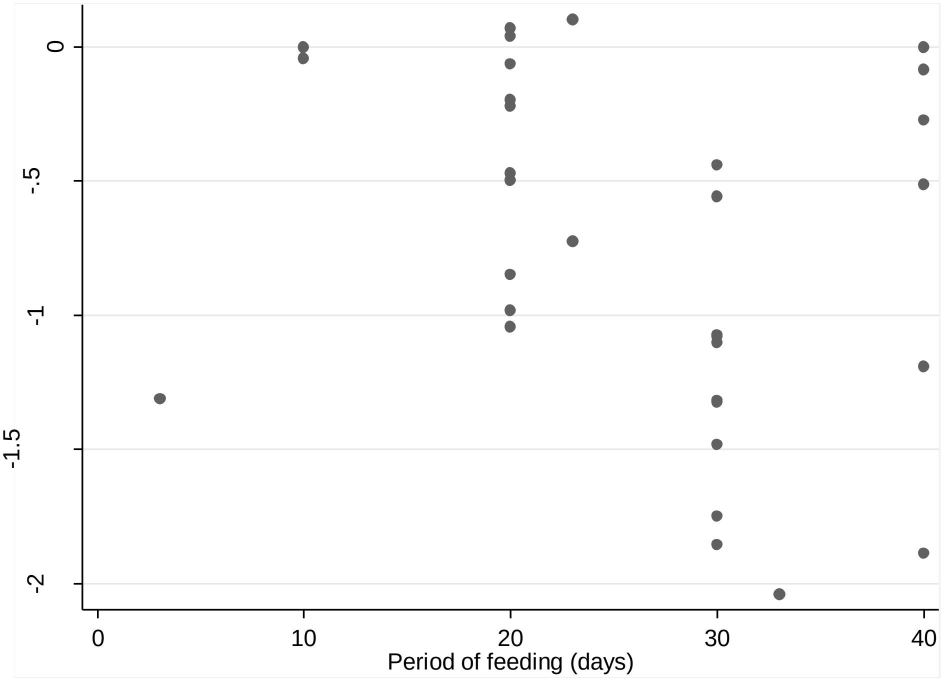


Figure 2.1.3 Effect of period of feeding (days) on the standardised mean difference of studies examining Zilpaterol and fat thickness.

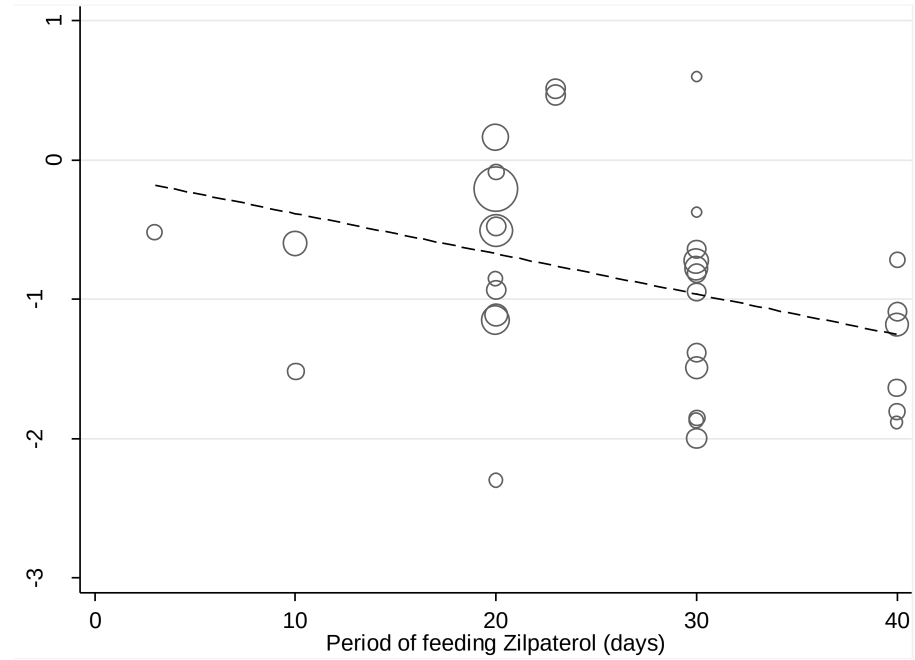


Figure 2.1.4 Effect of period of feeding (days) on the standardised mean difference of studies examining Zilpaterol and marbling.

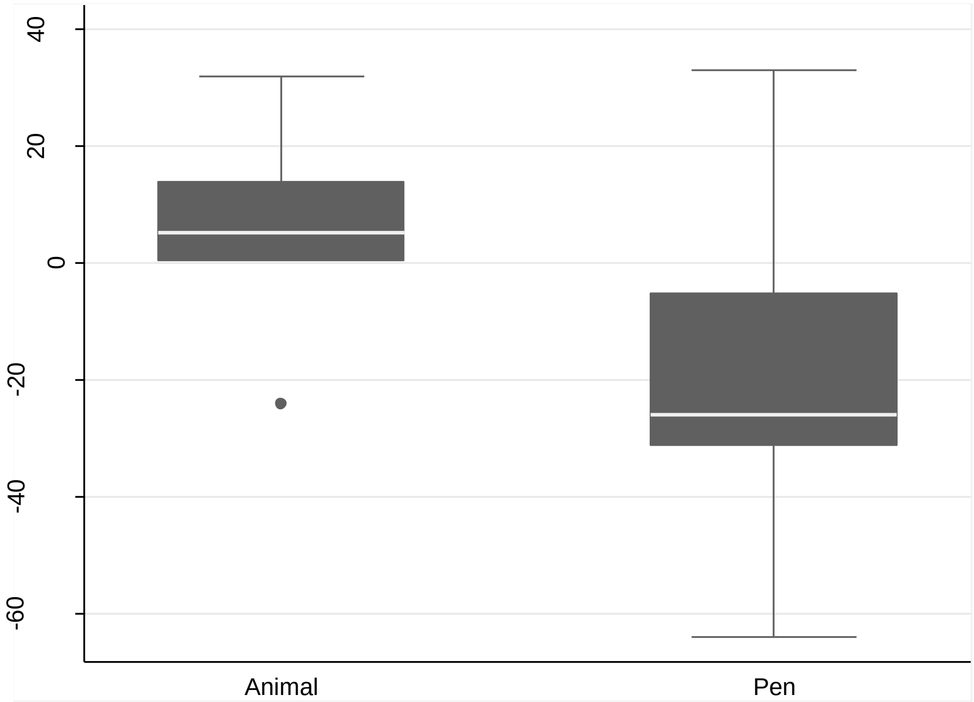


Figure 2.1.5 Raw mean differences for studies using animal or pen as the unit of interest for the effect of Zilpaterol on marbling score.

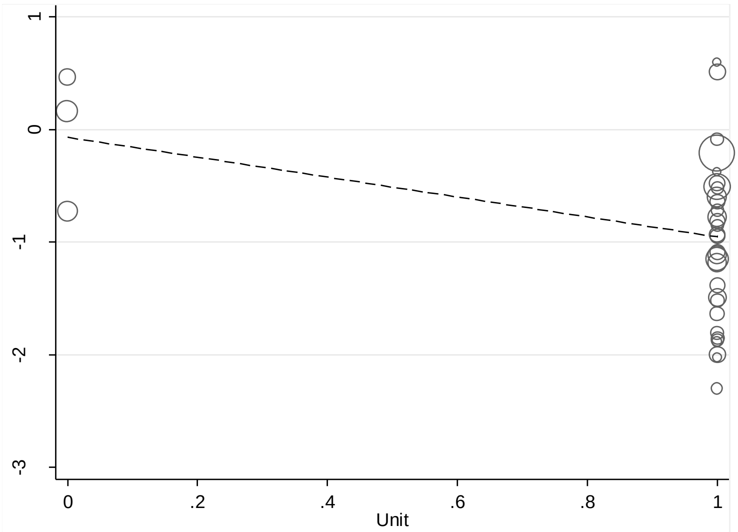


Figure 2.1.6 Effect sizes for studies using animal or pen as the unit of interest for the effect of Zilpaterol on marbling score.

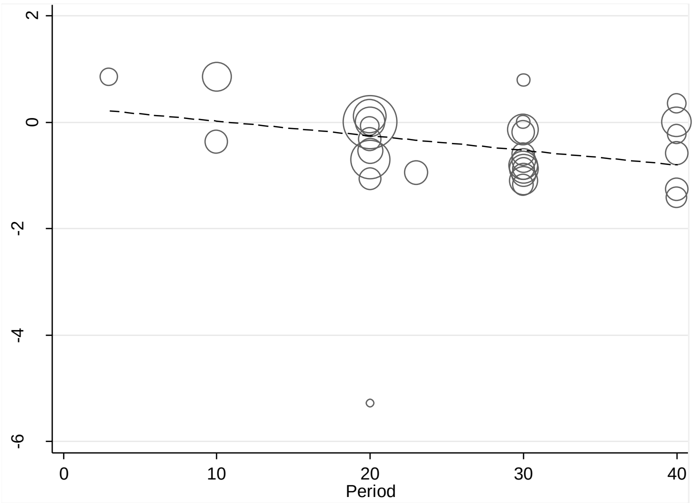


Figure 2.1.7 Effect sizes for length of feeding Zilpaterol on kidney, pelvic and heart fat score.

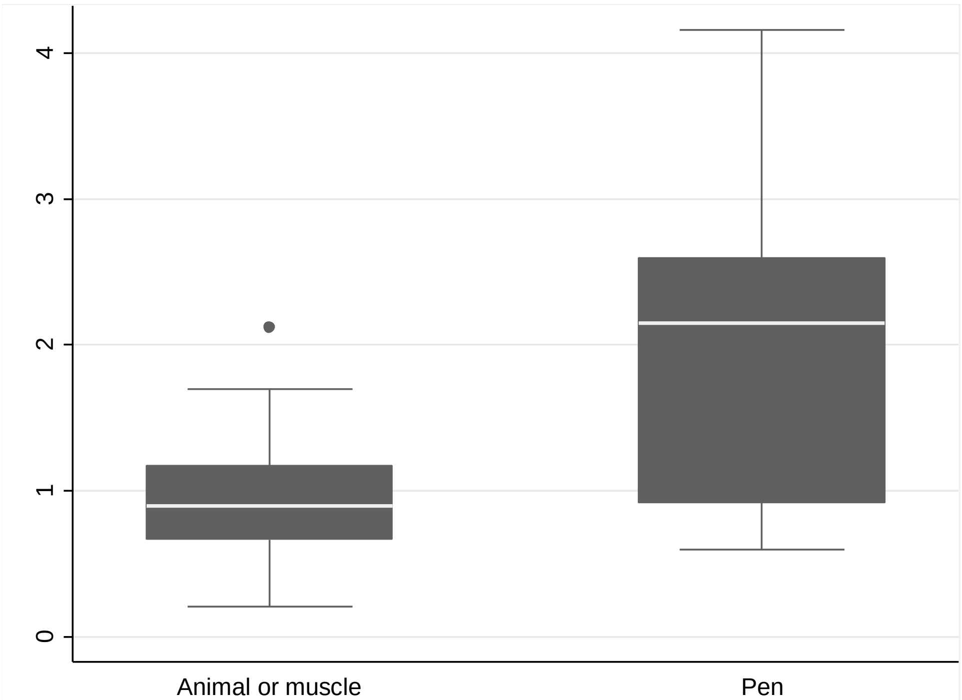


Figure 2.1.8a Standardised mean differences for studies using animal or pen as the unit of interest for the effect of Zilpaterol on Warner-Braetzler Shear Force (Kg).

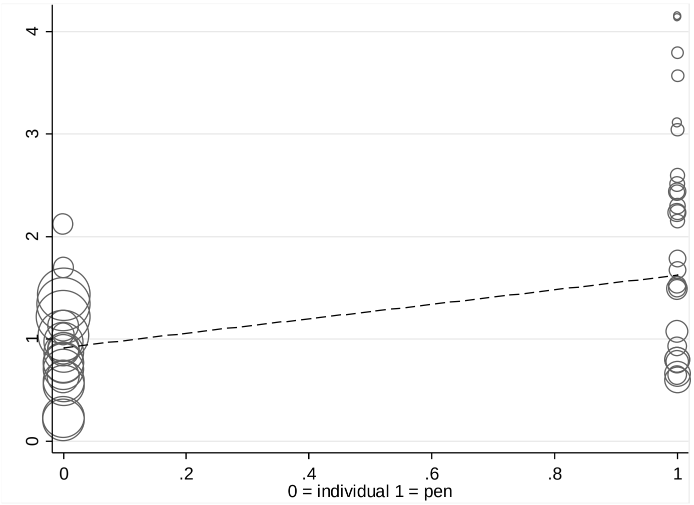


Figure 2.1.8b Standardised mean differences for studies using animal or pen as the unit of interest for the effect of Zilpaterol on Warner-Braetzler Shear Force (Kg).

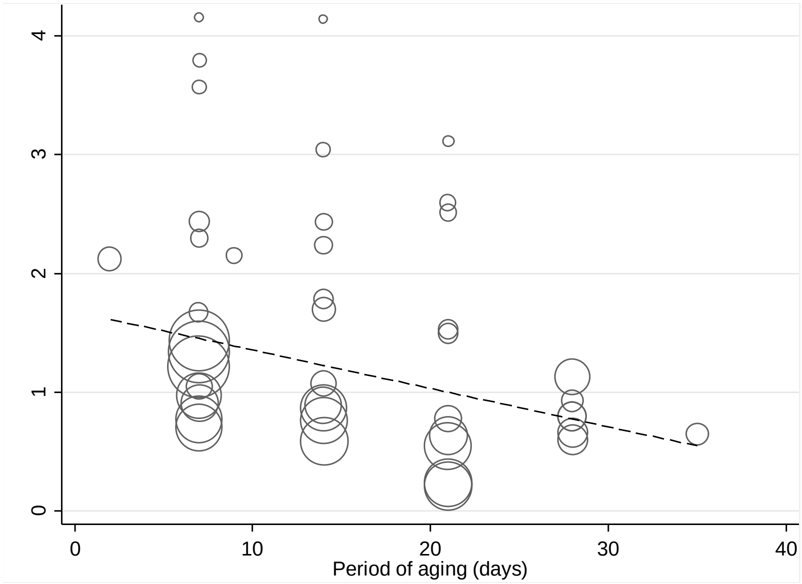


Figure 2.1.9 Effect of aging of steak (days) on the standardised mean difference of studies examining Zilpaterol and Warner-Braetzler Shear Force.

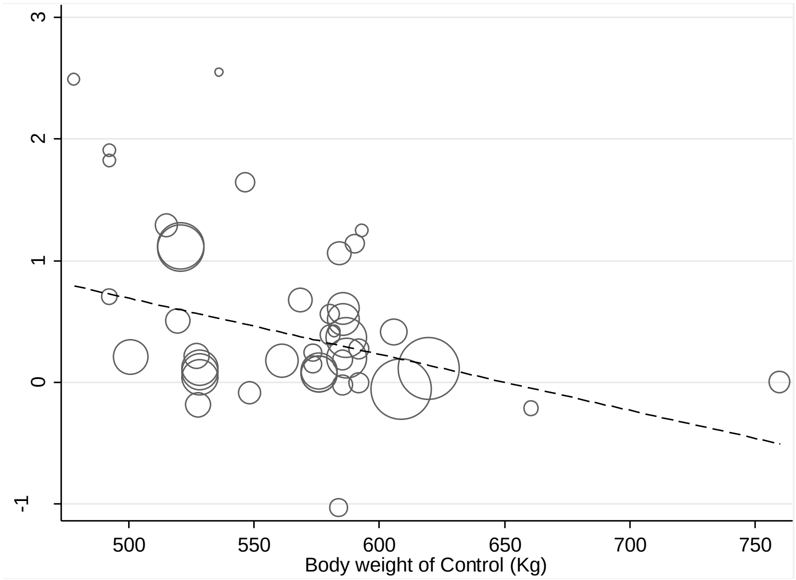


Figure 2.2.1 Effect of body weight of the control groups on the standardised mean difference of studies examining Ractopamine and body weight.

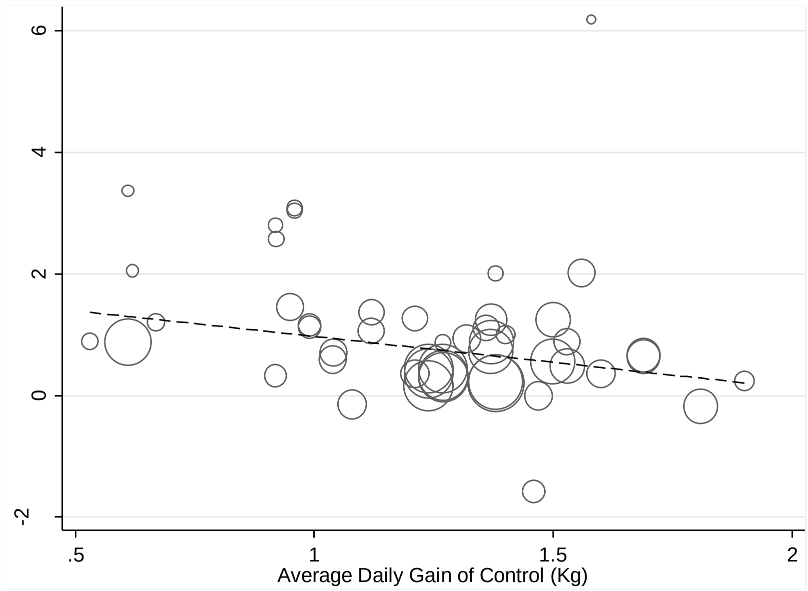


Figure 2.2.2 Effect of average daily gain (Kg) of the control groups on the standardised mean difference of studies examining Ractopamine and average daily gain.

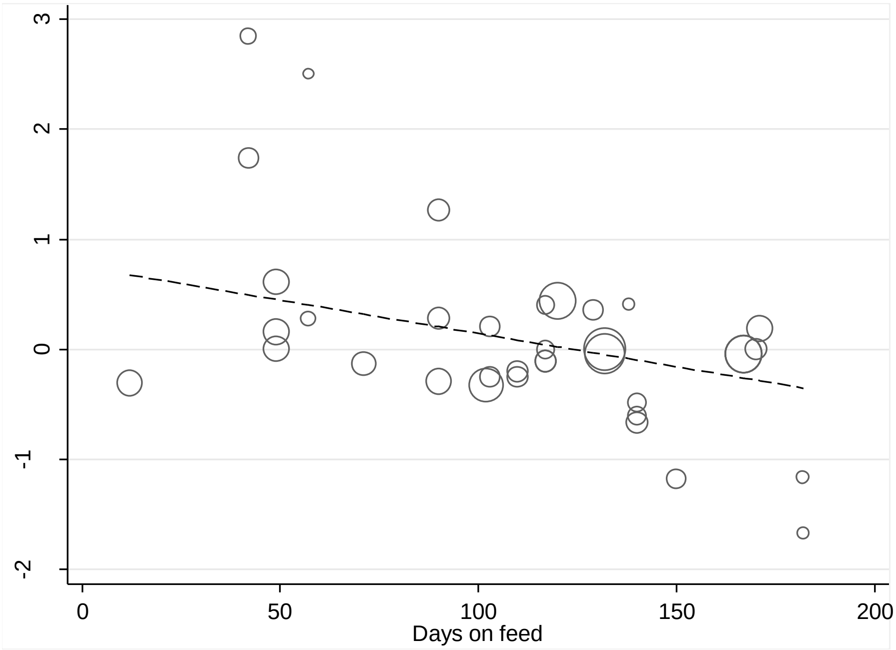


Figure 2.2.3 Effect of days on feed for the standardised mean difference of studies examining Ractopamine and fat thickness.

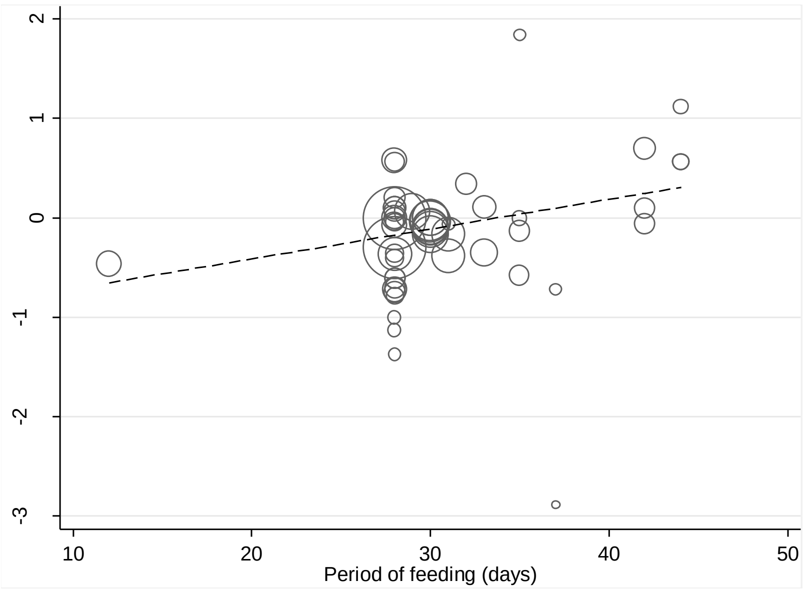


Figure 2.2.4 Effect of period of feeding (days) on the standardised mean difference of studies examining Ractopamine and yield grade.

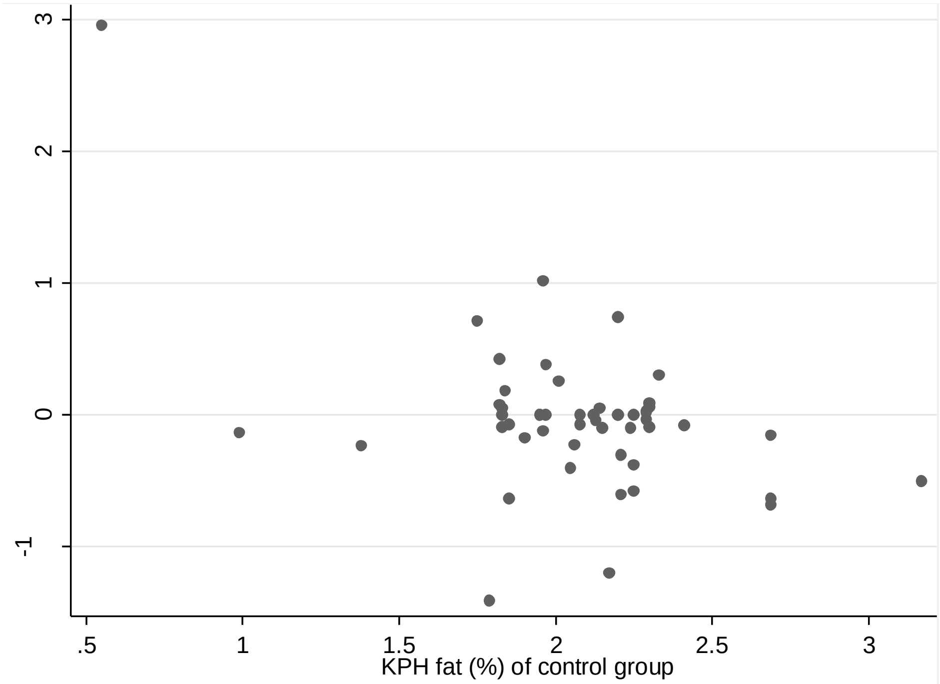


Figure 2.2.3 Effect of KPH fat % for the control group on standardised mean difference of studies examining Ractopamine and KPH%

Appendix 3

Countries identified that do not accept zilpaterol or ractopamine treated meat

Sources: Codex Alimentarius, Food and Agriculture Organisation – JECFA reports, http://www.farmfoundation.org/news/articlefiles/1754-Lively,%20Thad%20-%20ppt.pdf (US Meat Export Federation?), World Trade Organisation, USDA, over 40 other web sites. There appears to be no definitive source.

Stated as Banned: Russia, China, EU (27 countries), Egypt, Iran, India, Turkey, Taiwan, Kenya, Zimbawe, Australia, New Zealand, Argentina, Uruguay, Chile

Possible Bans: Switzerland, Ghana,

Users: Include USA, Mexico, Canada, South Africa (27 countries claimed)

Alternate views: Brazil approves Zilpaterol, Taiwan only bans pork and has a lower residual safety value.