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The Impact of Liver Abscesses on Performance and Carcass Traits in Beef Cattle: A Meta-Analysis Study

Rodrigo de Nazaré Santos Torres [1,*], David Attuy Vey da Silva [2,3], Luis Arthur Loyola Chardulo [1,4], Welder Angelo Baldassini [1,4], Rafael Assis Torres de Almeida [5], Marco Tulio Costa Almeida [5], Rogério Abdallah Curi [1,4], Guilherme Luis Pereira [1,4], Jon Patrick Schoonmaker [6] and Otavio Rodrigues Machado Neto [1,4]

1 School of Veterinary Medicine and Animal Science, São Paulo State University, Botucatu 18618-681, SP, Brazil; luis.artur@unesp.br (L.A.L.C.); w.baldassini@unesp.br (W.A.B.); rogerio.curi@unesp.br (R.A.C.); guilherme.luis@unesp.br (G.L.P.); otavio.machado@unesp.br (O.R.M.N.)
2 Department of Veterinary Medicine, Freie Universität Berlin, 14163 Berlin, Germany; attuy.david@gmail.com
3 Department of Biological Safety, German Federal Institute for Risk Assessment, 10589 Berlin, Germany
4 School of Agricultural and Veterinarian Science, São Paulo State University, Jaboticabal 14884-900, SP, Brazil
5 Department of Animal Science, Federal University of Espírito Santo, Vitória 29500-000, ES, Brazil; mv.rafaelassis@gmail.com (R.A.T.d.A.); marco.t.almeida@ufes.br (M.T.C.A.)
6 Department of Animal Sciences, Purdue University, West Lafayette, IN 47907, USA; jschoonm@purdue.edu
* Correspondence: rodrigo.torres@unesp.br

Abstract: The use of high-grain diets in feedlots is associated with the development of acidosis and ruminitis, which can lead to the occurrence of liver abscesses (LAs). However, the effect of LA on carcass traits is not well known. This study assessed the effects of LA on the performance and carcass traits of beef cattle. Nine peer-reviewed publications with forty-seven treatment means were included in the data set. The effects of the LA were evaluated by examining the weighted mean difference (WMD) between LA (animal with LA) and control treatment (animal without LA). Heterogeneity was explored by meta-regression, followed by a subgroup analysis of the scores and percentages of liver abscess and concentrate level in the feedlot diet. Animals affected by LA showed a reduction in dry matter intake (−1.03%) and feed efficiency (−1.82%). Animals with an LA score of “A” (one or two small abscesses) exhibited a decrease in carcass weight (WMD = 3.41 kg; $p = 0.034$) and ribeye area (WMD = -1.37 cm^2; $p = 0.019$). When assessing the impact of LA on carcass traits, the most reliable finding indicates a 1.21% reduction in the ribeye area, with no adverse effects observed on subcutaneous fat thickness or the marbling score in the carcass.

Keywords: abscess; carcass; feed efficiency; feedlot; liver

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1. Introduction

Projections for global protein consumption estimate a 33% increase over the next 30 years [1], with an expected 14% increase in global meat consumption by 2030 [2]. In this scenario, it becomes necessary not only to intensify cattle production systems, but also to improve the efficiency of feed utilization.

However, intensifying production systems (e.g., feedlots) associated with higher grain inclusion diets, especially in beef cattle, increases the risk of nutritional and metabolic disorders (e.g., ruminal acidosis and ruminitis). The reduction in ruminal pH and the lack of effective fiber can injure the ruminal epithelium, leading to the inflammation and translocation of pathogenic ruminal microorganisms, particularly *Fusobacterium necrophorum* and endotoxins, to the liver via the bloodstream. Hepatic abscesses are a common sequela [3,4].

While ruminal health has received much attention, it is increasingly evident that the impact of high-grain diets on other sections of the gastrointestinal tract (GIT) substantially contribute to the overall pathophysiology of the GIT disease [5]. Indeed, the portal vein collects blood from the entire GIT, and recent evidence suggests that a considerable number of bacterial endotoxins and liver abscess microbes arise from the post-ruminal GIT [6–8].

The occurrence of liver abscesses (LAs) causes a reduction in animal performance and feed efficiency [9], as the liver is the central organ of metabolism, accounting for 40 to 50% of total oxygen consumption in cattle [10]. Liver abscess also decreases carcass weight and yield [11,12] or may lead to carcass condemnation when contamination occurs due to abscesses rupturing during slaughter. According to Harris et al. [13], liver condemnation due to the occurrence of LA is responsible for 58% of liver condemnations in the USA.

However, few studies in the literature assess the impact of LA on carcass traits and meat quality, resulting in a lack of standardization in assessing the occurrence of LA, rendering this parameter unreliable for comparison and practical applications. Liver abscess can be categorized by the incidence or severity of the abscess, with a score based on their number and size. However, there is no standardization in the classification of LA, leading to variation in the different scales reported. These have varied from a more comprehensive scale [14] to a narrower scale [15]. For example, Brown et al. [14] suggested a scale where: abscess score 0 = no abscess, A- = one or two small abscesses or inactive scars, A = one or two large abscesses or several small abscesses, and A+ = multiple large abscesses often involving collateral tissue. A simpler scale was suggested by Elanco, [15], where: abscess score of 0 = no abscess, A = one or two small abscesses, and A+ = one or more large abscesses. A standardization in classification is needed to ensure accuracy in assessing the impact of LA on carcass and meat quality characteristics.

Moreover, several factors influencing the occurrence of LA (e.g., genetic group, sex, diet, days on feed, and biological type; [16]) and the impact of LA on carcass traits are still not well understood. Therefore, we hypothesize that the negative impact of LA on carcass traits depends on factors such as genetic group, sex, diet, days on feed, and biological type. The objective of the present study was to evaluate the effects of liver abscesses in beef cattle on their performance and carcass parameters using a meta-analytic approach.

2. Materials and Methods

2.1. Data Set

A comprehensive literature search was conducted using three search engines: PubMed (https://www.ncbi.nlm.nih.gov/pubmed), Science Direct (http://www.sciencedirect.com/), and Wiley Library (https://onlinelibrary.wiley.com/search/advanced). The searches were conducted between 5 July 2023. A total of 340 publications were retrieved using the search terms "liver abscess AND beef cattle". Of the papers that were retrieved, only those that satisfied the predefined inclusion criteria were included in the meta-analysis. For inclusion into the meta-analysis, studies had to have the following standardized criteria: (1) the control group (without LA) and the treatment group (with LA); (2) the diet of the control group (without LA) could not include antibiotic additives; (3) data were only from beef cattle intended for meat production. A flowchart detailing the study identification and selection for analysis is shown in Figure 1. Based on the inclusion criteria, 9 peer-reviewed publications with 47 treatment means were used (Table 1). The complete data set is available in Supplemental File S1.

Table 1. Summary of the characteristics of studies included in the systematic review and subsequent meta-analysis.

	N of Animals	Genetic Type	LA score (Elanco 2019 [a])	LA %	Concentrate in Diet (g/kg)	Days on Feed	Variable
Brink et al. [11]	--	--	A, A, A+, A, A, A+	--	--	--	DMI, BWf, ADG, FE, CW, DRE
Brown and Lawrence [9]	72,225	--	A, A, A+, A, A	--	--	--	CW, MAR, RIB, SFT, KPH, USDA
Calderon-Cortes and Zinn [17]	32	Crossbreed	--	12.5; 12.5	840; 920	80	DMI, BWf, ADG, FE, CW, DRE, MAR, RIB, SFT, KPH, USDA

Table 1. *Cont.*

	N of Animals	Genetic Type	LA score (Elanco 2019 [a])	LA %	Concentrate in Diet (g/kg)	Days on Feed	Variable
Depenbusch et al. [18]	299	Crossbreed	--	2.4; 2.5; 4.8; 7.2; 2.4; 2.4	994; 1000; 994; 1000; 994; 994	--	DMI, BWf, ADG, FE, CW, DRE, MAR, RIB, SFT, KPH, USDA
Huck et al. [19]	306	Crossbreed	A, A, A, A, A, A, A, A	--	900	--	DMI, BWf, ADG, FE, CW, MAR, SFT, KPH
Jorgensen et al. [20]	48	Danish Friesian bull	--	9.09; 20.0; 22.72	--	210	DMI, BWf, ADG, CW, DRE
May et al. [21]	243	Crossbreed	--	3.1; 9.4; 3.1; 6.3; 9.4; 3.1; 9.4; 3.1; 6.3; 9.4	994		DMI, BWf, ADG, FE, CW, DRE, MAR, RIB, SFT, KPH, USDA
Mir et al. [22]	48	Crossbreed	--	36.0	860	157	DMI, BWf, ADG, FE, CW, DRE, MAR, RIB, SFT
Salim et al. [23]	102	Crossbreed	A	-	900		DMI, BWf, ADG, FE, CW, DRE, MAR, RIB, SFT

LA = liver abscess; ADG = average daily gain; BWf = final body weight; CW = carcass weight; DM = dry matter; DMI = dry matter intake; DRE = dressing; FE = feed efficiency; MAR= marbling score; RIB = ribeye area; SFT = subcutaneous fat thickness; KPH = kidney, pelvic, and heart fat; USDA = USDA calculated yield grade; (--) = not reported or informed. [a] Liver abscess score (Elanco, 2019): A = small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses (n $\geq$ 1), with inflammation of surrounding liver tissue (portions of the diaphragm are often adhered to the surface of the liver and have to be trimmed to separate the liver from the carcass).

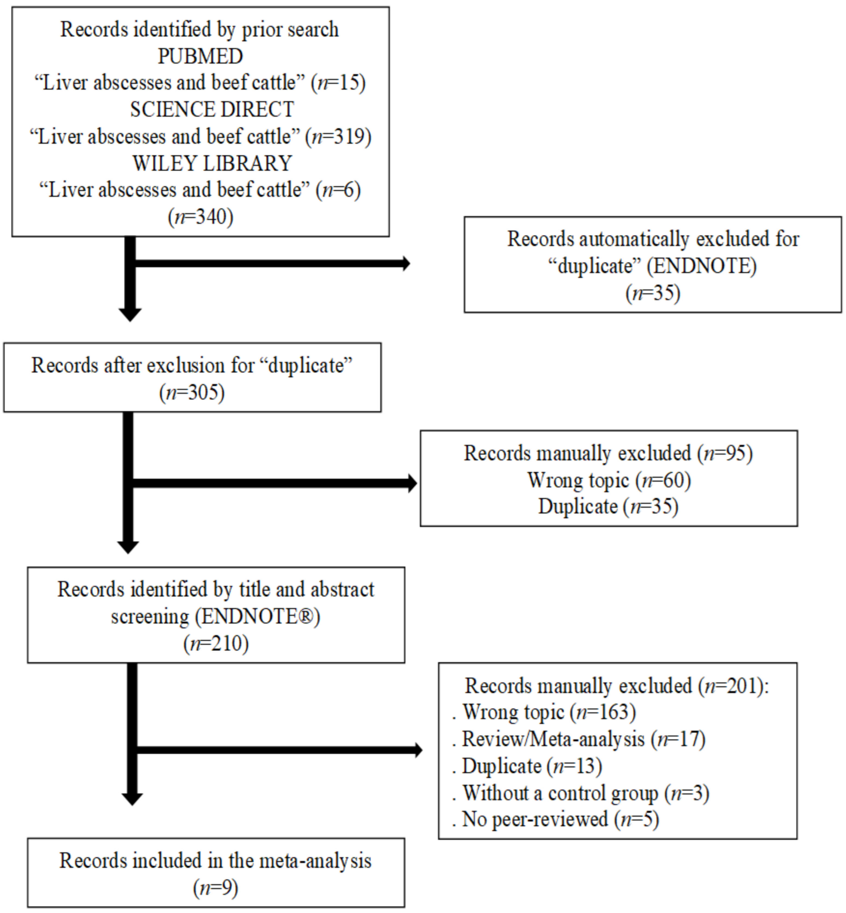

Figure 1. Flowchart showing results obtained from the search strategy and the selection of eligible studies for the meta-analysis on the effect of liver abscesses on performance and carcass traits in beef cattle.

2.2. Statistical Analysis

2.2.1. Weighted Mean Difference and Publication Bias

A meta-analysis was conducted using R Statistical Software (Metafor package, version 4.4.0; Viechtbauer, [24]). Forest plots were created using STATA software (Version 16.0; StataCorp LP, College Station, TX, USA) and the effects of liver abscess occurrence on the carcass parameters in beef cattle were evaluated by examining the weighted mean difference (WMD) between the presence and the absence of LAs. The treatment means were weighted by the inverse of the variance, according to the method proposed by Der-Simonian and Laird, [25] for the random effects model.

Between-study variability (i.e., heterogeneity of the treatment effect) was evaluated using both the chi-squared (Q) test of heterogeneity and I^2 statistics, which measures the percentage of variation due to heterogeneity [26]. Negative I^2 values were assigned as zero. An I^2 value lower than 25% indicates low heterogeneity, whereas values between 25% and 50% denote moderate heterogeneity, and those above 50% denote high heterogeneity [26].

Publication bias was evaluated using the funnel plot [27] (Figure S2) and asymmetry test (indicative of publication bias), which was performed according to the Egger regression asymmetry test among the WMD and SE [28]. Significance was declared at $p \leq 0.05$. Outliers were removed when studentized residuals were outside the range of −2.5 to 2.5 (outliers).

2.2.2. Meta-Regression and Subgroup Analysis

Meta-regression analysis was conducted to identify categorical covariate effects and select variables for subgroup analysis. A mixed model was applied to adjust the data in the meta-regression analysis using WMD as the dependent variable. The mixed-effect models were given by:

$$\theta i = \beta + \beta i\ xij + \ldots \beta ip\ xip + \mu i \quad (1)$$

where: θi = the true treatment effect in the ith explanatory variable; β = the overall true effect treatment; xij = the value of the jth covariate (j = 1, 2, . . ., p) for the ith explanatory variable; βi = change in the true effect size for a unit increase in the jth covariate; and $\mu i \sim N(0\ t^2)$. Here, t^2 indicates the amount of heterogeneity not explained by the covariate [24].

The calculation of the moment estimator of the between-study variance (Tau-squared = T^2) is used in DerSimonian and Laird random effects meta-analysis, but it is less suitable when covariates are included [29]. The restricted maximum likelihood estimate (REML) approach was used to estimate T^2 because it is less likely to underestimate or produce biased variance estimates [29,30]. Tests of the null hypothesis for the covariate coefficients were obtained from the multiparameter Wald test [31]. The adjusted R^2 for the model represents the proportion of between-study variance (heterogeneity) explained by the covariates [24,31]. The meta-regression criteria were: (1) $p \leq 0.05$ for the heterogeneity test; (2) $p \geq 0.05$ for the funnel plot; (3) no observations with values for studentized residuals out of the range −2.5 to 2.5 (outliers).

The covariates were divided as follows, due to differences in the scales used to assess LA severity (abscess score and abscess incidence) among studies. Abscess score scales were standardized according to Elanco [15] to enable the evaluation of the liver abscess score in the subgroup analysis:

- Liver abscess score A or A+, where A= small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses (n ≥ 1), together with inflammation of liver tissue surrounding the abscess (often, portions of the diaphragm are adhered to the surface of the liver and have to be trimmed to separate the liver from the carcass);
- Liver abscess incidence (2.4–4.8% or 6.3–9.4%);
- Levels of diet concentrate (840–900 g/kg or > 900 g/kg DM).

Subgroup analysis was performed when WMD's categorical covariates were significant at $p \leq 0.10$ (meta-regression analysis).

2.2.3. Standardized Mean Difference

The effect size was calculated as the standardized mean difference (SMD), which is the difference between the presence and the absence of LAs., standardized using the standard deviations from the groups with and without LAs. Consequently, the SMD data are expressed in standard deviation units [32]. The SMD estimates were calculated using the methods of DerSimonian and Laird [25] for random effects models.

3. Results

The dataset was composed of nine peer-reviewed publications with forty-seven treatment means. The predominant genetic group was crossbred animals, representing 70% (n = 33) of the treatment means, followed by Danish Friesian bull (6%; n = 3) and not informed (23%; n = 11). The studies included in the analysis showed that the LA score "A" (one or two small abscesses) accounted for 83% (n = 24) of the treatment means, followed by "A+" (one or more large abscesses; 17%, n = 5). The incidence of liver abscesses ranged from 2.4% to 4.8% in 50% (n = 14), followed by 27% (n = 8), 9% (n = 3), 4% (n = 1), and 4% (n = 1) of treatment means for incidences of 6.3–9.4%, 12.5%, 22.72%, and 36%, respectively. The information regarding the incidence was not provided in 5% (n = 2) of the treatment means.

Regarding the concentrate levels in the diets, 36% (n = 17) of the treatment means showed levels ranging from 840 to 900 g concentrate/kg DM in the diet, 34% (n = 16) above 900 g concentrate/kg DM, and 30% (n = 14) of the studies did not report this information. Table 2 describes how LA globally affects each response parameter.

Table 2. Effects of liver abscesses on the performance and carcass traits in beef cattle.

Item [1]	No Abscesses [2] Mean (SD)	*N* [3]	Liver Abscess		Heterogeneity [5]		Funnel Test [6]
			[4] $WMD_{Random\ effect}$ (95% CI)	*p*-Value	*p*-Value	I^2 (%)	*p*-Value
DMI, kg/d	9.36 (1.15)	39	−0.097 (−0.19, −0.01)	0.043	0.060	27.44	0.567
BWFinal, kg	551.73 (69.74)	41	−2.112 (−5.63, 1.14)	0.240	0.047	28.62	0.223
ADG, kg/d	1.57 (0.31)	42	−0.020 (0.13, −0.04)	0.131	0.033	30.71	0.132
FE, kg/kg	0.165 (0.018)	35	−0.003 (−0.01, −0.01)	0.031	0.058	28.91	0.260
Carcass weight, kg	341.80 (47.23)	47	−1.789 (−4.12, 0.54)	0.133	0.001	48.81	0.115
Carcass dressing, %	60.95 (2.75)	33	0.095 (−0.11, 0.29)	0.347	0.033	33.50	0.088
SFT, mm	11.09 (1.82)	36	−0.103 (−0.37, 0.17)	0.456	0.514	0.00	0.181
Ribeye area, cm^2	83.76 (6.91)	30	−1.018 (−1.64, −0.38)	0.002	0.676	0.00	0.432
KPH, %	2.37 (0.28)	29	−0.007 (−0.03, 0.02)	0.655	0.729	0.00	0.736
USDA YG (SMD) [7]	--	21	−0.004 (−0.02, 0.01)	0.722	0.729	0.00	0.449

[1] DMI = dry matter intake; BW = body weight; FE = feed efficiency; ADG = average daily gain; SFT = subcutaneous fat thickness; KPH = kidney, pelvic, and heart fat; USDA yield grade (YG). [2] Control treatment = no abscesses; a normal, healthy liver; SD = standard deviation. [3] N represents the number of comparisons for control and treatment with liver abscess (complete data set is available in Supplementary File S1). [4] WMD = weighted mean differences between control and animal with liver abscess. [5] I^2 proportion of total variation of size effect estimates due to heterogeneity. *p* value to χ2 (Q) test of heterogeneity. [6] Egger's regression asymmetry test (Funnel test). [7] SMD = standard mean difference (SMD random effect (95%CI)).

3.1. Feed Intake, Animal Performance, and Carcass Parameters

Animals affected by LA showed a reduction in dry matter intake (DMI; $p = 0.043$), feed efficiency ($p = 0.031$), and ribeye area ($p = 0.002$). However, the presence of LA had no significant effect on the final body weight ($p = 0.240$); average daily gain (ADG; $p = 0.131$); carcass weight ($p = 0.133$) and dressing ($p = 0.347$); subcutaneous fat thickness (SFT; $p = 0.456$); or kidney, pelvic, and heart fat (KPH; $p = 0.655$; Table 2).

3.2. Marbling Score and United States Department of Agriculture Beef Yield Grade

The effects of LA in beef cattle on the marbling score and United States Department of Agriculture (USDA) beef yield grade (YG) were evaluated through the standardized mean difference (SMD) analysis. This procedure was used because studies included in this meta-analysis used different methodologies for the marbling score and USDA YG, which limits the transformation of measurement units. In this sense, LA had no significant effect on the marbling score ($p = 0.841$; Figure 2) and USDA YG ($p = 0.722$; Table 2).

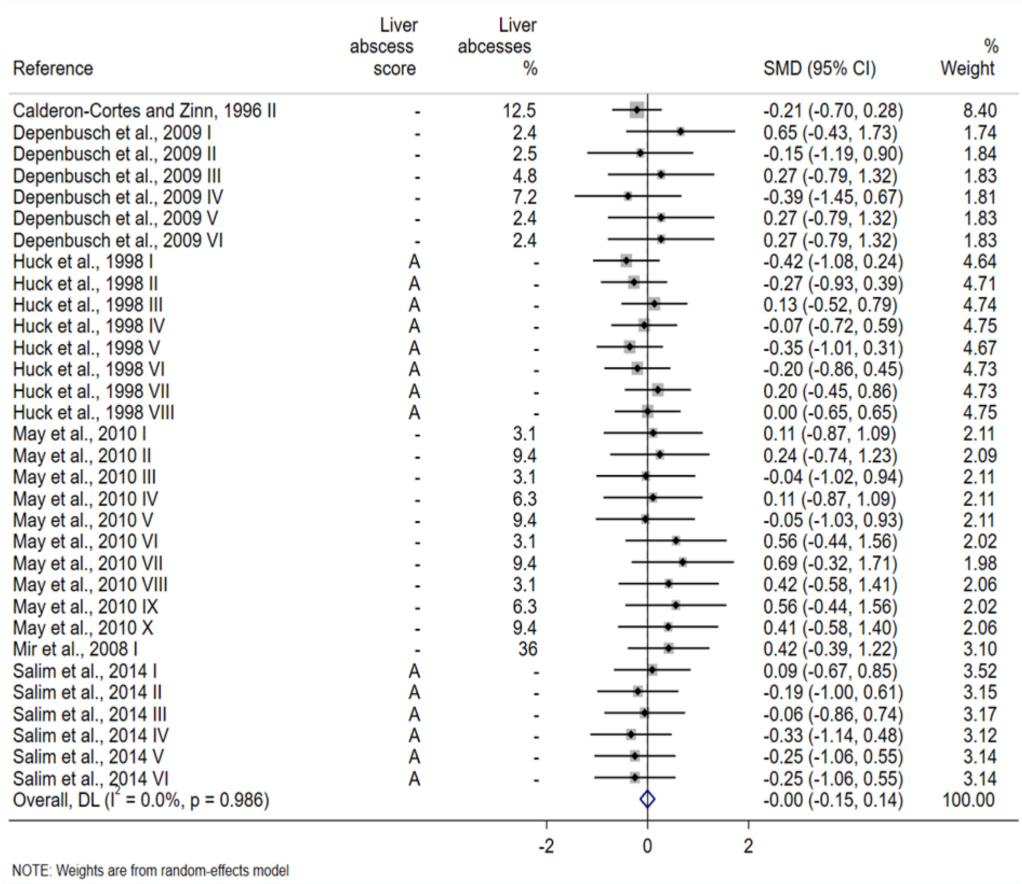

Figure 2. Forest plot of standardized mean difference (SMD) between the means calculated for the marbling score in beef cattle with and without liver abscesses. Liver abscess score is standardized after Elanco [15] where: A = small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses ($n \geq 1$), with inflammation of surrounding liver tissue. Solid squares for the separate individual studies (denoted by roman numerals) represent weighting by the inverse of their respective variances. The horizontal lines represent the 95% confidence interval (CI) of each study. The open diamond represents the overall SMD and its width represents the associated 95% confidence interval. I-squared (I^2) represents the proportion of total variation of effect size estimates due to heterogeneity, and % weight represents the contribution of the study to the overall effect size. Weights are from the random effects model. DL represents the treatment means weighted by the inverse of the variance, according to the method proposed by DerSimonian and Laird [25] for a random effects model. The reference are Calderon-Corte and Zinn [17], Depenbusch et al. [18], Huck et al. [19], May et al. [21], Mir et al. [22], Salim et al. [23].

3.3. Meta-Regression and Subgroup Analysis

For the variables evaluated in Table 2, medium heterogeneity was observed (I^2 statistic 25 to <50%). However, the presence of publication bias ($p > 0.05$) from the funnel plot asymmetry test (Funnel test) was not evident (Table 2). Table 3 presents the effect of the covariates on the variation of the response variables (meta-regression analysis).

The incidence of LAs was evaluated (covariate = liver abscess (%)), resulting in 2.4–4.8% of LAs and a reduced feed efficiency, with the calculated WMD = −0.004 kg/kg and $p = 0.028$ (Figure 3) and, conversely, an increase in carcass dressing, with WMD = 0.39% and $p = 0.001$ (Figure 4).

Table 3. Meta-regression of the effect of liver abscesses (LA) on performance and carcass traits in beef cattle on weighted mean differences (WMD) between the presence and absence of abscesses.

Dependent Variable	Meta-Regression Parameters (p-Value)				Adjusted R^2 (%) [2]	N^3
	Intercept	LA Score [1]	LA %	Concentrate in Diet (g/kg of DM)		
BWFinal, kg	48.4 (0.01)	−42.7 (0.01)	−34.5 (0.06)	−12.3 (0.02)	29.51	41
ADG, kg/d	0.44 (0.01)	−0.39 (0.01)	−0.27 (0.05)	−0.14 (0.01)	100	42
FE, kg/kg	−0.01 (0.68)	0.01 (0.12)	−0.01 (0.88)	−0.01 (0.01)	57.77	35
Carcass weight, kg	25.1 (0.03)	−26.9 (0.02)	−20.4 (0.09)	−3.10 (0.28)	25.88	47
Carcass dressing, %	−3.65 (0.05)	3.35 (0.08)	3.93 (0.04)	0.05 (0.87)	51.73	33

ADG = average daily gain; BW = body weight; FE = feed efficiency; DM = dry matter. [1] Liver abscess score (Elanco, 2019): A = small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses (n ≥ 1), with inflammation of surrounding liver tissue (portions of the diaphragm are often adhered to the surface of the liver and have to be trimmed to separate the liver from the carcass). [2] Adjusted R^2 = proportion of the between-study variance (heterogeneity) explained by the covariate. [3] N = the number of comparisons between animal with liver abscess and normal (no abscesses—a normal, healthy liver) (complete data set is available in Supplementary File S1).

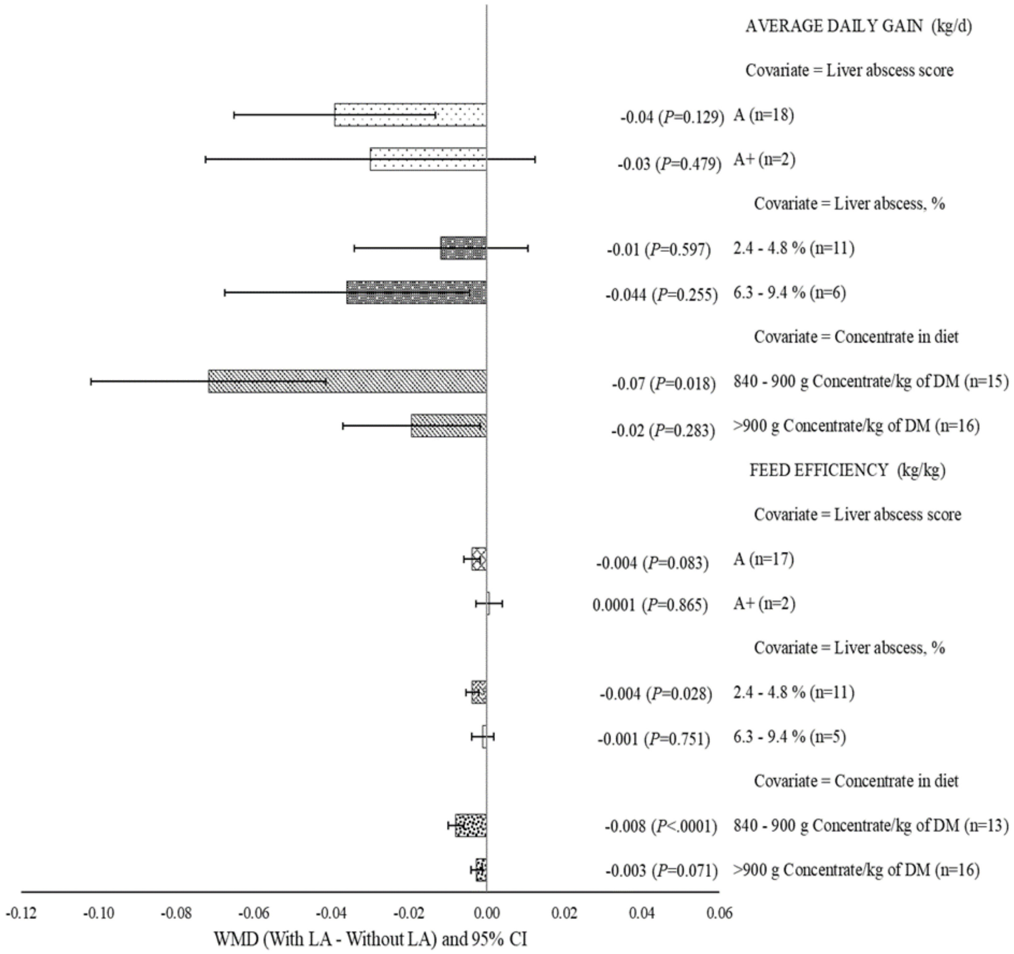

Figure 3. Subgroup analysis of the effect of liver abscess on beef cattle performance. Liver abscess score is standardized after Elanco [15] where: A = small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses (n ≥ 1), with inflammation of surrounding liver tissue. WMD = weighted mean differences between the presence and absence of liver abscess.

When assessing the effect of concentrate levels in the diet of animals with LA (covariate = concentrate in diet), it was observed that animals receiving diets with 840–900 g concentrate/kg DM had reduced average daily gain (WMD = −0.07 kg/d; p = 0.018), feed efficiency (WMD = −0.008 kg/kg; p < 0.0001; Figure 3), and ribeye area (WMD = −1.53 cm^2;

$p = 0.012$; Figure 4). The covariate "Liver abscess score" revealed a reduction in carcass weight (WMD = −3.41 kg; $p = 0.034$; Figure 4) when the abscess score "A" (one or two small abscesses) was assessed.

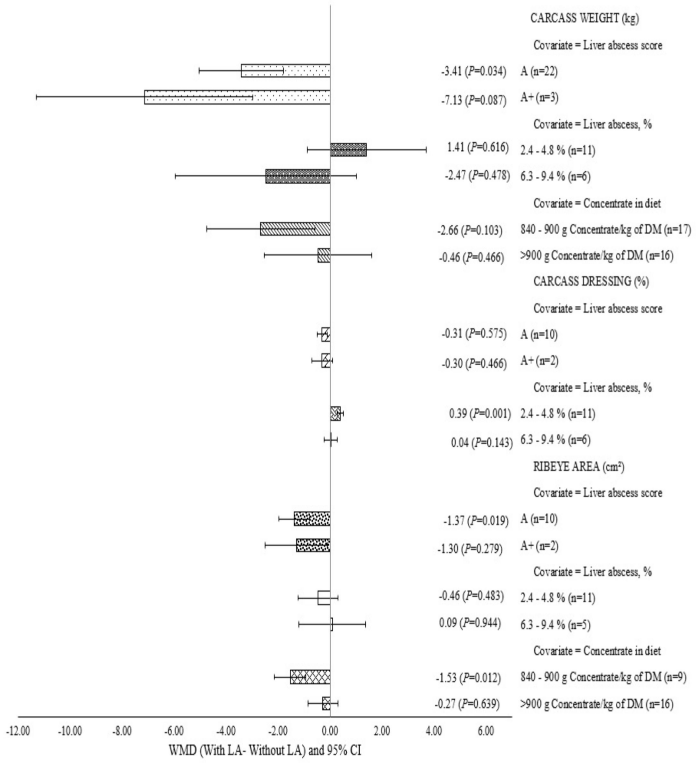

Figure 4. Subgroup analysis of the effect of liver abscess on carcass traits in beef cattle. Liver abscess score = liver abscess score, standardized (Elanco, 15): A= small abscesses (n = 1–2) or well-organized abscesses (n = 2–4) usually under one inch in diameter (the remainder of the liver looks healthy); A+ = large abscesses ($n \geq 1$), with inflammation of surrounding liver tissue. WMD = weighted mean differences between the presence and absence of liver abscess.

4. Discussion

The conducted meta-analysis revealed a mild-to-moderate severity of LA in beef cattle, which corroborates the data previously reported by Davis et al. [33] and Brown and Lawrence [9]. An LA incidence close to 10% was observed in 77% of the analyzed treatment means, and there was a percentage of 83% with regard to the presence of LA as "A" (one or two small abscesses [15]). The authors Davis et al. [33] and Brown and Lawrence [9] assumed that the mild-to-moderate cases of LA would cause no impact or only a minor impact on the animals' performance. However, our findings demonstrated reductions of 1.03% in DMI and 1.8% in feed efficiency in animals affected by LA.

A reduction in muscle deposition in the carcass is consistently associated with the presence of LA and, indeed, a decrease of 1.21% in the ribeye area (WMD = −1.02 cm^2) was observed in beef cattle affected by LA. Although opposite results were reported in the literature [9,33], the consistency of these responses is confirmed by the low heterogeneity value obtained in the analysis ($I^2 = 0.00\%$). The I^2 represents the proportion of total variance between studies due to true differences in effect sizes rather than chance. Furthermore, an I^2 of 0% indicates that all variability in the effect estimate is due to chance and none is due to heterogeneity [34]. These reductions can be explained due to the high occurrence of LA in ruminants, which manifest as localized infections in the liver [34,35].

Concerning DMI, this reduction in feed intake directly affects their nutrient intake and overall performance [35,36]. According to Fuerniss et al. [37], the liver plays a crucial role in digestion and nutrient metabolism. Thus, if abscesses compromise the liver, it may not function optimally, impairing metabolism and reducing nutrient utilization. These effects can lead to a limited growth rate (ADG) and lower feed efficiency in animals, as observed in this study.

The reduction of DMI and ADG can also explain the negative effects of LA on carcass traits such as carcass weight and dressing, which were influenced by the level of concentrate inclusion in the diet. According to Plaizier et al. [38], LA can impact the overall health and well-being of the animal, resulting in decreased carcass quality. Abscesses can lead to liver condemnations during post-mortem inspections, causing economic losses for the livestock industry [39].

However, the lack of effect of the LA presence on ADG, feed efficiency, carcass weight, and ribeye area in animals fed diets with concentrate levels above 90% could be attributed to a compensatory effect of the greater digestibility of these diets, which would offset the increased nutritional requirements of LA-affected animals. According to Batista and Holland, [12], the presence of LA can increase the net energy for maintenance requirements in cattle by up to 4.8%.

These results partially confirm our hypothesis that risk factors for LA, such as genetic group, sex, diet, feeding period, may impact carcass traits. However, it should be noted that we were only able to evaluate the effect of concentrate level in the feedlot diet as a covariate due to limitations in the information provided by the studies included in the dataset.

In addition, considering the impact of LA on carcass traits, the description of the severity of LA occurrence (score) had a significant effect on performance variables and carcass traits, which was not observed when evaluating the effect of LA presence by simply assessing its incidence (%). The reason that the LA score, rather than percentage, had a significant statistical effect could be the result of a dilution effect of LA on carcass traits when presented as the percentage of affected animals relative to the total number of animals in the experimental group, especially in studies with a low LA incidence. The present study demonstrated that LA occurrences below 9.4% did not affect the ADG, carcass weight, and ribeye area, whereas the presence of only one or two small abscesses (liver abscess score standardized as "A" by Elanco [15]) resulted in a reduction in carcass weight (WMD = 3.41 kg) by decreasing the size of the ribeye area (WMD = 1.37 cm^2).

The effect of moderate-severity LA on animal performance also may be associated with the level of concentrate in the diet, which can compensate for the increased nutritional requirements of the animals [9,33]. The LA effect on the tissue deposition pattern in the carcass should also be considered, since the presence of LA resulted in a reduction in muscle deposition (ribeye area reduction) without affecting fat deposition in the carcass (e.g., SFT and KPH). This result explains the absence of an LA effect on USDA YG on the carcass.

The decrease in muscle deposition can be explained by the inflammatory process resulting from the LA, which is associated with a reduction in the activity of gluconeogenesis enzymes [40]. Furthermore, a decreased ribeye area is also related to a decrease in protein synthesis and hepatic lipolysis [41] in response to an increase in the concentration of acute-phase proteins such as serum amyloid in LA-affected animals [42]. The increase in the circulating concentration of acute-phase proteins is associated with a greater mobilization of aromatic amino acids from skeletal muscle for their synthesis in the liver [43]. Decreases in muscle deposition can also relate to the increase in the circulating concentration of cortisol [44], as observed in LA-affected animals [45]. Corticosteroids reduce protein synthesis and stimulate degradation, mobilizing amino acids for gluconeogenesis under stress or food restriction [40] without affecting lipid synthesis in adipose tissue. Also, in addition to the inflammatory effect, LAs are associated with reduced blood concentrations of testosterone and thyroid hormones such as thyroxin-T4 [46], which can lead to a reduction in the hormonal stimulus for skeletal muscle deposition and an increase in the turnover of muscle protein.

Overall, the occurrence of LA of up to 10%, as well as the presence of one or two small abscesses, are associated with a reduction in skeletal muscle deposition without impairing fat deposition in the carcass. Liver abscesses can lead to significant losses in the meat processing chain, since the value of the carcass and meat depends on its protein content.

5. Conclusions

Our meta-analysis demonstrated that LA impacts the performance and carcass traits of feedlot beef cattle. When evaluating the effect of LAs on carcass traits, the most consistent response regarding the presence of LAs was a 1.21% reduction in the ribeye area, without impairing the SFT and KPH of the carcass.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ruminants4010005/s1, Table: Supplementary File S1 and Figure S2: Funnel plots.

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