Effects of dietary supplementation of peanut skins (Arachis hypogaea) on performance, digestibility, and rumen fermentation of cattle: A meta-analysis

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Abstract

The objective of this study was to estimate the magnitude of effects of the dietary inclusion of Peanut skins (PS) byproduct (*Arachis hypogea L.*) on intake, total-tract digestibility, and rumen fermentation of cattle via meta-analysis. Data were collected following the PRISMA methodology. Nine manuscripts and a graduate thesis met the inclusion criteria from 1983 to 2010. The effect size was estimated by calculating the weighted raw mean differences (RMD) between PS vs. control diets. The RMD was compared with a robust variance estimation method followed by a meta-regression and a dose-response analysis fitting the diet characteristics like crude protein (CP), NDF content, ether extract content (EE), PS level in diet (0 to 40%), and tannin content as covariates. Dietary PS decreased ($P < 0.01$) total-tract CP digestibility (52.0 vs. 64.3%), final body weight (371.5 vs. 397.9 kg), and average daily gain (1.14 vs. 1.44 kg/d) among treatment comparisons. Likewise, PS decreased total VFA (92.6 vs. 107.6 mmol/L) and NH_3N (8.22 vs. 12.1 mg/dL) among treatment comparisons, but no effects were observed on rumen pH (6.47 vs. 6.14), acetate (52.6 vs. 50.4%), propionate (31.9 vs. 33.1%), and butyrate (11.02 vs. 11.2%) molar proportions among treatment comparisons. Despite the between-cluster variance, dietary PS increased the ether extract digestibility (77.5 vs. 70.2%) among treatment comparisons. The subset and dose-response analysis revealed that PS should not exceed 8% (DM basis) in the diet to prevent negative effects on CP digestibility and animal performance. The tannin content in the diet strongly influenced the observed effects on rumen fermentation suggesting a low tolerance (> 3% in the diet) by cattle to tannins in PS. In conclusion, the results of this meta-analysis do not support the dietary inclusion of PS in cattle diets beyond 8%. However, low dietary levels of PS (up to 8%) could increase the incorporation of antioxidants and unsaturated fatty acids from PS in cattle.

Introduction

In tropical and subtropical areas like the southeast of the United States, peanut production (*Arachis hypogea L.*) is considered a significant agricultural activity with an estimated annual contribution to the economy of more than 1 billion dollars (Hill 2002; Clohessy et al 2021). Therefore, the peanut harvesting process is a heavily mechanized process that generates large amounts of peanut byproducts like peanut skins (PS) and peanut hulls (Hill 2002; Francisco and Resurreccion 2009; Saito et al 2016). However, unlike peanut hulls, PS has been poorly incorporated into cattle feed due to the high content of polyphenols like tannins and low tolerance to cattle these plant-secondary metabolites (Hill 2002; Saito et al 2016; Min et al 2019). Despite these nutritional challenges, PS is considered an important source of antioxidants like procyanidin dimers and phytochemicals like resveratrol and flavan − 3-ols (Francisco and Resurreccion 2009; Lewis et al 2013). Thus, PS byproducts are considered an inexpensive source of functional ingredients with anti-cancer and anti-inflammatory activities (Lewis et al 2013; Dean 2020).

Several studies have evaluated the effectiveness of PS in ruminant diets with inconsistent responses in performance between cattle and small ruminants (Hill 2002; Saito et al 2016; Min et al 2019). However, polyphenols like proanthocyanidins in PS have been used as oxygen scavengers and anti-microbial compounds to increase the preservation of meat products (Lorenzo et al 2018). Likewise, previous research reported that PS supplementation in goat diets increased carcass weight, concentration of intramuscular fat, and improved meat color (Min et al 2019; Kafle et al 2021). Similarly, we previously reported that dietary supplementation of PS did not affect animal performance but increased the incorporation of alpha-tocopherol in lamb meat (Idowu et al 2021). Thus, there is a need to incorporate PS into cattle diets as a sustainable strategy to provide antioxidants to cattle while minimizing the detrimental effects of tannins. Meta-analysis has demonstrated to be an effective method to establish empirical models and strategies that are useful in animal nutrition (Sauvant et al 2008; Sauvant et al 2020). Estimating the effect size of dietary inclusion of PS on performance, digestibility, and rumen fermentation in cattle via meta-analysis will provide a meaningful strategy to incorporate natural antioxidants in cattle. Thus, the objective of this study was to evaluate the effects of dietary inclusion of PS on performance, digestibility, and rumen fermentation of beef cattle following a meta-analytic approach.

Materials And Methods

Literature search and data extraction

The database was constructed after conducting a comprehensive literature search on Google scholar, The Web of Science, ScienceDirect, Scopus, PubMed, and the Directory of Open Access Journals databases. The systematic search considered the following keywords: 1) Cattle, 2) Peanut skins 3) Fermentation, 4) Performance, 5) Digestibility, and 6) Tannins. Since most of the available literature was published 40 years ago, the comprehensive database ranged from 1983 to 2010.

The final database considered the following criteria 1) peer-reviewed manuscripts or theses published in the English language, 2) studies conducted with cattle, 3) studies reporting intake, digestibility, weight gain, feed conversion, and feed: gain ratio 4) studies comparing the effects of PS vs. control, 5) studies reporting the chemical composition of the diet 6) studies reporting the standard error of the mean (SEM), standard deviation (SD) and the number of experimental units used per treatment. The data were extracted according to the PRISMA procedure (Moher et al 2009), and the methodology followed a previously implemented method (Pech-Cervantes et al 2022). Briefly, a total of 92 peer-reviewed manuscripts were initially included. Fifty manuscripts were excluded (wrong topic), eleven manuscripts were review papers, eight in vitro studies, thirteen studies with small ruminants, and nine manuscripts + a master thesis met the inclusion criteria.

The compiled database was generated with the total number of comparisons within experiments, means, and SEM extracted from both treatments (Pech-Cervantes et al 2022). The response variables used were dry matter intake (**DMI**), total-tract digestibility of dry matter (**DMD**), total-tract Neutral detergent fiber digestibility (**NDFD**), total-tract crude protein digestibility (**CPD**), total-tract ether extract digestibility (**EED**), Initial body weight (**IBW**), Final BW (**FBW**), average daily gain (**ADG**), Feed: Gain ratio (**F:G**) rumen pH, total volatile fatty acids (**TVFA**), ammonia (**NH_3-N**), molar proportions of acetate, propionate, and butyrate were recorded individually. The chemical composition like crude protein (**CP**), neutral detergent fiber (**NDF**), ether extract (**EE**), tannin content in the diet (% DM), and inclusion level of PS in the diets was recorded and used as covariates. The list of authors, treatments, and experimental units is reported in Table 1. Likewise, the list of variables measured in each manuscript is reported in Table 2 to clarify the inconsistencies in the number of comparisons analyzed. The experimental unit was the comparison (PS vs. Control) between clusters and between-studies-within-cluster.

Table 1
Summary of the studies conducted to evaluate the dietary effects of peanut skins on performance and rumen fermentation in cattle.

Reference	PS in the diet (% DM)	Tannins (% DM)	Animals per group
(Utley and Hellwig, 1985)	5	1.4	21
	10	1.7	21
(McBrayer et al., 1983)	10	2.2	6
	20	3.9	6
(Hill et al., 1985)	15	3.2	18
	15.5	4.1	18
	15	3.2	10
	15.5	4.1	10
(Hill et al., 1987)	15	3.6	24
	16	2.2	24
	15	3.6	24
	15	3.6	24
(Hill et al., 1987)	15	5.5	4
	15	5.8	4
	15	5.5	4
(Goetsch et al., 1993)	12	4.4	5
	12	4.4	5
(West et al., 1993)	8	3.93	5
	16	5.18	5
	24	6.2	5
(Patil et al., 1993)	4	2.5	6
	4.5	3.3	6
	7	5.5	6
(Utley and Hellwig, 1985)	7.5	3.3	16
	15	3.7	16
	7.5	3.3	16
	15	3.1	16
(Palmer, 2010)	20	0.8	6
	40	1.6	6
PS = Peanut skins			

Table 2
Chemical composition and descriptive statistics of the experimental diets for cattle fed with different levels of peanut skins (PS)

	Mean	Std	Min	Max	Median	N[1]
PS level[2]	12.3	5.1	0	40	15	28
DM %	82.6	12.1	62.7	96.3	88	28
CP %	15.1	4.5	10.5	26.5	14	28
NDF %	33.7	14.5	20	71	33.4	28
ADF %	22.5	11.3	12.3	47.7	21.9	28
EE %	5.7	1.1	3.1	7.9	6.2	28
Tannins[3]%	3.8	1.3	0	6.2	3.9	28
[1] Total number of comparisons						
[2] Inclusion level of Peanut skins in the diet (% DM)						
[3] Tannins (% DM)						

Statistical analysis

The effect size was calculated as the weighted raw mean difference (**RMD**) between PS vs. Control treatments. The size effect was adjusted (weighting) by the inverse of the variance following a hierarchical effects model with a robust variance estimation according to Tipton (Tipton 2015). The hierarchical effect model accounted for the variance estimation between-clusters and between-studies-within-cluster variance components (Pech-Cervantes et al 2022).

The I^2 value was calculated to estimate the heterogeneity which is the proportion of the variance effects of the treatment divided by the total variance observed(Lean et al 2018) according to Higgins (Higgins 2008). Briefly, each variance comparison between PS vs. control treatments was calculated as the square of the pooled SD. The pooled SD for PS vs. control comparison was calculated from the SEM reported considering SD = SEM x $\sqrt{n}$ where *n* represents the number of experimental units in the study (animals). Furthermore, the variance between clusters and between-studies-within-cluster were calculated for each response variable and regression (Borenstein et al 2017; Lean et al 2018; Arriola et al 2021). The τ^2 statistics and Ω^2 statistics were calculated to account for the between-clusters and between-studies-within-cluster variance components following a previously reported method (Hedges et al 2010; Fisher et al 2017). Then, the overall

The effects of the covariates (dietary components, tannin concentration, and PS inclusion level; Table 2) that influenced the effect size in each variable were calculated via meta-regression. The meta-regression analysis was performed following a robust variance estimation with a hierarchical effect model accounting for Ω^2 and τ^2 statistics (Hedges et al 2010; Fisher et al 2015; Arriola et al 2021). Significant covariates (P< 0.05) were analyzed via subset analysis to evaluate their influence on the response variable. Additionally, the dose-response trends between the different dietary levels of PS and their corresponding RMD were evaluated following the method proposed by Greenland (Greenland and Longnecker 1992; Greenland 1995) and implemented by (Farhat et al 2022). Briefly, the calculated effect size (RMD) was used to estimate the effects of PS supplementation in the diet on animal performance and fermentation. Then, different regression models (linear, quadratic, and cubic) were tested to select the best fitting with the lowest Akaike information criteria. The weighted RMD was fitted with the corresponding inclusion level of PS following Lean et al. ((Lean et al 2018); Pech-Cervantes et al 2022). Publication bias was calculated using the asymmetry test by Egger's regression method between RMD and SE (Egger et al 1997; Oliveira et al 2017) and the Cook's distances were used to remove outliers and influential points were detected using standardized residuals lower or equal to 2.3 between PS vs. Control.

The effect size with the corresponding confidence interval for each study was plotted using the package "robumeta" and following the method previously described by Arriola et al (2021). Likewise, funnel plots were used to visualize the bias following the methodology described in the package "metafor" and according to Oliveira et al (2017).

All data analyses were performed in R and Rstudio following the methods described by (Arriola et al 2021; Pech-Cervantes et al 2021). The RMD, forest plot and meta-regression analysis were performed using the robumeta (version 1.3.1093; https:// cran. r -project .org/ web/ https:// cran. r -project .org/ web/ packages/ robumeta/ robumeta .pdf) and metafor (version 1.3.1093; https:// cran. r -project .org/ web/ packages/ metafor) packages according to Fisher et al (2015); Viechtbauer (2010).

Results

Dietary composition, animal performance, and rumen fermentation

The chemical composition and corresponding descriptive statistics of the experimental diets fed with different levels of PS are shown in Table 2. Dietary inclusion of PS linearly ($P < 0.05$) increased tannin concentration, EE, and CP, but no influential points were observed across the literature.

Dietary inclusion of PS did not ($P > 0.05$) influence DMI (9.79 vs. 9.90 kg/d), DMD (66.91 vs. 66.70%), and NDFD (48.95 vs. 50.20%) among treatment comparisons (Table 3). Conversely, dietary PS decreased ($P < 0.01$) CPD (52 vs. 64.3%), FBW (371.5 vs. 397.9 kg) ADG (1.14 vs 1.44 kg/d), and increased EED (77.5 vs. 70.2%) compared to the control. Dietary PS reduced ($P < 0.05$) total VFA concentrations (92.6 vs. 107.6 mmol/L) and tended to reduce ($P = 0.1$) rumen NH_3N (8.22 vs. 12.1 mg/dL) concentrations, but no effects were observed in rumen pH (6.47 vs. 6.14), acetate (52.6 vs. 50.4%), propionate (31.9 vs. 33.1%), and butyrate (11.02 vs. 11.2%) molar proportions among treatment comparisons (Table 4). The variance component analysis revealed a greater between-cluster variance (τ^2) in intake and performance but a higher between-studies-within-cluster variance (Ω^2) in rumen fermentation parameters. Moreover, the funnel test showed a significant ($P < 0.05$) bias for EED, butyrate molar proportions, and rumen NH_3-H concentrations with a high to moderate heterogeneity observed in the response variables.

Table 3
Effect of dietary inclusion of peanut skins (PS) on dry matter intake, total-tract digestibility, and performance of cattle. Positive values in RMD indicate an increase by addition of PS, whereas negative values in RMD indicate a decrease by addition of PS respect to the control.

	Control[2]			RMD[3]		Variance component[4]		Bias[5]	
Item	N[1]	Mean	STD	Effect size	*P*-value	Ω^2	τ^2	Funnel test (*P*-value)	I^2 (%)
DMI[6] (kg/d)	24	9.9	4.3	-0.11(-0.79,0.56)	0.79	1.46	0	0.90	91.66
DMD[7] (%)	23	66.7	9.5	0.21(-2.16,2.58)	0.80	0	0	0.55	95.18
CPD[8] (%)	23	64.3	4.6	-12.3(-19.1, -5.5)	0.01	19.7	25.2	0.25	53.70
NDFD[9] (%)	18	50.2	11.3	-1.25(-6.6,4.1)	0.47	8.11	0	0.26	92.22
EED[10] (%)	15	70.2	13.9	7.28(-2.9, 17.5)	0.09	0	33.4	< 0.01	94.34
IBW[11] (kg)	22	323.1	59.7	-0.94(-2.62, 0.72)	0.21	0	0	0.48	0
FBW[12] (kg)	16	397.9	73.7	-26.4(-72.9, 16.4)	0.06	32.5	45.7	0.72	91.92
ADG[13] (kg/d)	21	1.44	0.39	-0.30(-0.59, -0.02)	0.03	0	0.13	0.10	94.55
F: G	17	8.8	3.6	5.05(-6.4,16.5)	0.28	17.9	0	0.20	79.81

[1] Total number of comparisons (PS vs. Control)

[2] No peanut skins in the diet

[3] Raw mean difference between control vs. PS treatment.

[4] Ω^2 = between-studies-within-cluster variance component τ^2 = between-cluster variance component (Hedges et al., 2010; Fisher et al., 2017),

[5] *P*-value for X^2 (*Q*) test for heterogeneity; I^2 = Proportion of total variation of size effect estimated due to heterogeneity

[6] Dry matter intake

[7] Total-tract dry matter digestibility

[8] Total-tract crude protein digestibility

[9] Total-tract neutral detergent fiber

[10] Total-tract ether extract

[11] Initial body weight

[12] Final body weight

[13] Average daily gain

Table 4
Effect of dietary supplementation of peanut skins (PS) on rumen pH, Volatile fatty acid concentration and rumen ammonia nitrogen of cattle. Positive values in RMD indicate an increase by addition of PS, whereas negative values in RMD indicate a decrease by addition of peanut skins respect to the control.

	Control			RMD[3]		Variance component[4]		Bias[5]	
Item	N[1]	Mean	STD	Effect size	*P*-value	Ω^2	τ^2	Funnel test (*P*-value)	I^2 (%)
pH	13	6.14	0.52	0.33 (-0.57, 1.25)	0.25	0.93	0	0.23	77.50
Total VFA[6] (mmol/L)	13	107.6	27.7	-15 (-24, 6.04)	0.02	0	0	0.89	0
Acetate (%)	13	50.4	7.3	2.59 (-9.95, 15.1)	0.31	0	0	0.20	44.15
Propionate (%)	13	33.1	8.9	-1.22 (-14.9, 12.5)	0.53	0	0	0.03	79.29
Butyrate (%)	13	11.2	2.8	0.18 (-7.35, 7.71)	0.89	0.31	1.62	< 0.01	89.06
A:P ratio[7]	13	1.82	0.92	0.76 (-0.79, 2.33)	0.25	0	0	0.91	39.35
NH_3-N (mg/dL)	10	12.1	6.1	-3.88 (-11.4, 3.66)	0.10	4.28	5.92	< 0.01	95.30

[1] Total number of comparisons

[2] No peanut skins in the diet

[3] Raw mean difference between control vs PS treatment.

[4] Ω^2 = between-studies-within-cluster variance component, τ^2 = between-cluster variance component (Hedges et al., 2010; Fisher et al., 2017)

[5] *P*-value for X^2 (*Q*) test for heterogeneity; I^2 = Proportion of total variation of size effect estimated due to heterogeneity

[6] Total volatile fatty acids

[7] Acetate: Propionate ratio

Meta-regression, subset analysis and, dose-response analysis

The meta-regression analysis of the dietary effects of PS on performance and rumen fermentation is in Table 5. Although the dietary level of NDF did not influence ($P > 0.05$) the effect size among treatment comparisons, dietary CP, EE, and tannins influenced ($P < 0.05$) the magnitude of effects of PS on DMD, CPD, ADG, and rumen pH among comparisons. The subset analysis revealed that the inclusion level in the diet of PS reduced (quadratic effect) CPD and FBW compared to the control (Fig. 1a). Similarly, the dietary level of PS increased (quadratic effect) total-tract EED but reduced (quadratic effect) ADG among treatment comparisons (Fig. 1b). The dose-response analysis (point of intersection) revealed that PS should not exceed 8% in the diet (DM basis) to prevent a decrease in FBW and ADG. Most of the covariates reduced the observed τ^2 and Ω^2 in the meta-regression analysis, but a higher variance was observed for CPD and EED.

Table 5
Meta-regression analysis of the raw mean differences (RMD) for animal performance and rumen fermentation of cattle fed with different levels of peanut skins.

Dependent variable	Intercept	*P*-value	Level[1]	*P*-value	NDF[2]	*P*-value	CP[3]	*P*-value	EE	*P*-value	Tannins	*P*-value	Ω^2	τ^2	N[1]
DMI (kg/d)	6.36	0.42	0.09	0.48	0.07	0.39	0.49	0.16	-1.48	0.35	-0.10	0.82	0	4.59	24
DMD (%)	-10.8	0.70	-0.61	0.58	0.07	0.79	2.23	0.04	-3.23	0.62	-0.06	0.98	0	34.7	23
NDFD (%)	18.3	0.42	1.77	0.18	-0.04	0.82	1.97	0.31	-15.7	0.12	5.3	0.28	0	0	23
CPD (%)	-47.9	0.10	-1.14	0.46	0.30	0.11	2.46	0.14	0.89	0.92	-0.08	0.95	8.96	25.4	18
EED (%)	6.2	0.74	2.95	0.22	-0.06	0.76	0.55	0.59	-16.3	0.17	0.21	0.92	0	38.7	15
Initial BW (kg/d)	1.93	0.73	-0.02	0.83	-0.01	0.89	-0.11	0.64	0.34	0.69	-0.79	0.33	0	0	22
Final BW (kg/d)	-55.1	0.59	-0.86	0.48	-0.05	0.92	12.5	0.09	-14.9	0.24	-11.4	0.13	0	0	16
ADG (%)	-1.07	0.25	0.01	0.72	0.01	0.57	0.20	< 0.01	-0.34	0.06	-0.04	0.35	0	0.01	21
F:G ratio	-24.7	0.48	1.77	0.37	0.24	0.67	-1.31	0.63	4.56	0.62	-2.36	0.65	42.5	0	17
pH	2.37	0.08	0.01	0.04	0.01	0.67	-0.09	0.15	-0.09	0.43	-0.25	0.06	0.02	0	13
Total VFA (mmol/L)	92.7	0.22	-0.19	0.27	0.09	0.23	0.04	0.25	0.51	0.36	-0.17	0.22	0	0	13
Acetate	-5.35	0.32	-0.91	0.09	-0.27	0.20	-0.35	0.51	7.3	0.09	-1.83	0.23	0	0	13
Propionate	13.6	0.52	1.9	0.14	0.24	0.55	1.24	0.17	-11.7	0.16	-0.30	0.91	0	0	13
Butyrate	12.91	0.57	-0.13	0.90	0.24	0.46	-1.47	0.10	-0.56	0.93	2.04	0.52	0	0	13
A:P ratio	-0.39	0.21	-0.09	0.13	-0.02	0.30	-0.07	0.17	0.72	0.12	-0.18	0.30	0	0	13
NH_3-N (mg/dL)	8.37	0.46	-0.15	0.79	0.79	0.02	-0.69	0.11	1.61	0.58	-3.26	0.04	0	5.78	10

[1] Total number of comparisons (PS vs. Control)

[2] No peanut skins in the diet

[3] Raw mean difference between control vs PS treatment.

The meta-regression analysis revealed that the dietary level of PS and tannin concentration in the diet strongly influence the magnitude of effects observed in rumen pH, fermentation and NH_3N concentration. Consequently, fitting the covariates to the model reduced the observed τ^2 and Ω^2 in the meta-regression analysis. The dose-response analysis revealed that dietary tannins should not exceed 3% in the diet (DM basis) to reduce total VFA concentrations in the rumen (Fig. 2a). Similarly, a tannin concentration in the diet higher than 3% drastically reduced NH_3-N concentrations in the rumen (Fig. 2b). Despite the high heterogeneity, condensed tannin concentration in the diet explained most of the variation observed total VFA and NH_3-N concentrations among treatment comparisons.

Discussion

The incorporation of natural antioxidants (like those present in PS) into cattle diets is an ideal strategy to protect animal tissues against oxidation and stressors that compromise animal health and performance (Nockels 1996; Descalzo and Sancho 2008; Constanza et al 2012). Although polyphenols like procyanidins in PS showed detrimental effects on protein metabolism and nitrogen efficiency in this meta-analysis, polyphenols exert important pharmacological effects like radical scavenging, anti-microbial, and anti-cancer properties in animal tissues (Constanza et al 2012; Lorenzo et al 2018; Pech-Cervantes et al 2021). Thus, the results of this meta-analysis suggest that a low inclusion level in the diet of PS (up to 8% DM) will promote lipid incorporation (expressed as EE digestibility) without compromising animal performance and nitrogen metabolism.

The incorporation of PS in the diet of small ruminants increased the antioxidant capacity, meat quality, and intramuscular fat content without compromising animal performance (Saito et al 2016; Idowu et al 2021; Kafle et al 2021). Likewise, the incorporation of unsaturated fatty acids and antioxidants from PS reduced intramuscular lipid peroxidation in the meat (Saito et al 2016; Lorenzo et al 2018). Unlike small ruminants, very few studies have evaluated the effects of PS on meat quality in cattle, and these studies examined their effects on meat products like ground beef

(Lorenzo et al 2018). The degree of polymerization of procyanidins in PS dictates the antioxidant activity, but also increases the concentration of polyphenols with detrimental effects on the performance and the rumen (Constanza et al 2012; Lewis et al 2013). In this study, the tannin content strongly influenced the responses observed in rumen fermentation and nitrogen metabolism suggesting that cattle have a low tolerance to tannins in PS. Thus, we hypothesize up to 8% of PS in cattle diets will promote the incorporation of antioxidants and unsaturated fatty acids without compromising animal performance.

Compared to cattle, small ruminants like goats can tolerate a relatively high content of tannins in the diet (> 3% DM) without a significant impact on performance and rumen fermentation (Pech-Cervantes et al 2021; Pannell et al 2022). The differences in tolerance to tannins between browsers like goats compared to grazers like cattle are associated with the absence of tannin-binding salivary proteins in the latter (Austin et al 1989; Lamy et al 2011). Tannin-binding proteins are proline-rich proteins that precipitate tannins and prevent the formation of indigestible aggregates with dietary proteins (Lamy et al 2011; Pech-Cervantes et al 2016). These results highlight the importance of feeding low amounts of PS to cattle to prevent the detrimental effects of tannins. Moreover, future studies are required to confirm the incorporation of antioxidants from PS in blood and muscle in cattle.

Previous research on small ruminants suggests that dietary PS (15% inclusion level in the diet) reduced NH_3-N concentrations in the rumen without compromising fermentation and animal performance (Shipp et al 2017; Min et al 2019). These findings disagree with the results reported in this meta-analysis supporting the hypothesis that cattle have a lower tolerance to tannins compared to small ruminants. Results from this meta-analysis suggest that dietary PS reduced DMI due to the astringent effect of tannins that reduced protein availability in the rumen but increased total-tract ether extract digestibility. However, phenolic extracts from PS increased the storage stability of beef products by reducing oxidation (O'Keefe and Wang 2006). Vitamin E (α-tocopherol) is a fat-soluble antioxidant that controls lipid oxidation in the mitochondria and maintains oxidative stability like polyphenols (Hu 2011; Lauridsen and Jensen 2012). Idowu et al (2021) reported that dietary PS (20% DM in the diet) increased the incorporation of α-tocopherol and monounsaturated fatty acids in the lean mean of lambs. Thus, more research is required to elucidate the mechanism of incorporation of antioxidants in the rumen and throughout the muscle in ruminants.

CONCLUSION

Dietary inclusion of PS was associated with lower intake, total-tract digestibility, and body weight gain in cattle compared to the control. Furthermore, dietary PS reduced fermentation and NH3-N concentrations in the rumen. The detrimental effects of PS were strongly associated with the concentration of tannins in the diet that impacted nitrogen metabolism in the rumen and increasing the level of supplementation of PS in the diet was associated with a higher ether extract digestibility but lower body weight gain. In the dose-response analysis, dietary PS should not exceed 8% in the diet to prevent detrimental effects on performance and rumen fermentation. Low levels of PS in the diet (< 8%) did not affect performance and rumen fermentation across treatment comparisons. This meta-analysis supports the inclusion of low levels of PS in the diet of cattle as a strategy to incorporate antioxidants in the muscle.

Declarations

Disclosures

The authors declare no real or perceived conflicts of interest

Author contributions

M.D. Idowu: Data collection, data analysis, and writing

A.A. Pech- Cervantes: Conceptualization, funding acquisition, data collection, data analysis, and writing

G. Taiwo: Writing

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T. H. Terrill: Conceptualization, data analysis, and writing

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Figures

A)

B)

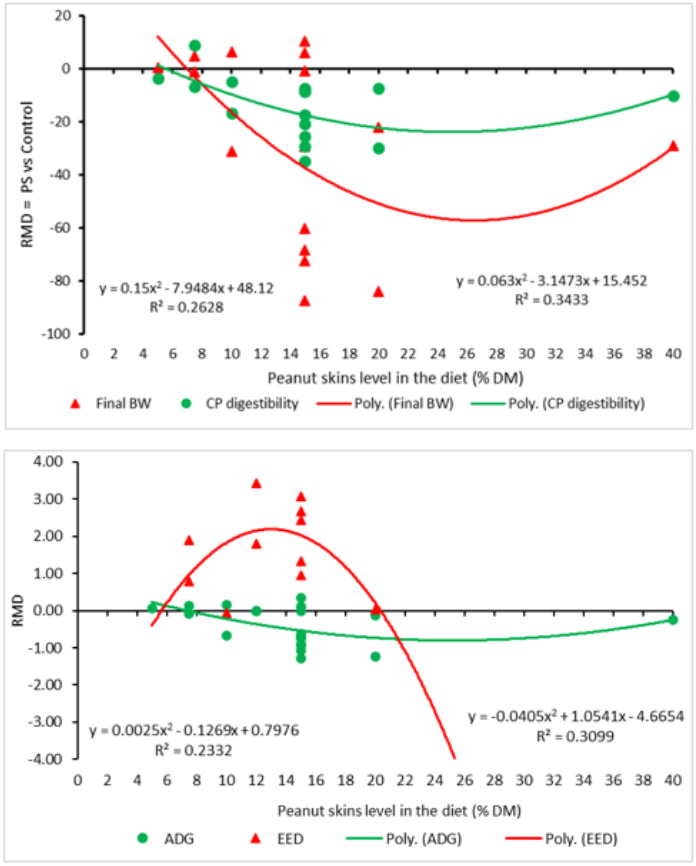
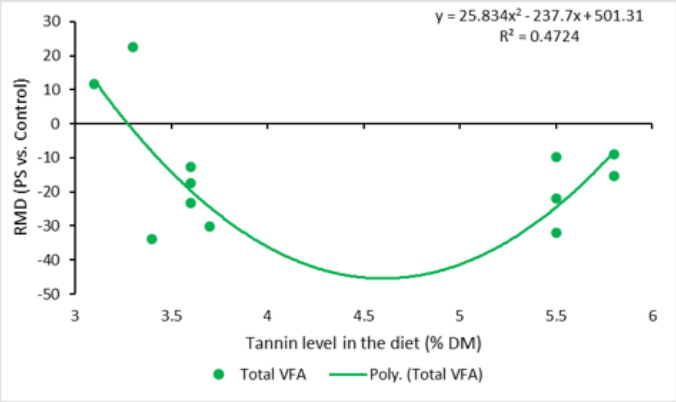


Figure 1

Dose-response analysis of the effect of dietary inclusion of peanut skins (PS) on A) total-tract crude protein digestibility and final body weight of cattle. B) Total-tract ether extract digestibility and average daily gain. Each point represents the weighted effect size between PS vs. Control

A)



B)

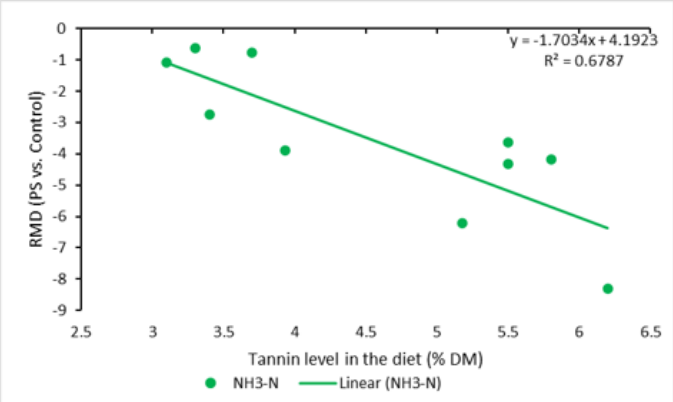


Figure 2

Dose-response analysis of the effect of dietary inclusion tannins from peanut skins on A) Total Volatile fatty acid concentration in the rumen of cattle B) Ammonia nitrogen concentration in the rumen of cattle. Each point represents the weighted effect size between PS vs. Control

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Rawdatapeanutskins.xlsx