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# Impact of the Diet with Purple Sweet Potato and Probiotics on Gas Emission in Swine

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**ABSTRACT**

Swine production is one of the main sources of greenhouse gas (GHG) emissions. This study evaluated the impact of including purple sweet potato (Ipomoea batatas L.) and probiotics (Lactobacillus plantarum) in pig diets to mitigate GHG emissions, specifically carbon dioxide ($CO_2$) and ammonia ($NH_3$). Thirty-six male pigs were used, distributed into nine dietary treatments combining different proportions of commercial feed, purple sweet potato, and Lactobacillus. $CO_2$ and $NH_3$ emissions were measured over 49 days using a gas detector. The results showed that treatments including purple sweet potato and probiotics significantly reduced $CO_2$ and $NH_3$ emissions. The most effective treatment combined 40% purple sweet potato with 40 ml of Lactobacillus, achieving a significant reduction in $CO_2$ (1270 ppm) and $NH_3$ (24.5 ppm) emissions. The Kruskal-Wallis and Wilcoxon statistical tests confirmed significant differences ($P \leq 0.001$) between treatments for both variables. In conclusion, the addition of purple sweet potato and probiotics to pig diets is a promising strategy for reducing GHG emissions, contributing to environmental sustainability without compromising the productive performance of pigs.

**Keywords:** Gas emissions; feed additives; gut microbiota; environmental sustainability; pig diet.

## INTRODUCTION

Pig production is one of the main sources of greenhouse gas (GHG) emissions. While providing food for the population, a large amount of waste accumulates, which not only serves as a valuable organic fertilizer but also becomes a source of environmental pollution as gases are released into the atmosphere during decomposition (Vorobel et al., 2024).

It is predicted that emissions of major greenhouse gases will increase by 25% to 90% by 2030 compared to 2000 levels if a series of measures are not adopted to improve the situation (Smith et al., 2008; Udova et al., 2014). The increase in the concentration of several harmful gases (emitted by manure) poses health risks for both animals and humans. The main gases produced on pig farms include methane, hydrogen sulfide, carbon dioxide, ammonia, sulfur dioxide, and volatile fatty acids, which are primarily derived from the fermentation of undigested or poorly digested nutrients (Hossain et al., 2024). In pigs, these gases are produced through microbial fermentation in the large intestine. This complex process is influenced by factors such as diet, intestinal microbiota activity, and digestive physiology, similar to other non-ruminant animals (Rowland et al., 2018).

Given this problem, there is a need to explore sustainable alternatives to reduce greenhouse gas emissions without compromising productive efficiency or animal welfare. In this context, nutritional regulation through dietary modification presents itself as a viable option, especially with the inclusion of feed additives such as probiotics. According to Martínez and Langella (2019), these live microorganisms can provide significant health benefits to the host.

Moreover, the polyphenols present in purple sweet potato, when incorporated into the diet, could help reduce the environmental and economic impact associated with its storage and processing, becoming an innovative source of antioxidants (Serra et al., 2021). In addition, the anthocyanins found in this tuber play a key role in promoting growth and health by positively influencing intestinal microbiota, gut physiology, and the immune system (Guo and Shahidi, 2023); besides, Hurtado et al. (2024) indicate the combined supply of sweet potato and *Lactobacillus plantarum* (LP) potentiates the benefits of both ingredients, where sweet potato fiber can help the LP adhere to the intestinal wall and thus improve efficacy.

The rationale for this research lies in the need to find practical and effective solutions to mitigate the environmental impact of pig production. The combination of purple sweet potato and probiotics could offer a novel approach to reducing GHG emissions by leveraging the functional properties of both ingredients to improve digestive efficiency and decrease GHG production. This approach would not only contribute to environmental sustainability but could also enhance the health and performance of pigs, generating economic benefits for producers.

The objective of this study is to evaluate the effect of including purple sweet potato and probiotics in the diet of pigs on the reduction of greenhouse gas emissions. This study aims to provide scientific evidence to support the use of sustainable feeding strategies in pig production, thereby contributing to the reduction of environmental impact through the development of mitigation strategies.

## MATERIALS AND METHODS

### Ethical Considerations

This study was designed and conducted in strict compliance with international animal welfare and research ethics standards. The experimental protocol, which involved feeding pigs with sweet potato and the inclusion of probiotics to evaluate gas emissions, was reviewed and approved by the Bioethics Committee of the Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López (ESPAM MFL). This committee ensures that all research complies with national and international ethical standards concerning the use of experimental animals.

Particular care was taken to ensure that the animals received proper handling, minimizing any form of suffering and providing optimal feeding, housing, and care conditions throughout the experiment. The techniques used to measure gas emissions were non-invasive and did not cause additional stress to the animals.

### Animals, diets, and experimental design

Thirty-six crossbred male pigs, resulting from the commercial crossing of sows (Landrace x Duroc) and boars (Pietran), at the fattening stage (100 days old, initial weight 42.77 ± 0.77 kg), were housed in metabolic cages for 49 days. The cages had been previously cleaned, flamed, and disinfected days before the animals' incorporation with a 25% iodine solution.

Commercial fattening feed (CF) was provided according to the nutritional management of the pig herd (ESPAM MFL). The feed had the following composition: crude protein 16%, fat 3%, fiber 4%, ash 8%, and moisture 13%. It was partially replaced with purple sweet potato flour (PSPF) at 20% and 40% inclusion levels (Table 1).

**Table 1. Nutritional content of purple sweet potato**

| Content | Unit/100g |
|---|---|
| Water | 64-74 g |
| Fiber | 1.2-3.5 g |
| Lipids | 0.5-2.1 g |
| Protein | 1.2-7.2 g |
| Fats | 0.4-3.0 g |
| Carbohydrates | 20.19-27.3 g |
| Sugar | 4.18-9.7 g |
| Glucose | 2.37-4.68 mg |
| Sucrose | 56.94-59.97 mg |

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| | |
|---|---|
| Fructose | 1.43-4 mg |
| Starches | 11.8 g |

Source: Lim et al., 2016; Wang and Zhu, 2016; Cusumano et al., 2013; Martí et al., 2011; Pagalo et al., 2010; Linares et al., 2008 (cited by Vidal et al., 2018).

The concentration of *Lactobacillus plantarum* (LP) incorporated into the different treatments (1x$10^{10}$ CFU.$mL^{-1}$) was obtained from the molecular biology laboratory (ESPAM MFL) after activation of the corresponding strain.

This study employed a completely randomized experimental design to evaluate the impact of different inclusion levels of purple sweet potato flour and *Lactobacillus* in the diet of pigs on gas emissions, specifically ammonia and carbon dioxide. The primary dependent variable was the amount of these gases emitted, which was measured twice daily (morning and afternoon) over 49 days.

Nine dietary treatments were distributed as follows: 100% CF (T1); 100% CF + 20 mL LP (T2); 100% CF + 40 mL LP (T3); 80% CF + 20% PSPF (T4); 80% CF + 20% PSPF + 20 mL LP (T5); 80% CF + 20% PSPF + 40 mL LP (T6); 60% CF + 40% PSPF (T7); 60% CF + 40% PSPF + 20 mL LP (T8); and 60% CF + 40% PSPF + 40 mL LP (T9).

Each treatment was assigned to two experimental units represented by individual pigs, with two replicates. Gas emission measurements were systematically performed both in the morning and in the afternoon for each animal during two periods (with and without the application of treatments) for 27 and 22 days, respectively.

The completely randomized design employed in this study allowed for the control of intrinsic variability among the animals, ensuring that the differences observed in gas emissions could be reliably attributed to the specific treatments applied. Randomization was key to minimizing experimental bias and enhancing the internal validity of the study, providing robust and scientifically sound results.

### Experimental management

The experimental nutritional combinations were provided twice daily: in the morning (8:00 a.m.) and in the afternoon (4:00 p.m.), according to the established treatments. These treatments consisted of partially replacing commercial feed (CF) with purple sweet potato flour (PSPF) and including *Lactobacillus plantarum* (LP).

The determination of the residual gas emission potential from the slurry, composed of a mixture of fresh feces (approximately 50 g) and urine, was carried out using a SKY2000-M6 gas detector. The mixture was placed in a 100 mL laboratory flask, and gas emission measurements (ppm) were conducted daily in two sessions (10:00 a.m. and 5:00 p.m.).

### Statistical analysis

The statistical analysis of the relative values (1764 data points) corresponding to gas concentrations ($CO_2$ and $NH_3$) was conducted using SAS software (V.9.4, 2023). Since the data did not follow a normal distribution, the non-parametric Kruskal-Wallis test was applied to detect significant differences between treatments. Additionally, descriptive analysis was performed using measures of central tendency (mean) and dispersion (standard deviation, coefficient of variation, maximum, and minimum values) for the different experimental periods (with and without treatment application). The Wilcoxon test for independent samples was used to compare two means, with a significance level set at 0.05.

## RESULTS

### Descriptive statistics of $CO_2$ and $NH_3$ emissions

Table 2 presents the results from the measurements of $CO_2$ and $NH_3$ emissions by pigs under different treatments. The table summarizes the mean concentration values, standard deviation (SD), coefficient of variation (CV), and the minimum and maximum recorded values for both variables.

**Table 2. Descriptive statistics of $CO_2$ and $NH_3$ emissions in pigs under different treatments.**

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| Treatment | Variable | n | Mean | SD | CV | Min | Max |
|---|---|---|---|---|---|---|---|
| 1 | $CO_2$ | 196 | 1400.00 | 0.00 | 0.00% | 1400.00 | 1400.00 |
| | $NH_3$ | 196 | 30.00 | 0.00 | 0.00% | 30.00 | 30.00 |
| 2 | $CO_2$ | 196 | 1379.55 | 17.24 | 1.25% | 1353.00 | 1400.00 |
| | $NH_3$ | 196 | 28.45 | 1.55 | 5.45% | 26.00 | 30.00 |
| 3 | $CO_2$ | 196 | 1370.13 | 22.27 | 1.63% | 1340.00 | 1400.00 |
| | $NH_3$ | 196 | 28.26 | 1.91 | 6.75% | 25.00 | 30.00 |
| 4 | $CO_2$ | 196 | 1359.51 | 38.63 | 2.84% | 1276.00 | 1400.00 |
| | $NH_3$ | 196 | 28.44 | 1.53 | 5.38% | 22.00 | 30.00 |
| 5 | $CO_2$ | 196 | 1344.76 | 39.56 | 2.94% | 1292.00 | 1400.00 |
| | $NH_3$ | 196 | 26.83 | 3.41 | 12.71% | 22.00 | 30.00 |
| 6 | $CO_2$ | 196 | 1359.53 | 29.95 | 2.20% | 1316.00 | 1400.00 |
| | $NH_3$ | 196 | 26.69 | 3.11 | 11.66% | 22.00 | 30.00 |
| 7 | $CO_2$ | 196 | 1369.62 | 24.14 | 1.76% | 1330.00 | 1400.00 |
| | $NH_3$ | 196 | 27.37 | 2.60 | 9.50% | 21.00 | 30.00 |
| 8 | $CO_2$ | 196 | 1360.61 | 27.22 | 2.00% | 1332.00 | 1400.00 |
| | $NH_3$ | 196 | 26.22 | 3.75 | 14.30% | 20.00 | 30.00 |
| 9 | $CO_2$ | 196 | 1278.49 | 92.60 | 7.24% | 1185.00 | 1400.00 |
| | $NH_3$ | 196 | 25.68 | 4.25 | 16.53% | 19.00 | 30.00 |

Treatment T1 shows a constant $CO_2$ concentration with a mean of 1400.00 ppm and no variability (SD of 0.00 ppm and CV of 0.00%). This indicates that the treatment applied at the start did not present fluctuations in $CO_2$ emissions. However, the mean $CO_2$ emissions progressively decrease from 1379.55 ppm (T2) to 1278.49 ppm (T9), with increasing variability. The SD varies from 17.24 ppm (T2) to 92.60 ppm (T9), and the CV ranges between 1.25% and 7.24%.

The decrease in $CO_2$ means across treatments suggests that these interventions are effective in reducing $CO_2$ concentrations. However, the variability in values, especially in T9 (SD of 92.60 ppm and CV of 7.24%), indicates that this treatment yields results that may be influenced by additional uncontrolled factors or greater heterogeneity in experimental conditions.

Regarding $NH_3$, the means decrease from 28.45 ppm (T2) to 25.68 ppm (T9). The SD ranges between 1.55 ppm (T2) and 4.25 ppm (T9), while the CV varies from 5.45% to 16.53%. This reduction suggests an effective role in reducing ammonia concentrations, but variability significantly increases in later treatments, particularly in T9, which shows the highest CV (16.53%), indicating less consistency in $NH_3$ emissions under this treatment, potentially linked to fluctuations in experimental conditions or pig responses.

The high variability observed in $CO_2$ and $NH_3$ emissions in some treatments, particularly T9, may be multifactorial, stemming from the interaction between experimental factors (diet variations, physical environment, animal handling), biological factors (changes in intestinal microbiota, individual metabolism), and technical factors (variations in measurement accuracy, sampling frequency, and duration of measurement periods).

**Comparison of $CO_2$ and $NH_3$ emission means**

The variance analysis yielded a P-value of 0.0001, indicating highly significant differences between treatments in terms of $CO_2$ emissions. The comparison of mean $CO_2$ emissions (Figure 1) shows the results for pigs subjected to nine different treatments, which combine various proportions of commercial feed (CF), purple sweet potato flour (PSPF), and *Lactobacillus plantarum* (LP). The bars reflect the mean $CO_2$ emissions in parts per million (ppm) for each treatment, with letters indicating significant differences between groups.

**Treatment T1 (100% CF):**

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T1 presents the highest average $CO_2$ emission (1410 ppm) and is labeled with the letter "F," indicating it is significantly different and higher compared to other treatments. This suggests that the exclusive use of commercial feed without additions of PSPF or LP leads to the highest $CO_2$ emissions.

**Treatments T2 and T3 (100% CF with addition of 20 mL and 40 mL LP):**

The addition of *Lactobacillus plantarum* in T2 and T3 reduces $CO_2$ emissions compared to T1, with averages of 1380 and 1365 ppm, respectively. These treatments are labeled with the letters "E" and "D," indicating that although there is a significant reduction in emissions relative to T1, there is also a significant difference between T2 and T3.

**Treatments T4 and T5 (80% CF + 20% PSPF and its combination with LP):**

T4, which includes 20% purple sweet potato flour, shows a $CO_2$ emission mean similar to T3 (1365 ppm) and is also labeled with the letter "D." The addition of 20 mL of LP to T4 (forming T5) results in significantly lower emissions (1325 ppm), labeled with the letter "B." This indicates that the combination of PSPF with a moderate amount of LP has a considerable impact on reducing $CO_2$ emissions.

**Treatments T6, T7, and T8 (80% CF + 20% PSPF with 40 mL LP and variations with 60% CF + 40% PSPF):**

T6 (80% CF + 20% PSPF + 40 mL LP) shows a reduction in emissions (1340 ppm) and is labeled "C." This treatment is not significantly different from T7 and T8, which use a higher proportion of PSPF (40%) with varying doses of LP (20 mL and 40 mL). T7 and T8 have similar average emissions (1340 ppm) and share the label "C," suggesting that a higher proportion of PSPF with LP does not offer a significant additional advantage over T6.

**Treatment T9 (60% CF + 40% PSPF + 40 mL LP):**

This treatment presents the lowest average $CO_2$ emission (1270 ppm) and is labeled "A," indicating that it is significantly different and lower than all other treatments. The combination of a high proportion of PSPF with the maximum dose of LP is the most effective in reducing $CO_2$ emissions.

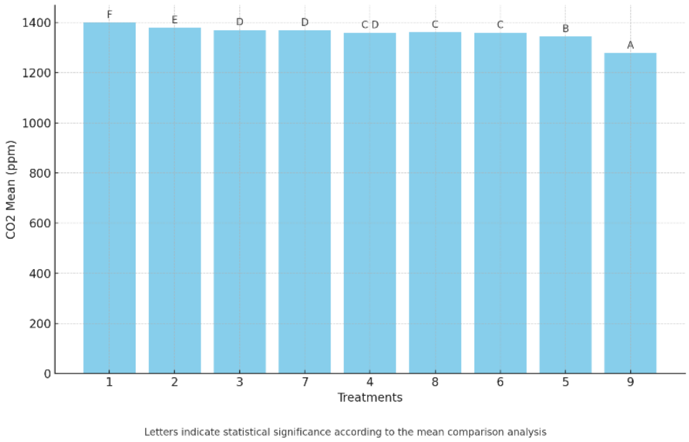


Figure 1. Comparison of mean $CO_2$ emissions across experimental treatments in pigs

In summary, the treatment based solely on commercial feed (T1) results in the highest $CO_2$ emissions, consistent with trends observed in other studies where conventional diets tend to increase gas production in pigs. Additionally, the inclusion of *Lactobacillus plantarum* reduces $CO_2$ emissions, especially when combined with purple sweet potato flour. The use of PSPF at both 20% and 40%, combined with LP, shows a clear reduction in emissions

**Comparison of ammonia ($NH_3$) emission averages**

Figure 2 shows the comparison of ammonia ($NH_3$) emission averages in pigs subjected to different treatments ($P \leq 0.001$), which include combinations of commercial feed (CF), purple sweet potato flour (PSPF), and *Lactobacillus plantarum* (LP). The bars represent the $NH_3$ emission means in parts per million (ppm) for each treatment, and the letters above the bars indicate significant differences between treatments.

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**Treatment T1 (100% CF):**

This treatment presents the highest average $NH_3$ emission (30 ppm) and is significantly different from the other treatments, as indicated by the letter "D" in the graph. This suggests that the exclusive use of commercial feed (without the addition of PSPF or LP) leads to higher ammonia emissions.

**Treatments T2 and T3 (100% CF with 20 mL and 40 mL of LP):**

The inclusion of *Lactobacillus plantarum* in the treatments (T2 and T3) significantly reduces $NH_3$ emissions compared to T1, with averages around 28 ppm. Both treatments are labeled with the letter "C," indicating that there is no statistically significant difference between them. This suggests that the addition of LP, regardless of the dose, reduces $NH_3$ emissions.

**Treatments T4 and T5 (80% CF + 20% PSPF and its combination with LP):**

The inclusion of purple sweet potato flour in the treatment (T4) also shows a reduction in $NH_3$ emissions (28.5 ppm), sharing the letter "C" with T2 and T3, indicating similarity in emission reductions among these treatments.

The addition of 20 mL of LP to the 80% CF + 20% PSPF treatment (T5) results in a greater reduction in $NH_3$ emissions (27 ppm), labeled with the letter "B." This suggests that the combination of PSPF with LP has an additive effect in reducing emissions.

**Treatments T6, T7, and T8 (80% CF + 20% PSPF with 40 mL LP and variations with 60% CF + 40% PSPF):**

T6 (80% CF + 20% PSPF + 40 mL LP) shows a similar average $NH_3$ emission to T5, and both share the label "A/B." This indicates that there are no significant differences between these treatments, but both are more effective than T1.

Treatments T7 and T8, which use a higher proportion of PSPF (40%) with different levels of LP (20 mL and 40 mL, respectively), show similar average emissions (26 ppm), also labeled "A/B." This reinforces the idea that increasing the proportion of PSPF combined with the addition of LP contributes to the reduction of $NH_3$.

**Treatment T9 (60% CF + 40% PSPF + 40 mL LP):**

This treatment shows the lowest $NH_3$ emission (24.5 ppm) and is labeled with the letter "A," indicating that it is significantly different and more effective than most other treatments in reducing $NH_3$ emissions. The combination of a high proportion of PSPF with the maximum dose of LP appears to be the most effective in reducing ammonia emissions.

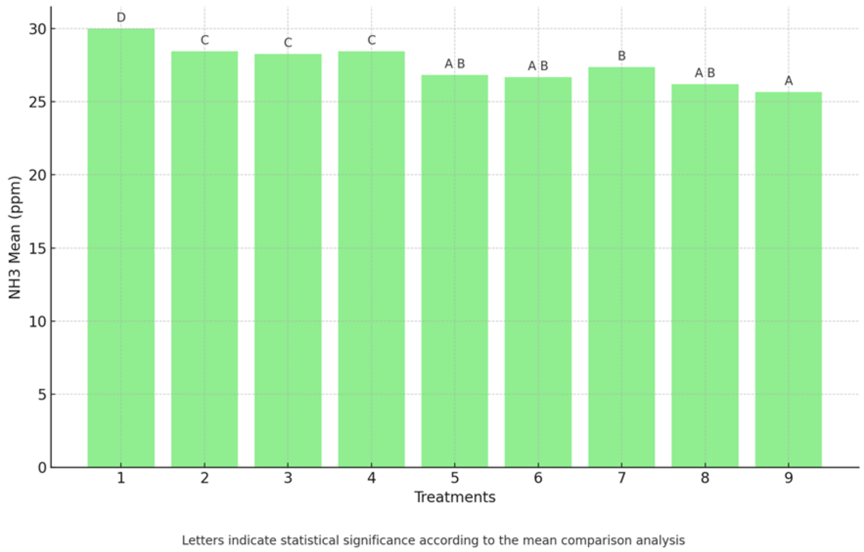


Figure 2. Comparison of $NH_3$ emission means across experimental treatments in pigs

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The treatment based exclusively on commercial feed (T1) results in the highest $NH_3$ emissions, which is consistent with the idea that the base diet directly influences the amount of ammonia produced.

The inclusion of *Lactobacillus plantarum*, whether at 20 mL or 40 mL, in combination with CF or PSPF results in a significant reduction in $NH_3$ emissions. Additionally, purple sweet potato flour also contributes to the reduction of emissions, especially when used at higher proportions (40% PSPF) and combined with LP.

The T9 treatment, which combines 60% CF with 40% PSPF and 40 mL of LP, is the most effective in reducing $NH_3$ emissions, suggesting a synergistic effect between these components.

This analysis is crucial for understanding how different dietary combinations can influence ammonia emissions, an environmental pollutant, and suggests that the use of ingredients such as purple sweet potato flour and probiotics may be a viable strategy to reduce these emissions in pig production.

**Analysis of $CO_2$ and $NH_3$ emissions with and without treatment (Residual Effect)**

The descriptive statistics for both phases (with and without treatments) are presented in Table 3**. With treatment**: The $CO_2$ concentration during the first phase shows a high mean of 1380.23 ppm with a relatively low standard deviation (35.32 ppm), indicating that the values are tightly clustered around the mean. The CV of 2.56% also suggests low relative variability in the measurements, indicating that the treatment effect is consistent in $CO_2$ production. The $NH_3$ mean is 27.86 ppm with a standard deviation of 2.67 ppm. The CV of 9.59% indicates higher relative variability compared to $CO_2$, which may suggest that the treatment affects $NH_3$ production more diversely. However, the values still fall within a relatively narrow range (20.00 - 30.00 ppm).

**Without treatment (residual effect)**: During the second phase, the $CO_2$ concentration slightly decreases to a mean of 1330.76 ppm. The standard deviation increases to 54.44 ppm, indicating greater dispersion in the values. The CV of 4.09% suggests higher relative variability compared to the first phase, which may reflect a more variable residual effect of the treatment on $CO_2$ production. The $NH_3$ mean during the second phase is slightly lower (27.16 ppm) compared to the first phase. The standard deviation of 3.39 ppm and the CV of 12.47% indicate greater relative variability in $NH_3$ production during this phase, suggesting that the residual effect of the treatment may be less consistent or influenced by additional factors generating more variability in ammonia emissions.

**Table 3. Descriptive Statistics of $CO_2$ and $NH_3$ Emissions in Pigs With and Without Treatment of Purple Sweet Potato Flour and *Lactobacillus plantarum***

| Group | Variable | n | Mean | SD | CV | Min | Max |
|---|---|---|---|---|---|---|---|
| With treatment | $CO_2$ | 972 | 1380.23 | 35.32 | 2.56% | 1185.00 | 1400.00 |
| | $NH_3$ | 972 | 27.86 | 2.67 | 9.59% | 20.00 | 30.00 |
| Without treatment | $CO_2$ | 792 | 1330.76 | 54.44 | 4.09% | 1188.00 | 1400.00 |
| | $NH_3$ | 792 | 27.16 | 3.39 | 12.47% | 19.00 | 30.00 |

**Group comparison (Phases)**:

Table 4 presents the results of the Wilcoxon test for independent samples, aiming to compare $CO_2$ and $NH_3$ concentrations at two different phases: with treatment application (Group 1) and without treatment application (Group 2). The Wilcoxon test for $CO_2$ returns a p-value of 0.000001, indicating a highly significant difference between the two phases. This implies that the application of treatments had a considerable influence on $CO_2$ concentration. For $NH_3$, the test shows a p-value of 0.0427, indicating a statistically significant difference between the two phases (with and without treatment application) at the 5% significance level. This suggests that the application of treatments had a significant effect on $NH_3$ concentration.

**Table 4. Statistical Results of the Wilcoxon Test for $CO_2$ and $NH_3$ Emissions in Pigs With and Without Treatment of Purple Sweet Potato Flour and *Lactobacillus plantarum***

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| Variable | Group 1 | Group 2 | n (1) | n (2) | Mean (1) | Mean (2) | SD (1) | SD (2) | W | p (2 tails) |
|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 1 | 2 | 972 | 792 | 1380.23 | 1330.76 | 35.32 | 54.44 | 44996250 | 0.000001 |
| $NH_3$ | 1 | 2 | 972 | 792 | 27.86 | 27.16 | 2.67 | 3.39 | 67864400 | 0.0427 |

*Group 1: With treatment; Group 2: Without treatment.*

The Wilcoxon test for $CO_2$ returns a p-value of 0.000001, indicating a highly significant difference between the two groups (phases). This implies that the application of treatments had a considerable influence on $CO_2$ concentration. For $NH_3$, the test shows a p-value of 0.0427, indicating a statistically significant difference between the two groups (with and without treatment application) at the 5% significance level. This suggests that the application of treatments had a significant effect on $NH_3$ concentration.

The results of the Wilcoxon test suggest that both $CO_2$ and $NH_3$ concentrations were significantly affected by the application of treatments. The statistical significance found in both variables reinforces the importance of the applied treatments in modifying the concentrations of these gases.

## DISCUSSION

### Global impact of emissions in pig production

Pig production is responsible for approximately 668 million tons of $CO_2$-eq annually, representing 9% of emissions from the livestock sector (Gerber et al., 2013). In addition to carbon dioxide ($CO_2$), other gases such as ammonia ($NH_3$), methane ($CH_4$), volatile organic compounds (VOCs), and hydrogen sulfide ($H_2S$) contribute to environmental problems such as eutrophication, reduced air quality, and climate change (Dalby et al., 2020). In response to this challenge, the FAO (2023) highlights the need for strategies to reduce greenhouse gas emissions, particularly considering the projected increase in demand for animal products by 2050.

### Gas emissions and factors influencing them

$CO_2$ emissions in pigs are influenced by physiological stage, body weight, and food intake. In the case of $CH_4$, its production is primarily related to fermentation in the hindgut, underscoring the importance of diet in generating these gases. $CO_2$, $CH_4$, and $N_2O$ emissions represent 81%, 17%, and 2% of total emissions in pig farms, respectively (Philippe & Nicks, 2015).

### Effect of a purple sweet potato and probiotic diet on emissions

The results of this study show that the inclusion of purple sweet potato (*Ipomoea batatas*) and *Lactobacillus plantarum* in pig diets significantly reduces $CO_2$ and $NH_3$ emissions. This aligns with previous research highlighting the role of probiotics and phytochemicals in modulating the gut microbiota (Biswas et al., 2024; Vadopalas et al., 2020). This reduction suggests that the polyphenols in purple sweet potato play a key role in improving the conditions for fiber fermentation, thereby reducing the production of harmful gases (Kilua et al., 2019).

### Benefits of polyphenols and anthocyanins from purple sweet potato

The anthocyanins in purple sweet potato have demonstrated prebiotic properties, promoting the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus* while inhibiting pathogens like *Staphylococcus aureus* and *Salmonella typhimurium* (Lippolis et al., 2023; Sun et al., 2018; Zhang et al., 2016). These prebiotic effects are crucial in reducing gas emissions by promoting a healthy gut microbiota (Peng et al., 2020).

### Reduction of ammonia through dietary fiber and probiotics

The inclusion of dietary fiber in pig diets has a significant impact on manure composition and $NH_3$ and $H_2S$ emissions. Studies have shown a 30% reduction in $NH_3$ emissions and a 17% reduction in $H_2S$ emissions with high-fiber diets (Trabue et al., 2022). Additionally, better alignment of dietary intake with the physiological needs of pigs also reduces $NH_3$ emissions (Philippe et al., 2011).

Probiotics, when combined with prebiotics, can improve digestibility and reduce harmful gas emissions (Chu et al., 2011). In pigs fed diets fermented with *Lactobacillus*, there has been demonstrated improvement in growth performance and reduced fecal and urinary nitrogen excretion (Liu et al., 2024; Lan et al., 2017).

**Synergy between polyphenols and probiotics: implications for environmental sustainability**

The results of this study confirm that the combination of polyphenols in purple sweet potato and *Lactobacillus plantarum* produces a synergistic effect that significantly contributes to reducing $CO_2$ and $NH_3$ emissions in pig production. This interaction between phytochemicals and probiotics favorably modulates gut microbiota, reducing the production of pollutant gases, which is consistent with previous studies (Zhang et al., 2019). These findings have important implications for developing sustainable feeding strategies that promote the use of natural additives, which not only improve animal health but also mitigate environmental impact. Further evaluation of this synergy in various production contexts is recommended to maximize its effect on the sustainability of animal production.

## CONCLUSIONS

Based on the results obtained, this study provides evidence of the positive influence of feed additives, specifically polyphenols and probiotics, in pig diets, highlighting the use of purple sweet potato (*Ipomoea batatas L.*) and *Lactobacillus plantarum*. These additives contribute to the reduction of $CO_2$ and $NH_3$ emissions, suggesting their potential to mitigate the environmental impact associated with pig production.

It is essential to conduct further evaluations that consider the effects of this combination of additives on productive parameters and animal health. A deeper understanding of the interaction between animal health status and feed additives could facilitate the development of sustainable strategies that promote the reduction of harmful gases for the environment.

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