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Growth response, ammonia emission and rectal temperature of finisher broilers fed varying levels of maize stover biochar (MSB)

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Abstract

This study was designed to assess the dietary effects of maize stover biochar (MSB) on the growth response, ammonia emissions, and rectal temperature of finisher broilers. A total of 120 broilers were randomly distributed into four treatments (T_1, T_2, T_3, and T_4) using a completely randomized design. Each treatment consisted of 30 broilers and was replicated three times, with 10 broilers per replicate. The birds in T_1 received no MSB, while T_2, T_3, and T_4 received MSB at inclusion levels of 0.5%, 1%, and 1.5%, respectively. Data collected on body weight gain, daily feed intake, rectal temperature, and fecal ammonia content were subjected to analysis of variance (ANOVA) in a completely randomized design (CRD) using SPSS version 21. Significantly different means were separated using Duncan's New multiple range test. Significant differences ($p<0.05$) in body weight gain, fecal ammonia content, and feed intake were observed among the treatments. The highest body weight gain of 2.94±0.01 kg was reported in T_4, with the lowest value of 2.43±0.02 kg recorded in T_1. Significant differences ($p<0.05$) were evident in average daily weight gain, total feed intake, and feed conversion ratio. T_4 displayed the highest average weight gain (52.64±0.27g), significantly surpassing T_3 (46.09±0.62g), while T_2 and T_1 exhibited the lowest values (44.30±0.68 and 43.41±0.51, respectively), which were comparable. Regarding feed conversion ratio (FCR), T_1 had the highest value (3.25±0.00), significantly higher than T_2 (2.72±0.00) and T_3 (2.69±0.01), whereas T_4 recorded the lowest value (2.35±0.03). In ammonia emission, T1 had the highest content (4.09 ± 0.19), while T_2 and T_3 had the values of 1.19 ± 0.03 and 1.32 ± 0.08, respectively. However, T4 had the lowest value of (0.90 ± 0.01) which was statistically ($p < 0.05$) different from other treatment groups. In rectal temperature, significant variations were observed over the weeks, with T_1 consistently recording the highest values and T_4 consistently displaying the lowest values. In conclusion, this study demonstrates that MSB positively impacted growth response, reduced ammonia emission, and mitigated rectal temperature in finisher broilers.

Keywords: Biochar; Growth response; Rectal temperature; Ammonia; Broilers

1. Introduction

It has been acknowledged that poultry farming offers a viable strategy for narrowing the gap in animal protein consumption (Adene and Oguntade, 2006). However, contemporary commercial poultry farming presents formidable demands on the cleanliness of pens, air quality within the pens, and the quality of the feed, as well as the management of waste and fecal matter (Gerlach and Schmidt, 2012).

The elevated population densities in poultry pens contribute to an increase in pathogenic microorganisms due to the weakened immune response of stressed animals, leading to a higher excretion of pathogens. Confining animals to a limited space results in a microbial environment dominated by organisms thriving on the animals and their excretions, elevating the risk of germ transmission, particularly in the presence of subpar pen and feeding hygiene. Moreover, the administration of anti-infection and antibacterial agents to poultry fosters an environment conducive to the selection

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of drug-resistant pathogens. Regardless of the poultry housing conditions, the proximity of animals to their excrement remains constant. The nutrient-rich fecal matter and humid excreta create favorable conditions for the proliferation of pathogenic microorganisms (Gerlach and Schmidt, 2012).

As a consequence, the microbial decomposition of excrement leads to the emission of high levels of ammonia, a pungent gas known to be harmful to animals. Ammonia, with its strong positive electric charge, exhibits corrosive properties, posing health risks to animals by irritating mucous membranes, attacking the lungs, weakening the immune system, and accumulating in the bloodstream (Maliselo and Nkonde, 2015). Beyond its impact on animal welfare, ammonia emission contributes to a decline in animal performance and poses environmental hazards (Gerlarch and Schmidt, 2012).

Biochar, which is generated through heating of organic materials like wood waste or straw in an oxygen-free or low-oxygen environment (Hallbar, 2014), possesses exceptional porosity, making it an effective natural filter with a substantial internal capacity for water and ions. Yarrow (2015) highlighted that biochar, specifically derived from waste wood, has the potential to mitigate emissions of ammonia, methane, nitrous oxide, hydrogen sulfide, urea, and organic acids. Biochar is presumed to bind ammonia into ammonium before excretion, minimizing nutrient out-gassing and losses. More so, biochar acts as a catalyst, facilitating the reaction of essential elements, especially charged ions, while remaining unchanged at the end of the process (Yarrow, 2015). Given the limited existing information on the impact of maize stover biochar (MSB) on serum biochemistry, rectal temperature, and ammonia emission from broiler fecal matter, this study was therefore designed to address this gap. The objectives of the study are to;

- Evaluate the effects of MSB on growth performance of broiler finishers
- Investigate the effect of MSB on the rectal temperature of the broiler finishers
- Determine the effects of MSB on the level of ammonia emission from the fecal matters.

1.1. Location of the Study

The study was carried out at the Department of Animal Science Teaching and Research Farm, University of Nigerian, Nsukka. Nsukka lies in the Derived Savannah Region, and is located on longitude 60^{0}C 25 N and latitude 7^{0}C 24 E (Ofiomata, 1975), at an altitude of 430m above sea level (Nwosu *et al.,* 1981). The climate is a humid tropic setting with a relative humidity range of 56.01%-103%. Average diurnal minimum temperature ranges from 22^0 C -24.7^{0c} C while the average maximum temperature ranges from 33^{0c} -37^{0c} (Energy Centre UNN, 2008). Annual rainfall ranges from 1680mm-1700mm (Breinholt *et al*., 1981).

1.2. Duration of the Study

The study was made of experiments 1 and 2. Each experiment lasted for eight (8) weeks during which the experimental birds were fed *ad-libitum*.

2. Materials and methods

2.1. Experimental Material (Maize Stover Biochar)

Figure 1 Maize Stover Biochar (MSB)

Maize stovers were collected and prepared into biochar using the normal process i.e. (pyrolysis). They were pulverized into powder form after burning them in a kiln and were included at the levels of 0, 0.5%,1%,1.5%/kg of feed.

Table 1 Percentage composition of the broiler finisher diet

Ingredients	**%composition**
Maize	53.0
Wheat offal	10.0
P K C	5.5
G N C	15.0
Fish meal	1.5
S B M	10.0
Bone meal	4.0
Salt	0.25
Lysine	0.25
Methionine	0.25
Vitamin premix	0.25
Total	100
Calculated composition	
Crude protein (%)	20.1
Gross energy (Mcal/kg)	2.72
Crude Fibre (%)	4.02

2.2. Experimental Procedure

A total number of one hundred and twenty broiler chicks were used. The study lasted for eight weeks. The chicks were randomly divided into four treatments, each with three replicate. The treatments are T_1, T_2, T_3 and T_4. T_1 served as control, with 0% biochar. T_2, T_3 and T_4 contained 0.5%, 1.0% and 1.5% of MSB respectively.

2.3. Experimental parameters measured

2.3.1. Parameters measured were

Growth performance (initial body weight, final bodyweight, weight gain, feed intake, feed conversion ratio)

2.3.2. Growth performance evaluation

Body weight, body weight gain, feed intake and feed to gain ratio were determined on weekly basis throughout the experimental period. Initial live weight, final weight, weight gain, feed intake, feed conversion ratio, feed cost/kg weight gain were calculated. All the birds in each replicate were weighed separately using a 5kg top loading Salter weighing scale. Weighing was done weekly in the morning hours before the days feeding. Initial body weight of the birds was taken at the start of the experiment, and this was used to calculate the weight gain as follows

$$\text{Weight gain} = \text{final weight} - \text{initial weight}$$

$$\text{Feed conversion ratio} = \frac{\text{feed intake}}{\text{weight gain}}$$

Daily feed intake was also measured by subtracting the left over feed from the weight supplied. Feed cost/kg was calculated by adding prevailing market prices of the different feed ingredients per kg multiplied by their inclusion levels and divided by 100.

2.3.3. Rectal temperature of the birds

This was determined by inserting clinical thermometer in the rectum of the birds. It was done bi-weekly throughout the experiment.

2.3.4. Analysis of faecal materials

This was determined in the laboratory at the end of eight weeks in experiments.

2.4. Data Collection/Analysis

Data collected were subjected to analysis of variance (ANOVA) in a completely Randomized Design (CRD) as outlined by Steel and Torrie (1982) using Statistical Package for the Social Science (SPSS) windows 17.0. Significantly different means were separated using the method of Duncan's New multiple range test (Duncan, 1955).

2.5. Experimental Design

The experimental design was completely randomized with the statistical model as follows:

$$X_{ij} = \mu + X_i + \Sigma_{ij}$$

Where:
Xij = Observed value of dependent variable
μ = Overall mean
Xi = Effect of ith Biochar on body weight (where i = 1, 2, 3… n)
Σij = Random error associated with observation.

3. Results

Results showed that final body weight of the experimental birds increased significantly ($p<0.05$) as level of MSB in the diet increased. Birds on Treatment 4 had the highest value of 3.00±0.01 which differed ($p<0.05$) from values of 2.63±0.03 2.53±0.03 and 2.48±0.02 recorded in birds on T_3 T_2 and T_1 respectively. Total weight gain and the average daily weight gain followed the same pattern with birds on T_4 having highest value of 2.94±0.01.

Table 2 Growth Performance of Broilers fed MSB at Varying Inclusion Levels

Treatment	**T_1 (0.0%)**	**T_2 (0.5%)**	**T_3 (1.0%)**	**T_4 (1.5%)**	**P. value**
Initial Body Weight (kg)	$0.05±0.00^{NS}$	$0.05±0.00^{NS}$	$0.05±0.00^{NS}$	$0.05±0.00^{NS}$	1.00^{NS}
Final Body weight (kg)	$2.48±0.02^c$	$2.53±0.03^c$	$2.63±0.03^b$	$3.00±0.01^a$	0.00**
Total weight gain (kg)	$2.43±0.02^c$	$2.48±0.03^c$	$2.58±0.03^b$	$2.94±0.01^a$	0.00**
Av. Daily weight gain (g)	$43.41±0.51^c$	$44.30±0.68^c$	$46.09±0.62^b$	$52.64±0.27^a$	0.00**
Total feed intake (kg)	$7.92±0.10^a$	$6.75±0.09^b$	$6.97±0.13^b$	$6.94±0.05^b$	0.00**
Av. Daily feed intake (g)	$141.47±1.81^a$	$120.58±1.71^b$	$124.51±2.39^b$	$123.96±1.04^b$	0.00**
Feed conversion ratio	$3.25±0.00^a$	$2.72±0.00^b$	$2.69±0.01^b$	$2.35±0.03^c$	0.00**

^{ab}: Means on the same row with different superscripts are significantly different ($P \leq 0.05$ or $P \leq 0.01$)

Results showed that birds on control (T_1) had higher significant ($p <0.05$) total feed intake value of 7.92±0.10 which differed from the values of 6.94±0.05, 6.97±0.13 and 6.75±0.09 recorded for birds on T_4, T_3 and T_2 respectively. Birds on T_1 had higher significant ($p <0.05$) average daily feed intake value of 141.47±1.81 which differed from the values of 124.51±2.39, 123.96±1.04 and 120.58 ± 1.71 recorded for T_3, T_4 and T_2 respectively.

The results showed that the feed conversion ratio decreased significantly ($p < 0.05$) as the level of biochar in the diet increased. Birds on T_1 had the highest value of 3.25±0.00 which differed ($p<0.05$) from values of 2.72±0.00, 2.69±0.01, and 2.35±0.03 recorded for birds on T_2, T_3 and T_4 respectively.

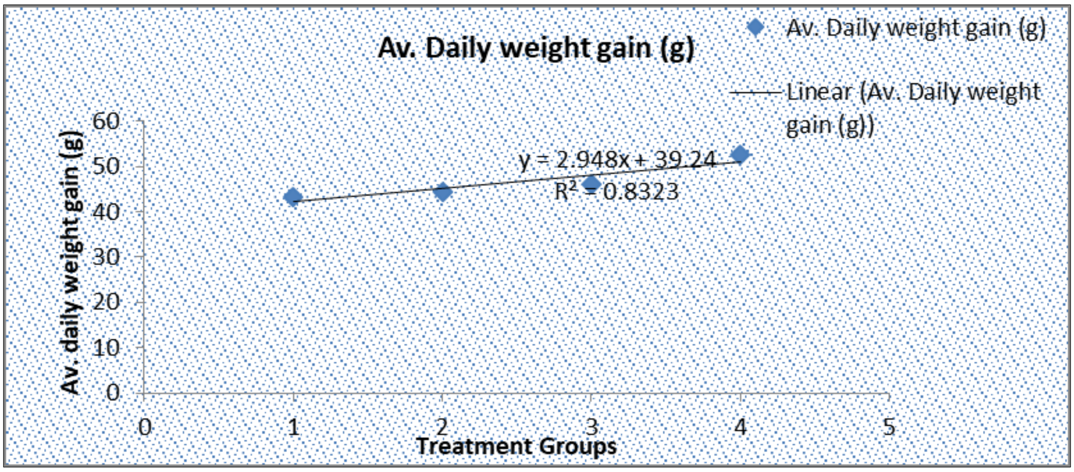

Figure 2 Average daily weight gain of finisher broilers fed varying levels of MSB.

Figure 2 above shows the average daily weight gain of the broilers fed varying levels of MSB with T4 recording the highest average daily weight gain which was linearly higher than other treatment groups.

Table 3 Ammonia Emission in the faecal matter of broilers fed MSB

Treatment	T_1 (0.0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	P. value
Wk 8	4.09 ± 0.19^{a}	1.19 ± 0.03^{bc}	1.32 ± 0.08^{b}	0.90 ± 0.01^{c}	0.00^{**}

^{ab}: Means on the same row with different superscripts are significantly different ($P \leq 0.05$ or $P \leq 0.01$)

Results showed that the value ammonia content in control (T_1) 4.09+0.19 was significantly higher and differed from the values 1.32+0.08, 1.19+0.03 and 0.90+0.01 recorded for birds on T_3, T_2 and T_4 respectively.

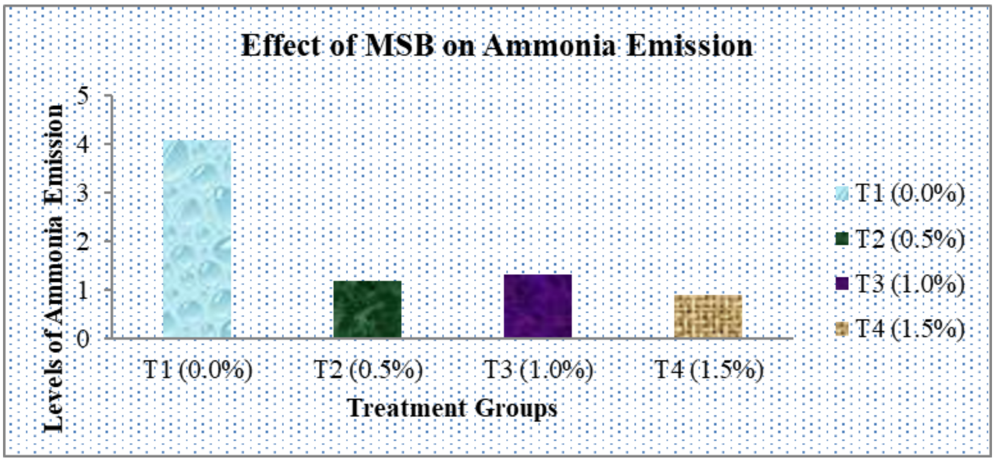

Figure 3 This chart represents the effect of MSB on ammonia emissions from broiler fecal matters

Figure 3 above shows that MSB were able to reduce the ammonia emission from the pens. T1 (control) had the highest level of ammonia emission of 4.09± 0.19 as against 0.90± 0.01 recorded on T4 (1.5%).

The table 4 shows the effect of MSB at various levels of inclusion on broiler birds. Highly significant ($P < 0.01$) results were recorded at week 2, 4 and 6, respectively. Thus, at week 8, no significant ($P > 0.01$) differences were reported. At week 2, the highest significant value was recorded at 0.0% biochar inclusion (T_4) and it is different from T_2, T_3 and T_4 with the lowest significant values. At week 4, the birds recorded the highest significant ($P < 0.01$) values at T_1 which are statistically ($p < 0.05$) different from T_3 and T_2 which were themselves similar but statistically higher than T_4 (41.00 ± 0.00). At six (6) weeks, the highest rectal temperature was T_1 (control) with the value of 42.86 ± 0.02 which was statistically higher than T_2 (42.86 ± 0.02) T_3 (41.00 ± 0.00) T_4 (41.13 ± 0.02) which were themselves similar.

Table 4 Rectal temperature of broilers fed varying levels of MSB

Treatment	T_1 (0.0%)	T_2 (0.5%)	T_3 (1.0%)	T_4 (1.5%)	P. value
Week 2	41.86 ± 0.02^{b}	41.56 ± 0.02^{b}	41.33 ± 0.02^{b}	41.09 ± 0.02^{a}	0.02**
Week 4	42.50 ± 0.00^{a}	41.97 ± 0.02^{b}	41.93 ± 0.02^{b}	41.00 ± 0.00^{c}	0.01**
Week 6	42.86 ± 0.02^{a}	42.86 ± 0.02^{a}	41.00 ± 0.00^{b}	41.13 ± 0.02^{b}	0.00**
Week 8	43.00 ± 0.00	42.96 ± 0.00	42.00 ± 0.00	42.00 ± 0.00	0.24^{NS}

^{abc}: Means ± SEM on the same row with different superscripts are significantly different ($P \leq 0.01$).

4. Discussion

4.1. Growth Response of Finisher Broilers

It is an established fact, that biochar functions as a catalyst expediting digestion and remains unchanged at the end of the reaction. In the current investigation, the inclusion of maize stover-derived biochar at varying levels exhibited a discernible impact on broiler performance. Birds that received 1.5% MSB inclusion demonstrated significantly higher final body weight, total weight gain, and average daily weight gain. This phenomenon can be ascribed to the MSB's digestive enhancement, feed efficiency improvement, and better feed conversion ratio. More so, biochar supplementation in broiler diets results in minimal excretion of nitrogen as waste ammonia; rather, nitrogen is metabolized into amino acids, contributing to protein synthesis which may have resulted in weight gain as observed in this study.

Evans *et al*. (2017) found that incorporating 2% broiler litter-based biochar in the diet of one-day-old broiler chicks had no adverse effects, yielding similar weight gain and Feed Conversion Ratio (FCR) compared to the control group. In this current study, a higher percentage of 1.5% MSB had a positive impact on weight gain, feed consumption, and feed conversion ratio.

Gerlach and Schmidt (2012) reported that the utilization of biochar as a feed supplement demonstrates its potential to enhance performance metrics such as weight gain, nutrient digestibility, and feed efficiency in broiler chickens and ducks Kana et al. (2010) and Ruttanavut *et al*. (2009).

Our current findings align with that of Odunsi *et al.* (2007), Kana *et al*. (2010), and Jiya *et al*. (2013), who reported that dietary biochar inclusion at levels of 2% or higher could impede growth rates and final body weights of broiler chickens. Conversely, our results contradict the reports of Kutlu *et al.* (2000), Kana *et al*. (2010), Prasai (2013), and Jiya *et al*. (2013), whose studies indicated improved growth performance of broilers with biochar inclusion at levels of 0.2-0.6%. Kana et al. (2014) also noted that including born charcoal and canarium charcoal at 0.4% and 0.2%, respectively, improved body weight and weight gain in broilers fed diets containing aflatoxin (AFB1).

This study is in consonance with the earlier work of Hien *et al.* (2018) on the impact of biochar inclusion in feed and chicken litter on chicken growth performance. However, reports on feeding biochar to chickens vary (Hien *et al.,* 2018). In contrast, research on poultry fed with wood-based biochar demonstrated better weights (60.6g±1.14g) and FCR (2.20g±0.042g) compared to the control group (Prasai *et al*., 2018). Additionally, Mongo et al. (2020) reported that coconut (*Cocos nucifera*) shell biochar positively influenced the growth performance of broilers.

4.2. Ammonia Emission of Finisher Broilers

Reflecting on the detrimental and perilous consequences of ammonia in poultry production, the incorporation of biochar derived from maize stover at different levels in feed proved effective in diminishing ammonia levels in fecal matter. This outcome can be ascribed to the absorbent qualities of biochar, which binds ammonia into ammonium before excretion, resulting in minimal nutrient out-gassing and loss. Consequently, birds exhibit minimal excretion of nitrogen as waste ammonia thus, nitrogen undergoes more comprehensive metabolism into amino acids, subsequently contributing to protein synthesis. The primary source of ammonia emissions in poultry houses stems from high-protein formulated chicken diets.

This current study aligns seamlessly with the findings of Ritz (2011), who observed a substantial reduction in ammonia content in chickens supplemented with 3% activated carbon compared to those without any char. Similarly, Marie

(2013) reported that including biochar from pine chips, peanut hulls, and locally available woods in the diet led to a significant decrease in ammonia and phosphorus content in poultry droppings, along with reduced odour and water content in the resulting fecal matter.

Ritz *et al*. (2011) discovered that directly applying biochar to bedding materials can effectively reduce ammonia emissions, particularly when the biochar possesses a high surface area or has been treated to lower pH. Application rates ranged from 0 to 0.73 kg/m2 to the floor of pens containing broilers at a commercial density of 0.07m2/bird. Acidified chars, in particular, resulted in significant reductions in NH3 concentrations by approximately 50%.

Zhang *et al*. (2016) in their work supported the aforementioned findings, as they compared acidified biochar to sodium bisulfate (PLT) and determined that achieving a similar reduction in ammonia emissions required twice the amount of acidified biochar as PLT (sodium bisulfate). Applying acidified biochar at a rate of 200 lb/1000 square feet led to a reduction in NH3 by up to 47%.

It is crucial to note that the specific surface area, pH, and liming capacity of biochar materials can vary significantly depending on feedstock and processing parameters. While these results demonstrate the potential of biochar in controlling ammonia emissions, they also underscore the importance of considering other factors such as pH, C: N ratio, and biochar surface chemistry.

4.3. Rectal Temperature of Finisher Broilers

The temperature values reported by Olanrewaju *et al*. (2010) (40.60 - 41.70 °C) were lower than the values observed in this current study (41.80 to 42.00 °C). Conversely, the values recorded by Aengwanich (2008) (42.83 - 44.21 °C) were higher when compared with the values obtained in this study.

The assessment of core body temperature is widely considered a reliable indicator of health status (Rose-Dye *et al*., 2011), thermal balance (Gaughan *et al*., 2010), and stress-induced hyperthermia (Sanger *et al*., 2011) in animals. According to Lees *et al*. (2018), rectal temperature has traditionally been deemed the most accurate estimate of core body temperature. Broilers tend to rest or crouch near walls during periods of heat stress (Yanagi *et al.,* 2002). Heat stress can lead to the depletion of potassium and other minerals in the body, resulting in poor performance (Tao and Xin, 2003). Panting and drooping of the wings are thermoregulatory mechanisms employed by broilers to alleviate heat stress. Furthermore, when broiler birds are exposed to conditions beyond their thermoneutral zones, they exhibit susceptibility to environmental heat stress (El-Deep *et al*., 2014), accompanied by various physiological and behavioral changes (Ozek *et al*., 2012). Several authors have suggested dietary manipulation as a strategy to address ,heat stress (Attia *et al*., 2011; Attia and Hassan, 2017).

An interesting observation from study indicates that at weeks 4 and 6, the rectal temperature values are optimal with 0% and 0.5% inclusion of MSB. This suggests that these inclusion levels may be recommended for mitigating heat stress and promoting overall improvement in broiler performance. According to Gerlach and Schmidt (2012), incorporating MSB into the diet of broiler birds deactivates toxins in the digestive tract and enhances the activation of intestinal flora, resulting in improved vitality. These positive effects may not have been achievable without addressing heat stress. The results at week 2, 4 and 6 showed that the treatment groups had the lowest rectal temperatures, indicating favorable conditions.

5. Conclusion

- The findings of this study have shown that the inclusion of MSB in the diets of finishing broiler chickens resulted in enhanced growth performance.
- MSB demonstrated its ability to reduce ammonia emissions in the birds' feacal matters, thereby reducing pollution in the poultry house and its surroundings.
- Finally, the birds treated with MSB exhibited lower rectal temperatures, indicating their increased ability to withstand heat stress compared to the birds in the control group.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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