
Fish-based organic nutrients in hydroponics: A viable alternative to chemical fertilizers for lettuce growth

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Abstract These findings indicated that butterhead lettuce in the presence of commercial chemical nutrient solution was remarkably superior to any of the methods applied to grow it in all attributes, as depicted: average height of the plants was 11.87 cm, leaf width was 10.57 cm, as well as an increase in leaf length, canopy size, root length, and post-trim weight. The variance was above odds at 95% accuracy. Of all organic solutions, the one supplemented with fish fertilizer, vermicompost extract, and liquid organic fertilizer at a 3:1:1 ratio yielded the second-best growth, with improved height, leaf width, and plant mass. Additionally, the existing research is indicated that using organics (presumably fish-based additives) to enhance an environmentally friendly and effective alternative to conventional fertilizers for hydroponic vegetable production, as it can reduce the use of these chemicals.

Keywords: Hydroponic, Fish steaming water, Butterhead lettuce

Introduction

The long-term negative impacts of chemical fertilizers make sustainable agriculture and environmental impact reduction important approaches in today's farming. Continuing use of chemical fertilizers contributes to toxic build-up in soil and water, which adversely affects biodiversity and public health. As a result, the move to organic fertilizers of natural raw materials has become crucial for the sustainable development of soils and decreasing the reliance on chemical fertilizers (Edwards, 2015; Bhat *et al.*, 2021). Fish steaming water is considered a potential raw material for organic fertilizer production. It is abundant in nitrogen, phosphorus, and potassium, which are important macronutrients for

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plant growth (Gobbi *et al.*, 2013). When molasses is fermented with fish steaming water, it provides a positive enhancement of nutrient bioavailability, as molasses promotes microbial growth which is crucial for organic matter digestion, therefore improving efficient release and uptake of nutrients for vegetation (Chia *et al.*, 2019; Garg and Chandel, 2021). Because of the controlled environment in which plants can be grown, hydroponic farming has gained increasing popularity among both farmers and commercial growers. However, conventional hydroponic systems rely to a significant extent on chemical nutrient solutions, which may leave residues on consumable crops.

Now, organic nutrient solutions in hydroponic systems have become an attractive alternative that meets the demand for safe, eco-friendly agricultural products. So, instead of mixing with the chemical solutions, an organic nutrient solution is prepared from the fermented fish steaming water and molasses. Another benefit of this alternative is that it also reduces production costs and the likelihood of chemical contamination of food. The ideal organic nutrient solution can only be created through a delicate optimization of the compositions of fish steaming water and molasses used for the fermentation process. Both of which help plant growth in hydroponic platforms (Gobbi *et al.*, 2013; Chia *et al.*, 2019), and the concentrations of these components may play a critical role in the composition of the nutrients and pH in solution. The experiment aimed to determine the optimal organic nutrient solution for leafy green production by measuring the different dilutions of fish steaming water and molasses used in the experiment.

Materials and methods

Testing the optimal dilution ratio of fish steaming water and molasses in the fermentation process for organic fertilizer production

A 10-liter glass container and precise measuring instruments were prepared for this experiment. Fish steaming water was diluted with water and mixed with molasses to obtain a total volume of 5 liters per treatment, following the predetermined experimental ratios. The fish steaming water and molasses mixture was thoroughly stirred in each treatment. An air circulation system was then connected to the fermenting containers, programmed to introduce air for 10 minutes every hour, only during daytime. Each container was covered with mulberry paper to allow ventilation while preventing contamination from insects and other particulates. The setup was placed in a shaded, well-ventilated area, and fermentation was allowed to proceed for 15 days (or until bubbling ceased and the pH stabilized between 3 and 4). Measurements of pH, electrical

conductivity (EC), and nutrient content were taken. Additionally, observations of the physical characteristics of the fermenting liquid were recorded for each treatment.

The experiment was designed using a Completely Randomized Design (CRD) with five treatments, each replicated three times, as follows:

Treatment 1: 100% fish steaming water

Treatment 2: Fish steaming water diluted 1.5 times (1 part) + 1 part molasses

Treatment 3: Fish steaming water diluted 3 times (1 part) + 1 part molasses

Treatment 4: Fish steaming water diluted 5 times (1 part) + 1 part molasses

Treatment 5: Fish steaming water diluted 10 times (1 part) + 1 part molasses

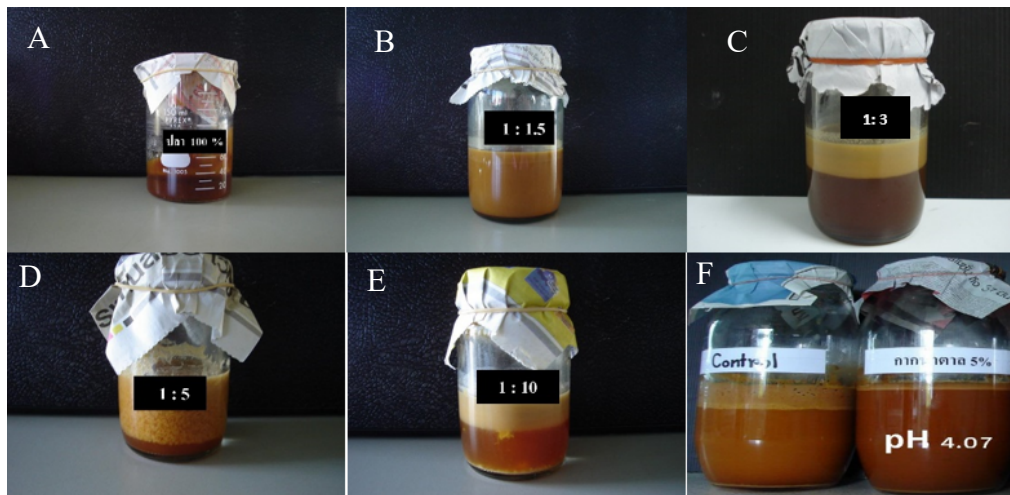


Figure 1. The mixtures used in the experiment. Formulations 1-5 include 100% fish steaming water (A), diluted 1.5 times (B), diluted 3 times (C), diluted 5 times (D), and diluted 10 times (E), while F represents the mixture of molasses with the fish steaming water

Testing the organic nutrient solution formula on butterhead lettuce cultivation in comparison with commercial chemical nutrient solution in a hydroponic system

Fourteen-day-old butterhead lettuce seedlings were transplanted into a Deep Flow Technique (DFT) hydroponic system. Each nutrient solution was prepared by diluting the organic formulas 100-fold with water, then aerated for

5 days to increase oxygen levels before filtering out sediment. The seedlings were grown in 28-inch tubs, each containing 10 liters of the nutrient solution. After three weeks, the water level was adjusted to maintain a 4 cm gap between the water surface and the foam sheet, promoting optimal oxygenation for the root system. Air stones were used to maintain oxygen levels in the solution, and nutrient levels were carefully monitored throughout the experiment. Growth data of the lettuce plants were recorded for subsequent analysis.

The experiment employed a Randomized Complete Block Design (RCBD) with six treatments, each replicated three times across three tubs. The treatments were as follows:-Treatment 1= Plain water, Treatment 2 = Commercial chemical nutrient solution, Treatment 3 = Fish fertilizer + vermicompost extract + liquid organic fertilizer (3:1:1), Treatment 4 =Fish fertilizer + vermicompost extract + liquid organic fertilizer (4:1:1), Treatment 5: Fish fertilizer + vermicompost extract + liquid organic fertilizer (4:1:2) and Treatment 6 = Fish fertilizer + vermicompost extract + liquid organic fertilizer (5:1:2).

Statistical analysis

Statistical analysis using ANOVA and Duncan's Multiple Range Test (DMRT) was conducted to evaluate significant differences in growth parameters, including height, leaf width, canopy size, root length, and post-trim weight, at the 95% confidence level. This analysis facilitated an understanding of the relative efficacy of each nutrient solution, underscoring the potential of fish-based organic fertilizers as viable alternatives in sustainable hydroponic vegetable production.

Results

Testing the optimal dilution ratio of fish steaming water and molasses in the fermentation process for organic fertilizer production

The result from indicated significantly differences in pH, electrical conductivity (EC), and nutrient content across the treatments of organic fertilizer derived from fish steaming water (Table 1). Treatment 1 displayed the highest pH value (5.60), while Treatment 2 had the lowest (3.86). EC values were highest in Treatment 2 (0.68 mS/cm), suggesting a greater ion concentration, while Treatments 3, 4, and 5 showed lower EC values (0.22-0.23 mS/cm). Nitrogen content was highest in Treatment 1 (5.76%), significantly surpassing other treatments, whereas Treatment 5 had the lowest nitrogen content (0.74%). Phosphorus was also highest in Treatment 1 (0.57%) and decreased across

subsequent treatments, with Treatments 4 and 5 showing the lowest levels (0.10%). Potassium content was notably higher in Treatments 4 and 5 (2.67%), with Treatment 2 displaying the lowest value (1.53%). Calcium and magnesium levels were highest in Treatment 5 (1.02% and 0.56%, respectively), while Treatment 1 had the lowest calcium (0.14%) and Treatment 2 had the lowest magnesium (0.17%). Overall, the findings suggest that different dilution ratios and compositions of fish steaming water and molasses significantly affect the nutrient profile of the organic fertilizer, with Treatment 1 showing high nitrogen and phosphorus levels, while Treatments 4 and 5 demonstrated higher potassium, calcium, and magnesium contents.

Table 1. pH, electrical conductivity (EC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) content in organic fertilizer derived from fish steaming water

Treatment	pH	EC (mS/cm)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
1	5.60 a	0.57 b	5.76 a	0.57 a	1.65 c	0.14 e	0.22 d
2	3.86 d	0.68 a	3.34 b	0.15 b	1.53 d	0.20 d	0.17 e
3	4.28 b	0.22 c	1.91 c	0.13 c	2.52 b	0.59 c	0.38 c
4	4.26 b	0.23 c	1.86 d	0.10 d	2.67 a	0.66 b	0.40 b
5	4.09 c	0.23 c	0.74 e	0.10 d	2.67 a	1.02 a	0.56 a
CV%	1.22	5.30	0.59	3.55	0.28	0.85	0.00
F-Test	**	**	**	**	**	**	**

Note: Means followed by the same letter within a column do not differ significantly ($p < 0.01$) based on Duncan's Multiple Range Test.

Testing the organic nutrient solution formula on butterhead lettuce cultivation in comparison with commercial chemical nutrient solution in a hydroponic system

The experimental results revealed that butterhead lettuce cultivated in a hydroponic system using the chemical nutrient solution in Treatment 2 achieved the greatest average height of 11.87 cm, with the widest average leaf width of 10.57 cm. Additionally, it exhibited the highest values for leaf length, canopy size, root length, and post-trim weight compared to other treatments, with statistically significant differences at a 95% confidence level. Meanwhile, the organic nutrient solution in Treatment 3 showed the second-best results across all parameters. The study findings are illustrated in Figure 1, with further details as follows.

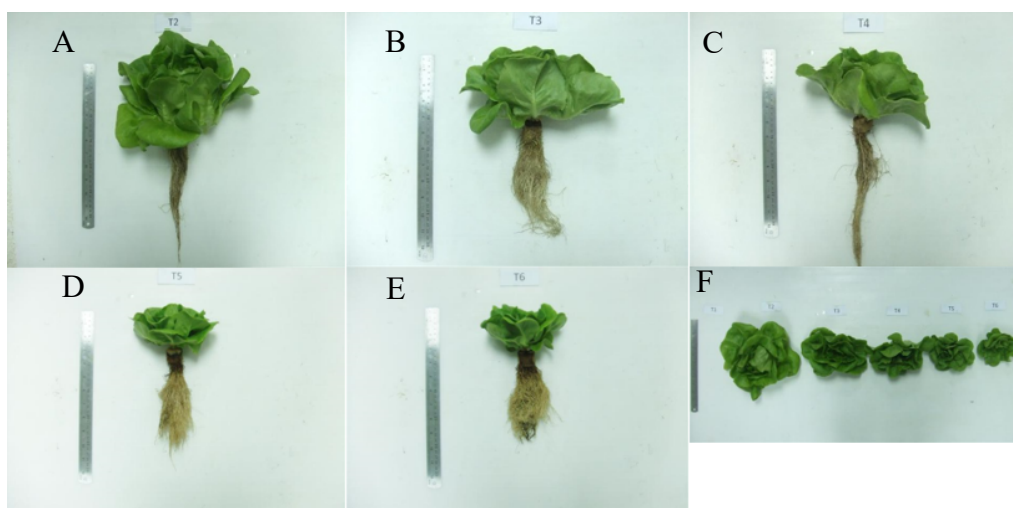


Figure 2. Characteristics of butterhead lettuce: A–E represent experimental formulas 2 through 6, and F shows a comparison of formulas 2–6

The average height data for butterhead lettuce cultivate in a hydroponic system showed that Treatment 2, which used a chemical nutrient solution, achieved the greatest average height of 11.87 cm at 49 days post-transplant. Treatment 3, an organic nutrient solution, displayed the second-highest growth at 10.71 cm, while Treatment 6 demonstrated the lowest average height. Growth in height exhibited statistically significant differences at a 95% confidence level across treatments throughout the growth period (Table 2).

For leaf width, Treatment 2 consistently showed the widest leaves, with an average of 10.57 cm at 49 days. Among organic treatments, Treatment 3 achieved the best results, with an average leaf width of 8.45 cm. Statistical analysis indicated significant differences in leaf width among treatments at the 95% confidence level (Table 3).

In terms of average leaf length, Treatment 2 recorded the highest average of 12.40 cm at 49 days, followed by Treatments 3 and 4 with comparable averages of 10.55 cm and 10.50 cm, respectively. Leaf length across treatments showed statistically significant differences throughout the trial period at a 95% confidence level (Table 4).

Table 2. the average height data of butterhead lettuce at 7, 14, 21, 28, 35, 42, and 49 days after transplanting in a hydroponic system

Experimental Treatments	Average Plant Height per Treatment (centimeters) by Days After Transplanting						
	7	14	21	28	35	42	49
1	0.97 ^b	1.34 ^c	1.46 ^d	2.13 ^c	0.00 ^d	0.00 ^b	0.00 ^c
2	0.93 ^b	4.91 ^a	5.76 ^a	6.38 ^a	7.96 ^a	10.46 ^a	11.87 ^a
3	1.05 ^a	2.66 ^b	3.79 ^b	4.31 ^b	7.50 ^{ab}	9.25 ^a	10.71 ^{ab}
4	0.89 ^b	1.47 ^c	2.75 ^c	4.04 ^b	6.96 ^{abc}	8.91 ^a	9.80 ^{ab}
5	1.02 ^a	2.27 ^b	3.46 ^b	4.18 ^b	6.52 ^{bc}	8.93 ^a	10.12 ^{ab}
6	1.12 ^a	2.92 ^b	3.80 ^b	4.24 ^b	6.27 ^c	8.27 ^a	9.26 ^b
CV%	14.56	16.93	8.05	16.82	9.18	15.41	12.84
F-Test	ns	*	*	*	*	*	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

ns = no statistically significant difference

Table 3. the average leaf width data for butterhead lettuce at 7, 14, 21, 28, 35, 42, and 49 days after transplanting in a hydroponic system

Experimental Treatments	Average Leaf Width per Plant (cm) at Days After Transplanting						
	7	14	21	28	35	42	49
1	0.78 ^b	1.15 ^b	1.02 ^c	0.99 ^d	0.00 ^c	0.00 ^c	0.00 ^c
2	1.41 ^a	3.56 ^a	6.70 ^a	7.35 ^a	8.02 ^a	9.49 ^a	10.57 ^a
3	0.84 ^b	1.95 ^b	4.20 ^b	6.12 ^{ab}	6.88 ^{ab}	8.05 ^{ab}	8.45 ^b
4	0.79 ^b	1.33 ^b	2.60 ^d	3.92 ^c	6.26 ^b	7.72 ^{ab}	8.32 ^b
5	0.79 ^b	2.03 ^b	3.25 ^{cd}	4.24 ^c	6.24 ^b	8.33 ^{ab}	7.62 ^b
6	0.96 ^b	1.82 ^b	3.55 ^{bc}	4.59 ^{bc}	5.36 ^b	6.09 ^b	6.72 ^b
CV%	17.28	32.43	11.42	19.62	16.38	19.00	15.02
F-Test	*	*	*	*	*	*	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

Table 4. the average leaf length per plant of butterhead lettuce at 7, 14, 21, 28, 35, 42, and 49 days after transplanting in a hydroponic system

Experimental Treatments	Average Leaf Length per Plant (cm) at Various Days After Transplanting						
	7	14	21	28	35	42	49
1	1.05 ^c	1.46 ^d	1.36 ^c	1.44 ^c	0.00 ^d	0.00 ^c	0.00 ^c
2	1.92 ^a	5.17 ^a	7.03 ^a	8.06 ^a	9.37 ^a	11.02 ^a	12.40 ^a
3	1.41 ^b	2.87 ^{bc}	5.05 ^b	7.59 ^a	8.90 ^{ab}	10.01 ^{ab}	10.55 ^{ab}
4	1.13 ^{bc}	2.06 ^{cd}	3.48 ^d	5.92 ^b	7.96 ^{abc}	9.63 ^{ab}	10.50 ^{ab}
5	1.21 ^{bc}	2.22 ^{bc}	4.16 ^{cd}	6.37 ^b	7.53 ^{bc}	9.16 ^{ab}	9.92 ^b
6	1.47 ^b	3.13 ^b	4.72 ^{bc}	5.87 ^b	7.13 ^c	8.25 ^b	9.08 ^b
CV%	13.00	18.49	9.82	10.57	12.03	12.44	12.24
F-Test	*	*	*	*	*	*	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

For canopy size, Treatment 2 demonstrated the largest canopy width of 21.99 cm at 49 days, while Treatment 3 had the largest canopy among the organic treatments, measuring 19.06 cm. Canopy size showed significant differences across treatments at the 95% confidence level (Table 5).

Table 5. the average canopy size per plant of butterhead lettuce at 7, 14, 21, 28, 35, 42, and 49 days after transplanting in a hydroponic system

Experimental Treatments	Average canopy size per plant (cm) at various days after transplanting						
	7	14	21	28	35	42	49
1	2.22 ^b	2.77 ^c	2.80 ^c	2.49 ^c	0.00 ^d	0.00 ^c	0.00 ^d
2	3.45 ^a	8.09 ^a	14.67 ^a	15.75 ^a	18.56 ^a	20.68 ^a	21.99 ^a
3	2.53 ^b	4.90 ^{bc}	10.56 ^b	15.09 ^a	16.72 ^{ab}	18.34 ^{ab}	19.06 ^{abc}
4	2.05 ^b	3.34 ^{de}	6.88 ^d	11.24 ^b	15.22 ^{bc}	18.32 ^{ab}	19.47 ^{ab}
5	2.28 ^b	3.88 ^{cd}	8.64 ^c	12.76 ^b	14.64 ^{bc}	16.57 ^b	17.60 ^{bc}
6	2.63 ^b	5.43 ^b	9.01 ^c	11.60 ^b	13.22 ^c	14.57 ^b	16.10 ^c
CV%	13.00	12.27	8.10	10.28	9.92	13.27	10.43
F-Test	*	*	*	*	*	*	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

Average root length data for harvested butterhead lettuce reveal that Treatment 2 had the longest average root length at 36.46 cm, followed by Treatments 4 and 3 with averages of 23.35 cm and 22.75 cm, respectively. Differences in root length between treatments were statistically significant at the 95% confidence level (Table 6).

Table 6. the average root length per plant of butterhead lettuce after harvest

Experimental Treatments	Root Length (cm per plant)
1	0.00c
2	36.46a
3	22.75b
4	23.35b
5	22.55b
6	21.39b
CV%	17.74
F-Test	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

Regarding weight before and after trimming, Treatment 2 showed the highest post-trim weight, with an average of 111.12 grams per plant. Among the organic treatments, Treatment 3 produced the best results, with an average post-trim weight of 76.74 grams per plant. Differences in weight before and after trimming across treatments were statistically significant at the 95% confidence level (Table 7).

Table 7. the pre-trim and post-trim weight data of butterhead lettuce after harvest

Experimental Treatments	Weight (grams/plant)	
	Before trimming	After trimming
1	0.00 ^c	0.00 ^c
2	129.26 ^a	111.12 ^a
3	84.05 ^{ab}	76.74 ^b
4	77.97 ^{ab}	72.55 ^b
5	64.51 ^b	58.98 ^b
6	59.55 ^b	55.31 ^b
CV%	29.29	28.59
F-Test	*	*

Note: Means were compared using Duncan's Multiple Range Test (DMRT).

* = a statistically significant difference at a 95% confidence level.

Discussion

It was reported that comparing the ratios of dilution in fish steaming water and molasses during the fermentation process showed considerable differences in nutrient profiles between treatments, and thus directly affects the efficiency of the organic fertilizer production. Treatment 1 with undiluted fish steaming water also showed the highest nitrogen and phosphorus content and a relatively high pH of 5.60. Its pH value is beneficial for soils that are relatively acidic to neutral, supporting microbial development and organic matter decomposition, which are vital for plant cultivation (Gobbi *et al.*, 2013). These results are in accordance with Gobbi *et al.* where organic fertilizers with high nitrogen and phosphorus contents enhance soil fertility by facilitating microbial activities. By contrast, Treatment 2 showed the least pH (3.86) and the highest electrical conductivity (EC) of 0.68 mS/cm, showing a fairly high ion concentration. These results also indicate that the fermentation process in this treatment was more efficient, attributable to microbial activity from the addition of molasses. Low pH and higher ion concentration are consistent with the study by Nguyen *et al.* (2015) that molasses induces positive microbial activity that leads to the acceleration of degradation of organic matter and nutrient release.

Additionally, Treatments 4 and 5, both containing higher dilution ratios of fish steaming water, showed elevated levels of potassium, calcium, and magnesium, confirming that these formulations were effective at amending soils lacking these nutrients. These secondary nutrients were highlighted by Edwards (2015) as critical elements in plant structural fortification, especially in hydroponic systems, where precise nutrient control is required. In a hydroponic system for butterhead lettuce cultivation, the highest average plant height (11.87 cm), the leaf width (10.57 cm), and the highest post-trim weight (111.12 g per plant) could be achieved in the chemical nutrient solution in Treatment 2. This is in agreement with Meneguz *et al.* (2018), who found that chemical solutions achieve maximum growth in hydroponic systems using readily available, nutrient-rich nutrients. However, organic nutrient treatment with fish steaming water and molasses also facilitated growth and was good, particularly at Treatment 3, where the average height was 10.71 cm and leaf width was 8.45 cm. This treatment is a less efficient solution than chemical solutions but is an acceptable one for the safe production of organic vegetables. These findings, reported in Garg and Chandel (2021) and Kraissittipanit *et al.* (2025), highlighted that organic nutrient solutions and plant hormones reduced chemical inputs, thereby promoting a sustainable agricultural system. According to them, chemical nutrient solutions were the best for promoting butterhead lettuce growth (height, leaf size, and post-trim weight) based on their hydroponic system results. However, there were some promising results for organic nutrient solutions

prepared with fish steaming water together with molasses (both of which can be done properly) in optimal proportions. These organic options provide a safe and environmentally friendly alternative for hydroponic vegetable production. Organic nutrients in the form of organic food solutions would reduce dependence on chemicals, which is in line with sustainable agricultural practices and contributes to the transition toward environmentally sustainable food production.

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Conflict of interest

The authors declare no conflict of interest.

Ethical approval

This study did not involve any live animal handling, breeding, or sacrificing, and no live animals were brought into the laboratory. The fish steaming water utilized in the fermentation process was obtained strictly as a liquid by-product collected from commercial fish-steaming vendors in a local market. Consequently, this research is entirely exempt from animal ethics review, and institutional ethical clearance for animal research was not required.

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