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Research Article

EVALUATION OF MEALY FEED DISTRIBUTION METHODS FOR *OREOCHROMIS NILOTICUS* REARED IN PONDS DURING THE GROW-OUT

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ABSTRACT

Efficient feed distribution is essential in fish farming to minimize losses and optimize growth. This study evaluated the effects of four mealy feed distribution methods on the growth performance and economic efficiency of *Oreochromis niloticus* reared in earthen ponds during the grow-out phase. A total of 4 620 monosex juvenile tilapia (mean weight: 9.8 ± 0.38 g) were stocked at a density of 2.2 fish/m^2 across 12 ponds and fed over 126 days using one of the following methods: on-the-fly distribution, fixed floating frame distribution, self-feeder distribution or distribution on submerged tables. Significant differences (P<0.05) were observed in growth parameters such as weight gain and daily growth rate among the feeding methods, with the fixed floating frame showing the best overall performance with an average weight gain of 212.41 ± 9.70 g and a daily weight gain of 1.60 ± 0.11 g. However, the self-feeder method demonstrated the highest economic profitability due to reduced labor costs. No significant differences (P>0.05) were noted in water quality or survival rates across treatments. These findings suggest that both fixed floating frames and self-feeders can improve feed utilization, but the self-feeder offers the most cost-effective option for small-scale pond culture of *O. niloticus.*

Keywords: Meal feed, Distribution methods, Nile tilapia, Self-feeder, Monosex.

INTRODUCTION

Aquaculture makes a significant contribution to achieving food security and global nutrition (FAO, 2022). Faced with the stagnation of fishery products, it is up to aquaculture to provide high-quality proteins to the world's population, whose average fish consumption, which is growing rapidly, rose from 16 to 20.2 kg per capita per year from 2000 to 2020 (FAO, 2022). Fish makes up about half of the total animal protein consumed in Côte d'Ivoire (Anvo *et al*., 2023). Because of its many exceptional fish farming qualities, including its quick growth, effective conversion of natural and prepared foods, resistance to disease and handling (Chevassus-au-Louis & Lazard, 2009; Fontaine *et al.,* 2009), high level of environmental tolerance, organoleptic and nutritional quality of flesh, and commercial value, the Nile tilapia (*Oreochromis niloticus*) is the primary aquaculture species in Côte d'Ivoire (Kimou *et al*., 2016). According to Groga *et al.* (2025), local aquaculture production is still insufficient to satisfy the growing demand. Only 10% of the nation's fish demands are satisfied by domestic production, despite Côte d'Ivoire has perfect natural conditions for aquaculture. The low productivity of aquaculture is attributable to the many challenges facing the sector, the main one being the cost and quality of feed. The food component in aquaculture accounts for between 60 and 75% of total production costs (Babalola & Apata, 2012 ; Kimou *et al.,* 2016). The

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economic viability of aquaculture is therefore highly dependent on the availability, cost and appropriate use of feed (Tacon *et al.,* 1997 ; Hoffman *et al.,* 1997). Reducing feed costs, and consequently controlling the production cost of farmed fish, is therefore one of the priorities in aquaculture (Watanabe, 2002). Fish feeding methods must so be economically efficient (Barrows & Hardy, 2001). An inadequate feeding can reduce fish growth, pollute the farming environment and increase production costs (Guillaume *et al.,* 1999). According to Kimou *et al.* (2016), 71.1% of fish farmers in Côte d'Ivoire directly feed their fish with a meal made from agricultural byproducts. However, the mealy form causes food losses through the wind, which blows the food on the dykes, and through leaching into the muddy bottom of fishponds. To reduce these feed losses, several methods of distributing meal feed to fish have been developed, the principle being to concentrate the feed in one or more sectors of the rearing environment and prevent it being washed out and/or washed to the bottom. These include distribution with a fixed floating frame, a fixed submerged table, and the use of a self-feeder. The aim of this work was to compare the efficiency of the mealy feed by improving distribution methods in *O. niloticus* during the grow-out.

MATERIALS AND METHODS

Breeding infrastructure

The experimental trials were carried out from at the Inland Fisheries and Aquaculture Research Station of the National Center for Agricultural Research in Bouaké, Côte d'Ivoire. 12 ponds, each with a surface area of 175 m², were used, with three replicates allocated to each of the four feed distribution methods.

Biological material

The fish used in the experiment were juvenile tilapia *Oreochromis niloticus* with an average weight of 9.8±0.38 g. These fish were produced at the Inland Fisheries and Aquaculture Research Station. A total of 4 620 male monosex tilapia juveniles of *O.niloticus* of the Bouaké strain were used for the test.

Detailed description of the device

Four feed distribution systems were used in this study (Figure 1, 2 & 3). The feeding device were made from locally available, low-cost materials: On-the-fly distribution: This method consisted of broadcasting the feed into the pond using scoop. Fixed floating frame distribution: This device had a surface of 1 m^2 and was made of wood. The frame was anchored at in the center of the pond. Feed was placed onside the frame at fixed times. Demand feeder distribution: This was an automated feeding system consisting of a 20L plastic bucket, a funnel, and a pendulum mechanism mounted on a floating support. Each feeder was placed at the center of the pond. To avoid mold or feed compaction, the devices were checked daily. Submerged table distribution: This method used a wooden table with a surface area of 0.7 m^2, submerged just below the water surface. Feed was manually placed on the table at fixed times.

Figure 1. Self-feeder.

Figure 2. Submerged table

Figure 3. Fixed floating frame

Experimental procedure

The trials involved *Oreochromis niloticus* juveniles (mean weight 9.8±0.38 g), stocked at a density of 2.2 fry/m², reared in 12 ponds of 175 m² at the Inland Fisheries and Aquaculture Research Station in Bouaké (Côte d'Ivoire) for 126 days. They were given mealy food using four different methods: on-the-fly distribution (OFD), distribution on submerged tables (DST), distribution in a fixed floating frame (D3F), and distribution using a self-feeder (DSF). The methods used to distribute the daily rations to the fish varied according to the feeding method. The day ration was therefore divided into two (02) phases for OFD, D3F, and DST (in the morning and in the afternoon). The feed is first wetted to allow it to sink and settle on the table for feeding on submerged tables. For the self-feeder, the feed trough held the full day ration all at once (8 hours). Each treatment was randomly allocated across three replicate ponds (Figure 4). The quantity of feed was set according to the average biomass of the fry every 4 weeks after control fishing on a sample of 50 individuals. The fish were fed a mealy feed produced at the research center, consisting mainly of agricultural products and by-products and containing 38.24% protein and 9.50% lipids (Table 1). The feeding rates applied varied according to the weight of the fish (Table 2). At the end of the experiments, all the ponds were emptied in order to assess the survival rate.

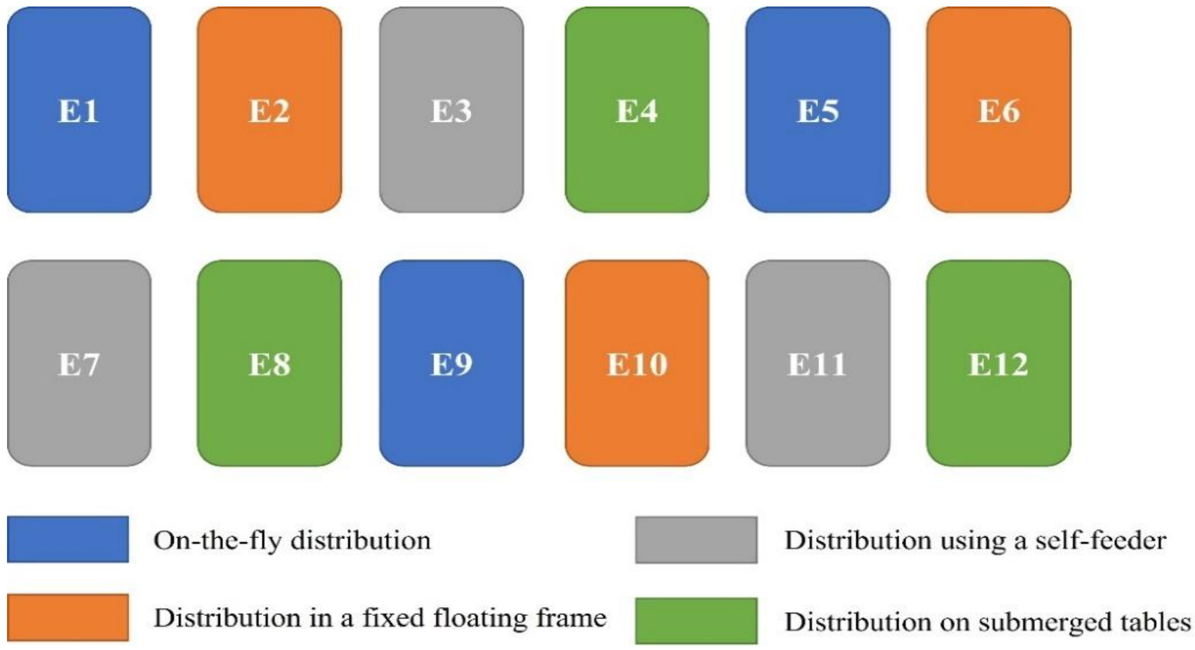

Figure 4. Experimental setup: E1 to E12 = Pond 1 to 12.

Table 1. Ingredients (g/kg) of ration and theoretical biochemical composition (%) of experimental feed.

Ingredients	Quantities (g)
Rice meal	244
soybean meal	500
Local fish meal	200
Vitamin Mineral Complex	2
Methionine	2
Lysine	2
Red palm oil	50
Total	**1000**
Theoretical biochemical composition	
Protein (%)	38.24
Fat (%)	9.50
Ash (%)	7.67

Table 2. Rationing table for Nile Tilapia individuals according to weight class (Kreman *et al*., 2020).

Weight class	Ration rate
[5 – 21]	4.6
[21 - 51]	4.0
[51 - 101]	3.0
[101 - 201]	2.8
[201 - 401]	2.1
[401 and over]	1.8

Water quality monitoring

The quality of the rearing environment was monitored by measuring the following physico-chemical water parameters: pH, dissolved oxygen, temperature and conductivity. These parameters were measured once a week at 08:00 and 15:00 using a HANNA HI 9828 series multi-parameter.

Economic evaluation

Economic parameters were carried out to determine the expenditure, production costs and profits generated by the use of these different feeding methods. This analysis concerned the labour involved in feeding, the cost of the feed used, the cost of the fry and the cost of the feeding devices. In this section, the comparison between treatments focused on the labour cost of feeding, the production cost per 1 kg of fresh weight, the total cost generated, and the profit margins achieved.

Expression of results

Several parameters were calculated in order to compare the different feed distribution methods used in this trial.

Daily weight gain (DWG, g/d) = (Final weight (g) - initial weight (g)) / rearing period;

Specific growth rate (SGR, %/d) = 100 × [Ln (final weight) - Ln (initial weight)] / rearing period;

Survival rate (SR, %) =

100 x (final number of fish / initial number of fish);

Feed conversion rate (FCR) =

Quantity of dry feed distributed (g) / fresh weight gain (g)

Coefficient of variation of average weight (CV, %) = 100 x (Standard deviation / average weight);

Total biomass (TB, Kg) =

Final average weight (Kg) x final number of animals;

Net biomass (NB, Kg) =

Final biomass (Kg) - Initial biomass (Kg);

Rate of increase in biomass compared to control (T Ag, %) = [(Biomass per are of control feeding method - Biomass per are of test feeding method) x 100] / Biomass per are of control feeding method;

Cost of feed used (CFU, USD) =

Price per kg of feed (USD) x Quantity of feed used (Kg);

Cost of feeding (USD) = [Time per feeding (15 min) x number of feeds per day x daily wage x rearing period (d)] / [Working time per day (min)]

Production cost (USD/Kg) =

Total expenditure (USD) / Net biomass (Kg)

Rate of reduction in production cost compared with the control (TxR, %) = [(Production cost with control feeding method - Production cost with test feeding method) x 100] / Production cost with control feeding method.

Statistical analysis of the data

Statistical analyses of the variables measured were carried out using R software, version 4.2.3 (2023-03-15 ucrt). The parameters measured during this experiment (physico-chemical parameters and zootechnical performance of the fish) were subjected to analysis of variance (one-factor ANOVA). If significant differences (P<0.05) were found, the Tukey test was used to assess the differences between the treatments for each parameter calculated.

RESULTS AND DISCUSSION

The average values of the physicochemical parameters of the breeding environments are presented in Table 3. The values of the water parameters tested in the ponds of fish exposed to the four feed distribution techniques did not differ significantly (P>0.05). Average temperatures during the experiment varied between 27.57±1.68°C and 28.05±1.85°C respectively in the ponds fed by broadcasting and by self-feeders. Oxygen values ranged from 4.50±1.05 mg/L to 4.80±1.21 mg/L. The lowest values were observed in the broadcast-fed ponds, while the highest values were observed in the submerged table-fed ponds. Average pH values ranged from 7.04±0.40 (distribution on a submerged table) to 8.08±0.51 (distribution in a fixed floating frame). Regarding the conductivity, the average values obtained were between 0.33±0.03 and 0.34±0.03 mS/cm and were observed respectively in ponds fed with a fixed floating frame and on a broadcast basis.

Table 4 displays the fry of *O. niloticus* fry's zootechnical and feed utilization parameters following 126 days of upbringing. Survival rates ranged from 87.72±6.35 to 95.33±2.93%. These rates were respectively observed in fish fed using DSF and OFD. Furthermore, there was no significant difference between the survival rates observed (P>0.05). Mean final weights and specific growth rates (SGR) varied respectively from 198.46±6 to 221.83±9.97 g and from 3.96 ±1.68 to 4.16 ±1.99 %/dr. The highest values of these parameters were observed in fish fed in a D3F and the lowest in those fed with OFD. However, mean final weights and specific growth rates values were significantly similar (P>0.05) between the different feeding methods. The mean values of weight gain and daily weight gain ranged from 188.44±6.63 to 212.41±9.70 g and 1.46±0.04 and 1.60±0.11 g/day respectively, obtained in fish fed on a OFD and D3F.

Table 3. Physico-chemical parameters of the water in the ponds of O. niloticus fed with different feeding methods.

Physico-chemical parameters	Feed distribution methods			
	On the fly	In a fixed floating frame	On request	On a submerged table
Temperature (°C)	27.57±1.68	27.84±1.73	28.05±1.85	28.03±1.09
pH	7.06±0.56	7.08±0.51	7.06±0.47	7.04±0.40
Dissolved oxygen (mg/l)	4.50±1.05	4.57±0.94	4.72±1.03	4.80±1.21
Conductivity (mS/cm)	0.34±0.03	0.33±0.03	0.34±0.02	0.34±0.03

Values represent means and standard deviations of two replicates. Values not marked with the same letter are significantly different (Anova, *p<0.05*) for each row of the table.

Table 3. Average values of zootechnical parameters of *Oreochromis niloticus* according to feeding method.

Zootechnical parameters	Feed distribution methods			
	On the fly	In a fixed floating frame	On request	On a submerged table
Average initial weight(g)	10.03±0.63	9.42±0.27	9.89±0.33	9.8±0.11
Average final weight (g)	198.46±6.0	221.83±9.97	203.38±22.86	208.60±6.93
Weight gain (g)	188.44±6.63^{a}	212.41±9.70^{b}	193.49±22.54^{ab}	198.75±6.82^{ab}
Daily weight gain (g/dr)	1.46 ±0.04^{a}	1.60 ±0.11^{b}	1.52±0.06^{ab}	1.52±0.07^{ab}
Food Conversion rate	1.09±0.48	1.06± 0.47	1.10±0.50	1.09±0.48
Specific growth rate (%/dr)	2.33±0.024	2.42±0.036	2.35±0.089	2.37±0.026
Survival rate (%)	87.72±6.35	92.86±1.29	95.33±2.93	91.95±4.04
Coefficient of variation (%)	17.7±1.18	15.30±2.25	13.18±1.50	18.50±0.20

Statistical analysis of these data shows a significant difference (P<0.05) between the different feeding methods. Feed conversion rate (FCR) ranged from 1.06 ± 0.47 to 1.09 ± 0.48. These FCR were respectively observed in fish fed with D3F frames and OFD. The coefficient of variation (CV) varied between 13.18±1.50 (DSF) and 18.50±0.20 (DST). However, the FCR and CV values show no significant difference between the different feed distribution methods. The data relating to the various expenses, production costs and rates of reduction of these costs are shown in Table 5. Compared to OFD, D3F, and DST, which needed more labour (46.52 USD), the DSF's labour cost (feeding-related expenditures) was reduced at 23.26 USD. In terms of production costs, the cost recorded with OFD (2.39 USD / Kg of fish) is significantly better (P<0.05) than the costs obtained with D3F (2.64 USD), DST (2.85 USD) and OFD (2.88 USD). Regarding the total cost, rearing fish fed with DST (199.42±6.40 USD) and the D3F (197.59±1.27 USD) was more expensive *(P<0.05)* than rearing fish fed with OFD (185.05±2.43 USD) and with DSF (169.13±11.70 USD). These costs were largely influenced by labour expenses on one hand, and by the short lifespan of the feeding devices on the other. The latter was particularly evident with the wooden floating frame and submerged table, as the wood showed signs of rot after 126 days of rearing. Water quality was maintained within appropriate limits for rearing *O. niloticus*. Indeed. the mean values of temperature, dissolved oxygen, pH and conductivity observed for all treatments are within the recommended ranges of 20 and 35°C (Ngugi *et al*., 2007) above 3 mg/L (Ross, 2002), 6.1 to 8.3 (Makori *et al*., 2017) and 0.15 to 0.45 mS/cm (Mamadou, 1998). Moreover, there were no significant differences in the parameter values obtained using the four distribution methods. Thus, the differences observed in zootechnical parameters could be attributed to feed distribution methods. The percentage of survival obtained was between 87.72 and 95.33%. These results are comparable to those of Nobah *et al*. (2003) who recorded survival rates of between 90 and 98% in their study on the effect of frequency and method of feed distribution on the growth of hybrid tilapia and. Furthermore, the survival rates in the present study were slightly lower than the value of 98% reported by Bake *et al.* (2020) in tilapia fingerlings fed experimental feed containing tropical kudzu seeds. This could be due to the longer rearing period (126 days) in the present study compared to 56 days in the work of Bake *et al.* (2020). These results confirm the hardiness of the species. The growth parameters studied during this study revealed differences between the different feed distribution methods.

According to the results in Table 4. D3F showed the best performance in terms of weight gain (212.41 ± 9.70 g), daily weight gain (1.60 ± 0.11 g), average final weight (221.83 ± 9.97 g), food conversion rate (1.66 ± 0.09) and specific growth rate (2.42 ± 0.036 %/day) followed by DST with which the following performances were obtained: weight gain (198.75 ± 6.82 g), daily weight gain (1.52 ± 0.07 g/dr), average final weight (208.60 ± 6.93 g), food conversion rate (1.76±0.04) and specific growth rate (2.37 ± 0.026 %/dr). The mean final weights in the present study were higher than those of Bamba *et al.* (2008) who recorded final weights ranging from 40.24 ± 7.64 g to 54.03 ± 7.76 g and 36.65 ± 5.73 g to 46.11 ± 5.87 g recorded at densities of 10 individuals/m² and 13 individuals/m² respectively. The best weight growth gains obtained in the present study would appear to be due initially to the stocking density. A high loading density can limit growth when physiological and spatial requirements are not met (Le Ruyet *et al*., 2008). However. the specific growth rates in the present study show relatively slow growth compared with the results of Sissao *et al*. (2019). This difference could be linked to the quality of the feed used which contained 58% protein compared with 38.24% for the feed used in our study. In this study, the daily growth performances were much better than those of Nobah *et al.* (2003) who recorded daily growths of 0.77 g/day with the DSF and 0.49 g/day (1 meal/d) and 0.63 g/day (2 meals/d) obtained with the OFD. Generally, fish fed using the test feeding methods (floating frame feeding, on-demand feeding and submerged table feeding) performed much better than fish fed on the fly (control feeding method). In other words, the growth of the fish was affected by the way the feed was distributed. The D3F exhibits the best performance since the frame is made to hold and concentrate the feed inside, preventing it from being dispersed by the wind and throughout the pond. This prevents the powdery feed from being carried to the monk and out of the ponds without being consumed as the water in the ponds is constantly renewed. This could explain the better conversion index obtained with this feeding method.

Table 4. Evaluation of production costs according to feeding method.

Parameters	Feed distribution methods			
	On the fly	**framed**	**Self-feeder**	**On table**
Rearing time (days)	126	126	126	126
Total area (are)	1.75	1.75	1.75	1.75
Initial biomass (kg)	3.87±0.23	3.63±0.11	3.81±0.13	3.81±0.01
Final number	343.5±16.26	357.5±4.95	367±11.31	354±15.56
Average weight (g)	198.46±6.0	221.83±9.97	203.38±22.86	208.62±6.96
Final biomass (kg)	68.12±1.17^{b}	79.33±4.66^{a}	74.51±6.09^{ab}	73.80±0.78^{ab}
Net production (kg)	66.26±1.50^{b}	75.70±4.56^{a}	70.70±5.96^{ab}	69.99±0.80^{ab}
Biomass per are (kg)	38.93±0.67	45.33±2.66	42.58±3.48	42.17±0.45
T Ag (%)	-	14.25	6.70	5.63
Total food distributed (kg)	126.98±2.88	135.63±1.50	133.19±13.90	135.02±7.61
Total food cost (USD)	106.88±2.43	114.16±1.26	112.10±11.70	113.64±6.40
Fry cost (USD)	32.15	32.15	32.15	32.15
Yield (kg/a/year)	106.37±1.55	125.31±7.54	117.03±9.87	115.85±1.32
Device cost (USD)	0	7.51	16.20	10.85
Service life of the devices (Months)	-	6	36	6
Device cost after depreciation (USD)	0	5.26	1.86	7.60
Feeding cost (USD)	46.03^{b}	46.03^{b}	23.01^{c}	46.03^{b}
Production cost (USD/Kg)	2.88±0.0041^{b}	2.62±0.17^{ab}	2.39±0.036^{a}	2.85±0.12^{b}
TxR (%)	-	9.19	16.88	1.04
Total cost (USD)	185.05±2.43^{ab}	197.59±1.26^{b}	169.13±11.70^{a}	199.42±6.40^{b}
Revenue (USD)	284.41±4.88	331.19±19.46	311.07±25.42	308.10±3.27
Net profit (USD)	99.35±2.45	133.60±20.72	141.94±13.72	108.68±9.67

T Ag (%): Rate of increase in biomass compared to control, TxR (%): Rate of reduction in production cost compared with the control (TxR, %): Values represent means and standard deviations of two replicates. Values not marked with the same letter are significantly different (Anova, $p<0.05$) for each row of the table.

The coefficient of variation in this study shows that only fish fed with DSF are homogeneous group (CV<15%), while those fed with D3F, OFD and DST form groups that are relatively more dispersed around the mean CV>15% (heterogeneous group). The weight heterogeneity observed with the fixed floating frame and the submerged table could be due to the surface area of the devices in which the feed is available. Indeed. with frames and submerged tables of 1m² surface area, not all individuals have equal access to the feed. Finally, the growth performance observed with the broadcast feeding method could be due to feed losses. With broadcast feeding, feed is lost in three (03) ways. Namely by the continuous renewal of the water, which carries part of the feed to the sparrow, by the washout of the feed at the bottom of the pond and by losses caused by the wind which precipitates the mealy feed onto the dykes. These feed losses could explain the low growth observed as part of the feed is lost without being consumed. The economic analysis of the zootechnical results shows that the test feeding methods (fixed floating frame feeding, on-demand feeding and submerged table feeding) have lower fish production costs compared with the broadcast feeding method (control) resulting in reduction rates of 1.04 to 16.88%. These differences in cost between the different feeding methods could be explained on the one hand by the cost of labour and on the other hand by the cost of manufacturing the different feeding devices (demand feeder, wooden frame and table) and the biomass produced.

CONCLUSION

This study therefore shows that mealy feeding of *O. niloticus* in a fixed floating frame, with self-feeder and feeding using submerged tables have an advantage over broadcast feeding in terms of reducing feed losses and therefore improving growth performance and production costs. Mealy feeding *O. niloticus* with self-feeders raised in ponds throughout the grow-out shown to be more advantageous economically than the other three distribution methods.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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