



Impact of genetics in tilapia production - A comparative trial between two strains in Brazil

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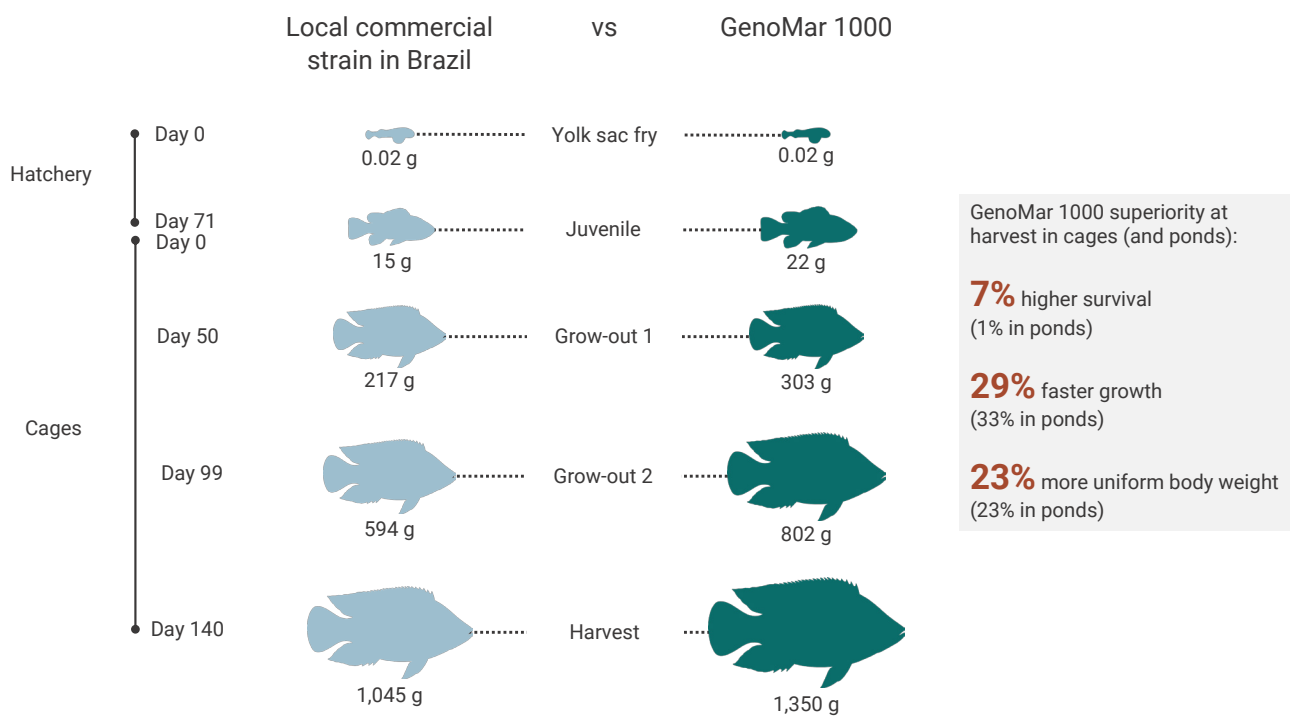
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SUMMARY

GenoMar's premium genetic tilapia line - GenoMar 1000 - and a market leading local strain were compared in both pond and cage production systems under commercial conditions in Brazil.

The results showed that GenoMar 1000 is superior for growth, survival, and uniformity, growing approximately 30 percent faster than the local strain.

With economic analysis suggesting a 31-36 percent annual increase in profits, the results demonstrate GenoMar 1000's potential to enhance productivity, profitability, and sustainability in the Brazilian tilapia industry.



Summery picture: Growth development, final survival and uniformity of GenoMar 1000 compared to a local commercial strain in Brazil. The weights presented are an average of two cages with a 50/50 mix of the two strains (common garden design).

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is one of the most important farmed fish species in the world, and Brazil is one of the leading producers of tilapia globally. In recent years, the Brazilian tilapia industry has experienced a significant increase in production volumes, with annual production surpassing 579,000 tonnes in 2023.

As Brazil continues to develop its tilapia production capabilities whilst maintaining high-quality standards, the country is well-positioned to further increase its share in the global tilapia export market. Despite having vast potential, the comparatively young Brazilian tilapia farming industry continues to encounter significant challenges, with one major hurdle being the limited availability of highly productive and efficient genetic strains.

Available local strains of tilapia typically exhibit lower productivity compared to improved strains that have undergone selective breeding for better growth, survival, and uniformity.

GenoMar Genetics is a leading producer of genetically improved tilapia fingerlings and juveniles under the brands GenoMar and Aquabel. Following 33 generations of selective breeding using state-of-the-art technologies, the GenoMar tilapia strain has been globally recognised for its superior growth, survival, uniformity, fillet yield and carcass quality.

Widely regarded as one of the most sought-after tilapia strains in production, the GenoMar strain contributes significantly to enhancing productivity and profitability in the global tilapia industry. Now, the GenoMar 1000, the premium genetic line of GenoMar strain, previously unavailable in Brazil, has been accessible to farmers since early 2024.

In this article, we have summarised the results of the three major key performance indicators (growth, survival, and uniformity) of GenoMar 1000 compared to a market leading strain of Nile tilapia under commercial pond and cage farming systems in Brazil.

GROWTH



We have summarised the growth performances in the trial using three different measurement units:

1. Body weight at harvest
2. Average daily gain
3. Time to reach 1 kg

[Additional information containing the statistical analyses for growth and survival are available at page 22 and 23.](#)

1. Body weight at harvest

The fish were harvested 140 days after stocking in both ponds and cages, with GenoMar 1000 outperforming the local strain in terms of growth in both ponds and cages under commercial rearing conditions (Figure 1).

In ponds, GenoMar 1000 grew 33 percent faster than the local strain (1,196 g compared to 902 g). In cages, GenoMar 1000 grew 29 percent faster than the local strain (1,350 g compared to 1,046 g).

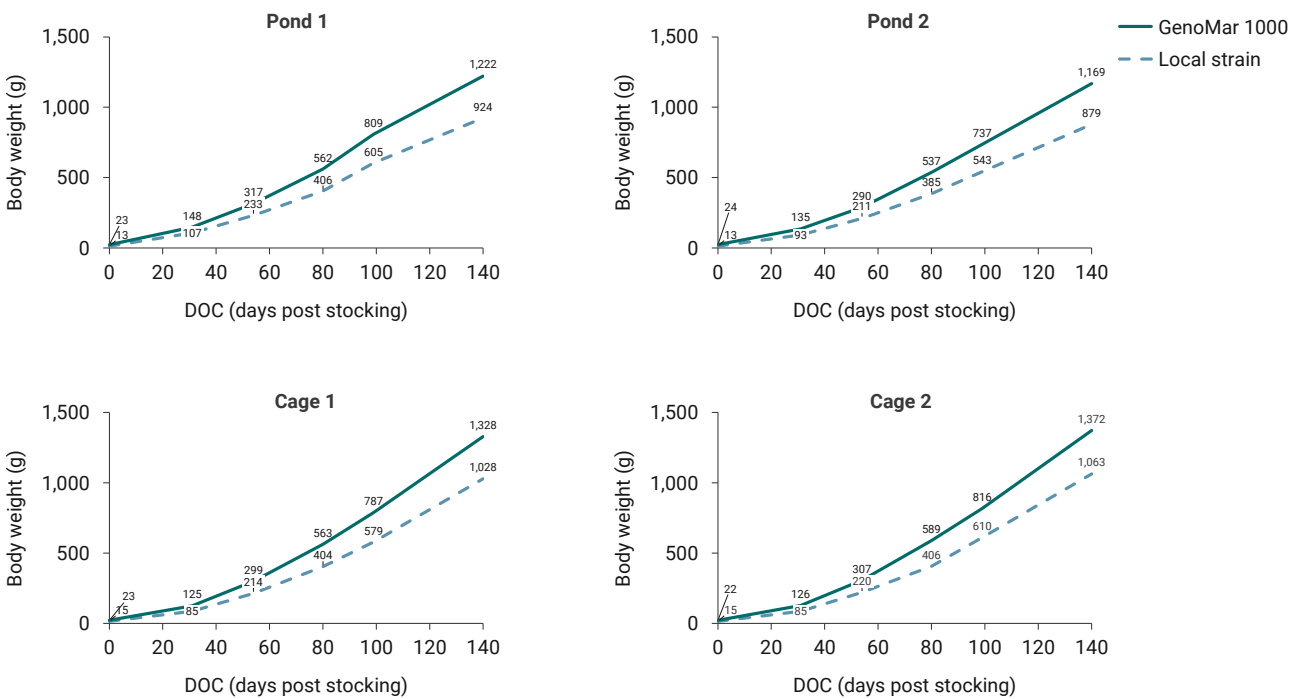


Figure 1. Growth curves for GenoMar 1000 and the local commercial strain of Brazil across various pond and cage production systems. The x-axis represents the days of culture (DOC), indicating the number of days after stocking in the production systems for common grow-out.



2. Average daily gain

The mean average daily gain (ADG) post stocking was higher for GenoMar 1000 compared to the local strain in both ponds and cage production systems (Figure 2).

Simplified, this means that, compared with the local tilapia strain, GenoMar 1000 grew approximately 33 percent faster when reared in ponds, and 29 percent faster when reared in cages.

In ponds, GenoMar 1000 grew at a mean daily rate of 8.37 grams, whilst the local strain of tilapia gained an average of 6.35 grams per day during the 140 days grow-out period. When reared in cages, ADG increased slightly for both strains, with GenoMar 1000 growing at an average of 9.49 grams per day, and the local strain gaining 7.37 grams per day, on average.

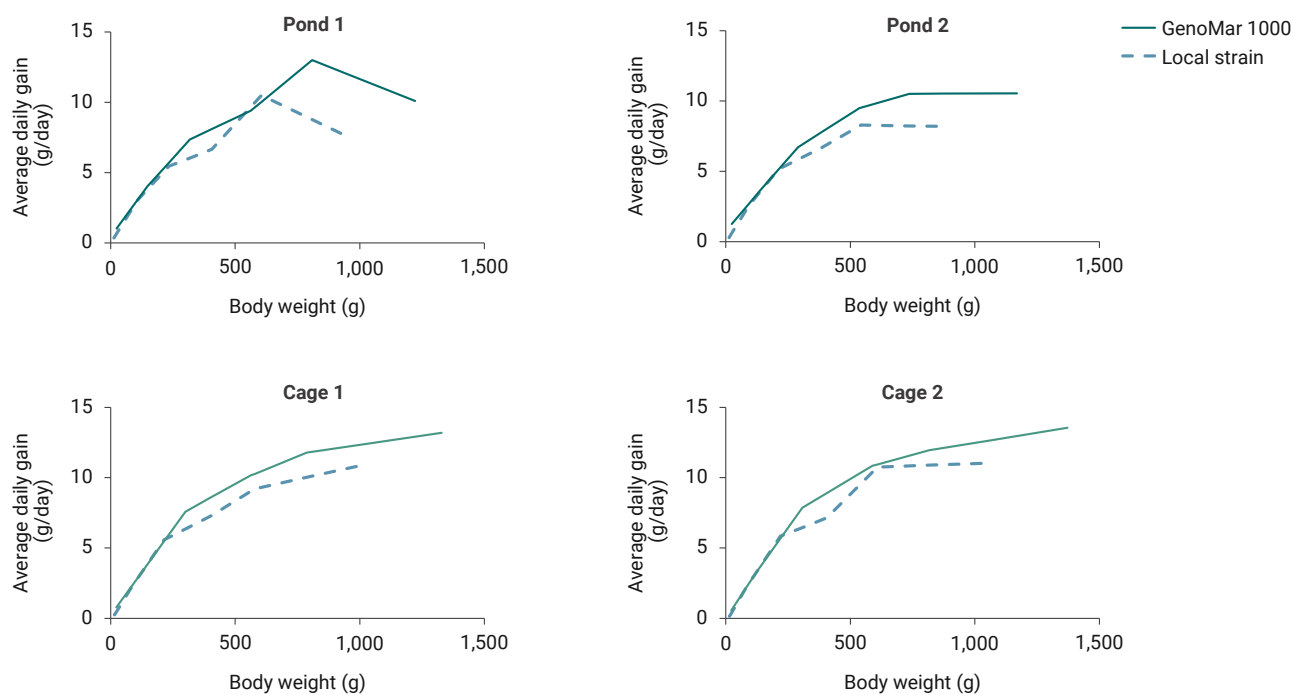


Figure 2. Comparative analysis of average daily gain (ADG) at various body weights for GenoMar 1000 and the local commercial strain in different pond and cage production systems in Brazil.



3. Time to reach 1 kg

GenoMar 1000 reached 1 kg faster than the local strain of tilapia in both pond and cage production systems. GenoMar 1000 reached 1 kg an average of 31.5 and 21.5 days faster than the local strain of tilapia in ponds and cages respectively (Figure 3).

These findings, from three different growth metrics, demonstrate the significant growth advantages offered by GenoMar 1000, highlighting its potential for enhancing tilapia farming productivity and sustainability.

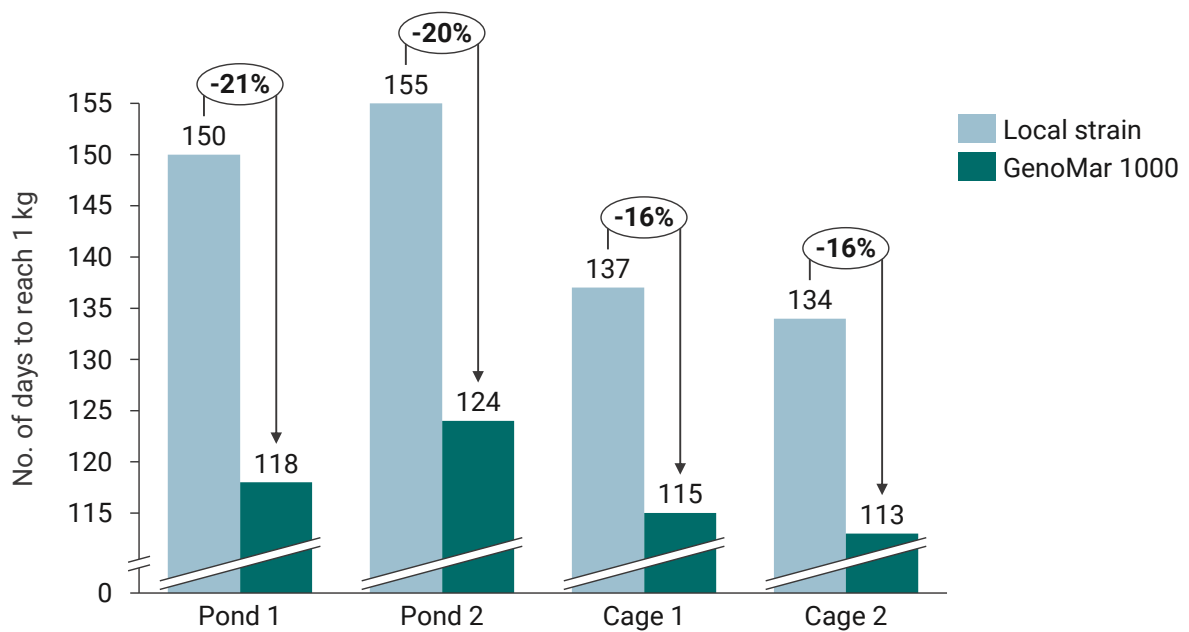


Figure 3. Comparative analysis of number of days to reach 1 kg for GenoMar 1000 and the local commercial strain of tilapia in different ponds and cage production systems. Number of days is calculated from the day of stocking in the production system for common grow-out.

SURVIVAL



In addition to growth rate, another key performance indicator for tilapia producers is survival rate, which holds paramount importance for both tilapia hatcheries and grow-out farmers. Thus, we have compared the survival rate of GenoMar 1000 and the local strain for two different time intervals.

Survival in hatchery stage (up to 10 g)

Higher survival rates allow hatcheries to produce more tilapia fry and fingerlings without increasing their consumption of resources. GenoMar 1000 tilapia were found to have significantly higher survival in the hatchery stages: both from 0.016 g to 1 g (sex reversal stage) and from 1 g to 10 g (pre-grow-out stage).

During the sex reversal stage, hatchery survival rates for GenoMar 1000 fish and the local tilapia strain were 56 percent and 36 percent, respectively. For the pre-grow-out stage, survival rates increased for both strains, with GenoMar 1000 tilapia surviving at a rate of 87 percent, compared to 78 percent for the local strain. Overall, the total hatchery survival rate for GenoMar 1000 fish was 72 percent higher than that for the local strain of fish (Table 1).

Table 1. Survival rates of GenoMar 1000 and the local commercial strain of tilapia fry in the hatchery stage.

Group	Stocking number	Survival		
		Up to 1 g	1 - 10 g	Total
GenoMar 1000	48,180	56%	87%	48%
Local strain	48,180	36%	78%	28%



Survival in grow-out stage

The fish in the experiment were not vaccinated so that the effect of their genetics on their survival could be observed. Thus, the difference in survival between the two strains is likely due to their different adaptations and abilities to tolerate diseases and general stress during grow-out.

GenoMar 1000 tilapia survived better in cages ($p < 0.001$), while there was no significant difference in survival between the two strains in ponds (Figure 4). This is likely because the ponds were located in a biosecure facility with low disease pressure, whilst the cages were placed in the Lake Palmas, an open environment with less biosecurity (see Photo 2).

Streptococcus agalactiae, a common fish pathogen, was detected at the cage site during the experiment, but no treatment was applied. The higher survival of GenoMar 1000 at this site suggests improved resistance to Streptococcosis infection due to specific selection for resistance to this pathogen every generation since 2016.

Despite being selected in an Asian environment, the trial demonstrates no negative effect on the adaptability and survivability of GenoMar 1000 in Brazilian conditions. On the contrary, the survival of GenoMar 1000 in the cage environment was significantly better.

Cage environments typically carry higher pathogenic pressure and stress levels. GenoMar 1000 has been bred to be more resistant to various economically important pathogens and production environments for a longer period.

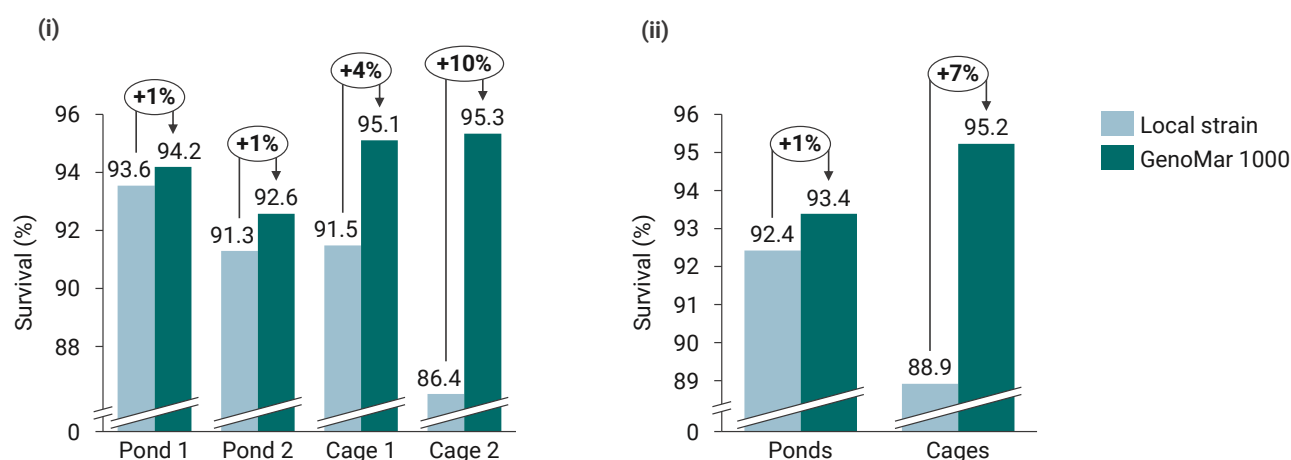


Figure 4. Survival during grow-out after stocking in the production system for GenoMar 1000 and the local commercial strain (i) in different pond and cage production systems (left) and (ii) mean of pond and cage production systems (right).



Total survival from yolk sac fry to harvest size

To visualize the difference in survival between GenoMar 1000 and the local strain during both hatchery stages and grow-out in cages, we modelled the data from Table 1 and Figure 4.

Out of ten yolk sac fry from GenoMar 1000, six survived until 1 g (survival rate = 56 percent), compared to four from the local strain (survival rate = 36 percent). The number of fish is rounded to the nearest whole number.

From these survived fingerlings, five from GenoMar 1000 survived the pre-grow-out stage and became juveniles (total survival rate = 48 percent), whereas three from the local commercial strain did (total survival rate = 28 percent).

Extending this comparison to the grow-out in cages, all five juveniles from GenoMar 1000 survived until harvest (survival rate = 95.2 percent), compared to two from the local strain (survival rate = 88.9 percent). Further hazard analysis (page 23) showed that the risk of death during grow-out stage is significantly decreased by 49 percent in GenoMar 1000, compared to the local strain of tilapia.

To summarize the entire experimental period: Out of ten yolk sac fry from GenoMar 1000, five survived until harvest, compared to two from the local strain (Figure 5).

These figures highlight GenoMar's commitment to advancing disease resistance and increasing survival via genetics. These findings validate the efficacy of our innovations in the tilapia breeding program, and demonstrate the potential for sustainable fish farming practices using GenoMar 1000 fingerlings.

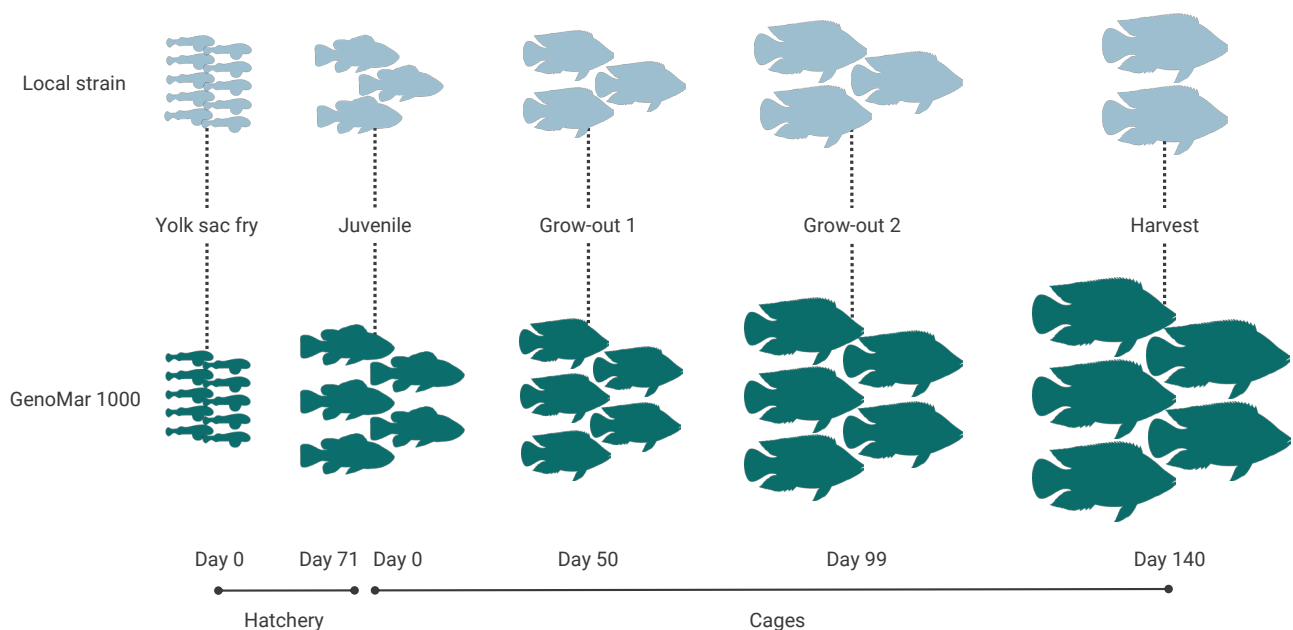


Figure 5. Out of ten yolk sac fry of GenoMar 1000, five survived until harvest, compared to two of the local commercial strain.

UNIFORMITY



Uniformity was measured by calculating the coefficient of variation (CV) of body weight at harvest (BWH). A higher CV means lower uniformity. GenoMar 1000 was found to be more uniform than the local strain of tilapia in both cages and ponds, exhibiting, 23 percent more uniformity than the local strain of tilapia, on average ($p < 0.001$).

Figure 6 describes the size variance of simulated populations of Genomar 1000 tilapia and the local strain for their respective CV values when the target weight being 1 kg. A significantly higher proportion of the GenoMar 1000 fish reached the desired harvest weight in both ponds and cage production systems, underscoring its suitability as genetic material for large-scale grow-out operations.

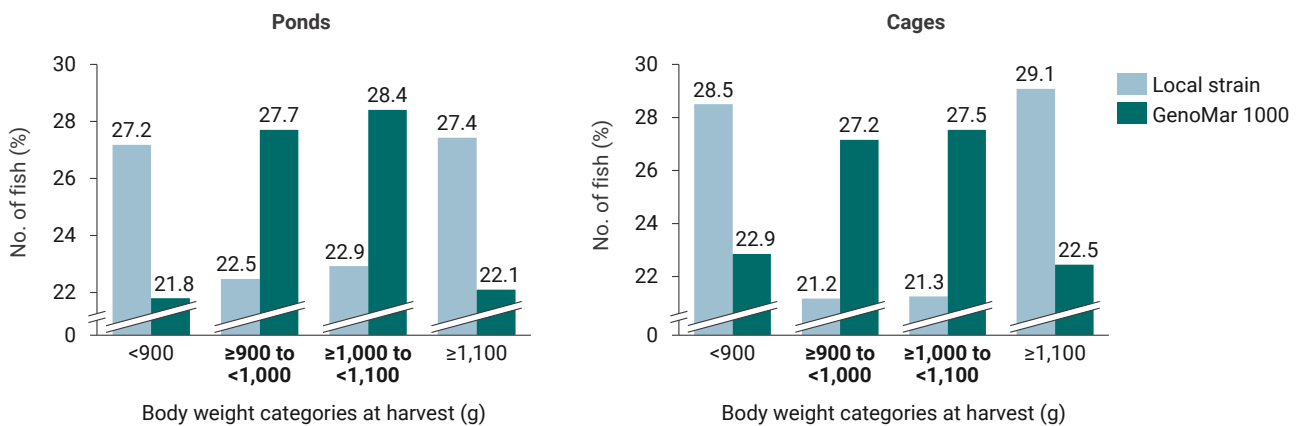


Figure 6. Simulation of a population of 20,000 from each of GenoMar 1000 and the local commercial strain of tilapia to show the size distribution of the fish populations when the targeted average harvest body weight was 1 kg.

PERFORMANCE AND YIELD OF JUVENILES



In the preceding sections, we evaluated the growth and survival of the two strains independently. However, to comprehensively assess the effectiveness of stocked juveniles in terms of both growth and biomass conversion into harvestable fish - a vital consideration for farm profitability - we required an index comprising both these traits.

We have summarised the performance and yield of juveniles using two different metrics:

1. Performance (g/fish/day)

The performance is calculated as:

$$\text{Performance (g/fish/day)} = \frac{(\text{Kg harvested tilapia} - \text{Kg stocked tilapia}) \times 1000}{\text{Total fingerlings stocked} - \text{Culture period in days}}$$

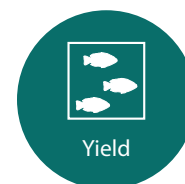
The metrics essentially calculates the average biomass production (in g) of each stocked juvenile (corrected to the initial stocking weight of the juvenile) per day in the production system.

Each stocked GenoMar 1000 juvenile surpassed this, producing approximately 2.5 g more, amounting to 9 g of harvested biomass per day.

In the cage production system, the GenoMar 1000 juveniles exhibited an average performance 38 percent higher than the juveniles of the local strain (Figure 7).

Similarly, in the pond production system the GenoMar 1000 juveniles showed an average performance that was 33 percent higher than the juveniles of the local strain (Figure 6). Each stocked juvenile of the local strain on average yielded 5.9 g of harvestable biomass per day, whilst the GenoMar 1000 juveniles produced 7.8 g of harvestable biomass per day.

Each stocked juvenile of the local strain yielded on an average 6.5 g of harvestable biomass per day.



2. Yield (kg harvested/unit of production system)

The yield is calculated as:

$$\text{Yield (kg harvested/unit of production system)} = \frac{\text{Kg harvested tilapia}}{\text{Total units of the production system}}$$

This metric essentially calculates the average biomass production (in kg) per unit area (m^2 of the surface area of the pond or m^3 of the cages in one harvest). The difference in the values for the yield between GenoMar 1000 and the local strain of tilapia is similar to that for the performance (Figure 7).

In the pond-based production system, the local strain yielded 1 kg/m^2 whilst GenoMar 1000 yielded an additional 0.4 kg for the same unit area. Similarly, in the cage production system the local strain yielded 25.6 kg/m^3 , whilst the GenoMar 1000 yield exceeded this, yielding 35.4 kg/m^3 .

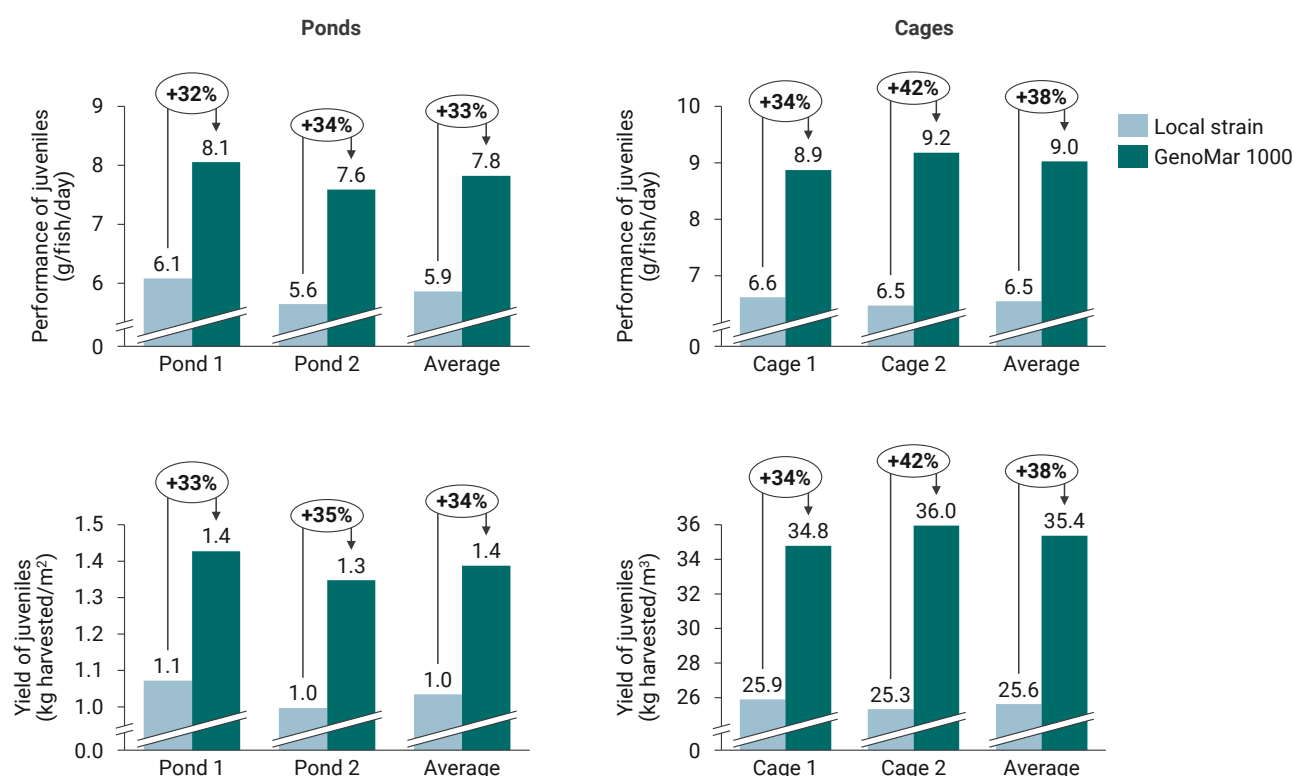


Figure 7. Comparison of Performance of juveniles (g per fish per day) and Yield of juveniles (kg harvested per unit) in the pond and cage production systems. A higher value for performance and yield indicates better growth, survival, and productivity of the juveniles in the production system.

ECONOMIC ANALYSIS



Choosing the right genetics is a strategic decision that significantly influences the long-term success of a tilapia production venture. For this, an economic analysis is imperative, providing insights into the monetary benefits for farmers and aiding them in making informed decisions.

Based on the outcomes of this trial, we conducted an economic analysis for both cage and pond production systems, focusing on harvesting tilapia at 1 kg. Both scenarios simulated a stocking of 200,000 tilapia (refer to Table 2).

Due to the fact that the ponds and cages were shared by fish of both strains, the feed conversion could not be directly measured and compared. Consequently, we used the same feed conversion ratios (FCRs) for both strains within each production system.

However, in practice, we have observed that superior growth and increased survival typically correlate with enhanced feed efficiency, ultimately increasing profit margins.

Considering a higher investment in genetically improved fingerlings from GenoMar 1000, a fish farm stocking 200,000 fish in a cage can achieve an annual increase in harvest of 128,895 kg and a profitability increase of R\$ 360,834 (equivalent to US \$72,167), representing a 36 percent increase in profits. Similarly, in the pond production system, the increase in harvest is 122,625 kg, with a profitability increase of R\$ 312,664 (equivalent to US \$62,533), reflecting a 31 percent increase in profits.

Table 2. Economic analysis of GenoMar 1000 vs the local commercial strain of tilapia under cage and pond production systems.

	Cages		Ponds	
	GenoMar 1000	Local strain	GenoMar 1000	Local strain
Stocking number	200,000	200,000	200,000	200,000
Initial average body weight (kg)	0.024	0.015	0.023	0.013
Final average body weight (kg)	1.00	1.00	1.00	1.00
Final survival (%)	95.2%	88.9%	93.4%	92.4%
Final harvest per cycle (kg)	190,400	177,800	186,800	184,800
Feed conversion ratio (FCR)	1.75	1.75	1.67	1.67
Production cycle (days)	114	135	121	153
Daily weight gain (g)	8.56	7.30	8.07	6.45
Production cycle per year	3.20	2.70	3.02	2.39
Final harvest per year (kg)	609,614	480,719	563,488	440,863
Profit per kilogram (US\$)	0.45	0.42	0.47	0.46
Total profit per year (US\$)	273,107	200,940	267,093	204,560
Difference in profitability (US\$)	72,167		62,533	

METHODOLOGY

Experimental population formation

To establish the experimental populations, broodstocks from GenoMar 1000 and the local strain were reproduced within the same facility in Tocantins. This approach aimed to synchronise spawning and minimise environmental variations.

The populations were created using a batch of eggs collected within the same week to ensure similar developmental stages, thus reducing the hatching interval of the larvae to a maximum of five days, mirroring commercial practices (Figure 8).

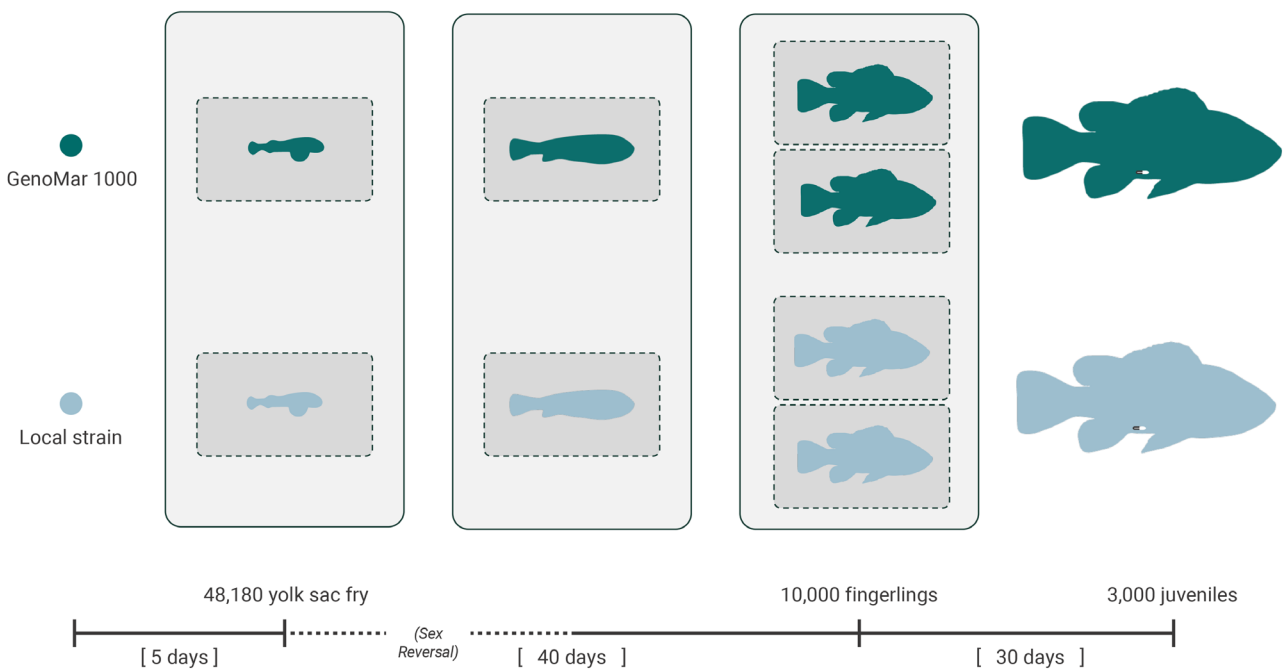


Figure 8. Experimental design from hatching till individual tagging (pre-grow-out) before stocking for grow-out in ponds and cages.

At one day post-hatching, 48,180 yolk sac fry from each strain were stocked in two separate hapas within the same pond, receiving identical treatment. This nursery stage lasted 40 days, with sexual reversal during the first 21 days. Subsequently, in the pre-growth stage, 10,000 fingerlings of each strain were randomly collected and stocked in four hapas, two for each strain (with two additional hapas for backup), within the same pond to minimise environmental effects (Photo 1).

Over the next 30 days, these fish were raised under identical water quality conditions and received the same feeding/nutritional program until they reached tagging size. Subsequently, 3,000 juveniles from each strain were randomly collected from all hapas, tagged, and transferred to the grow-out stage for a common garden experiment.



Photo 1. The pre-grow-out phase of the trial was conducted in a pond at Serra da Tilapia, Monte do Carmo in Tocantins, Brazil.

Common garden experimental design

Following individual tagging, an equal number of fish from GenoMar 1000 and the local strain of tilapia (selected randomly) were stocked together in two different ponds and two different cages for a blind grow-out. This design ensures that the two groups of fish are reared under the same environmental conditions in each pond and cage (Figure 9).

The 32 m³ cages were stocked to a density of 55 juveniles per m³, with an expected harvest of 70 kg/m³. Comparatively, the 500 m² ponds were stocked to a density of 2.48 juveniles per m², with an expected harvest of 3 kg/m².

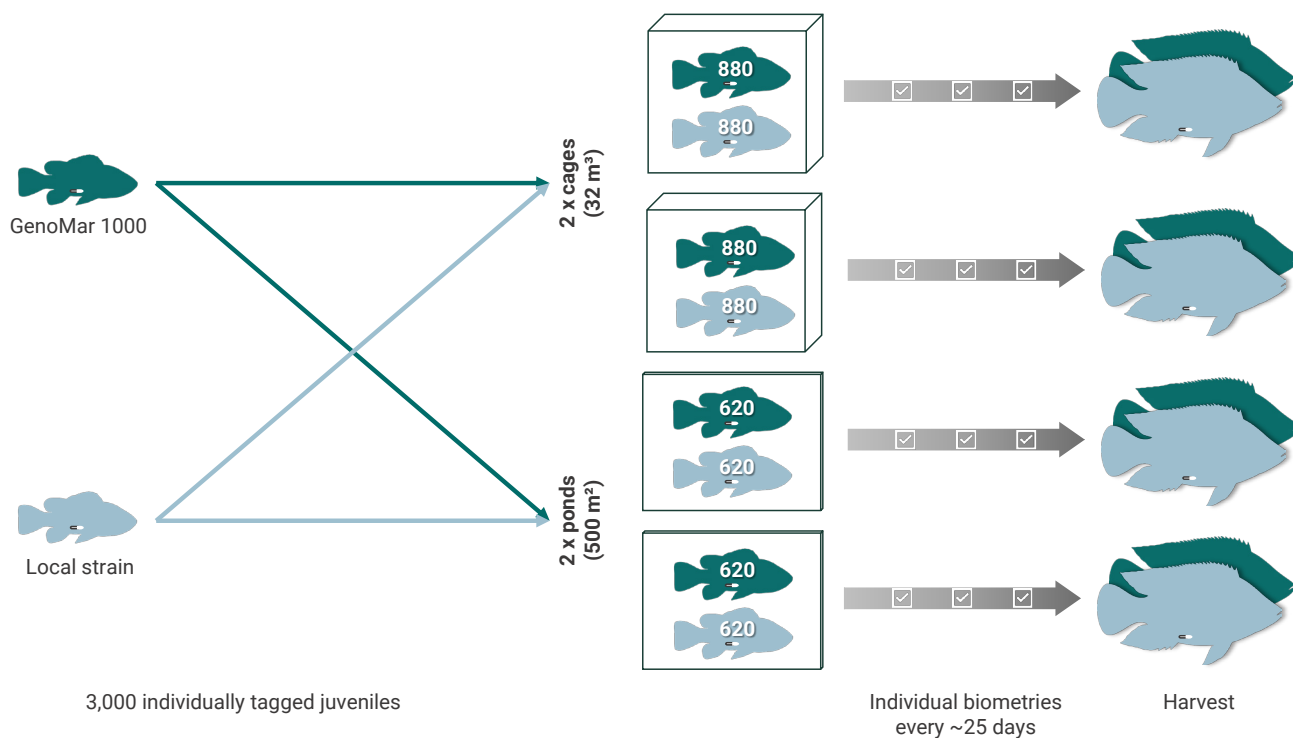


Figure 9. Experimental design of the individually tagged fish for blinded common garden grow-out in cages and ponds.

The cages were positioned in Lake Palmas, where commercial tilapia farming is already in operation. The ponds were located within GenoMar's Tocantins facilities (Photo 2). Activities at both locations were synchronised, and a strict feeding programme was followed to simulate commercial production conditions.

The grow-out phase was closely monitored until harvest, with individual biometry measurements taken approximately every 25 days.



Photo 2. The grow-out phase of the trial was conducted in ponds at Serra da Tilapia, Monte do Carmo in Tocantins, Brazil (left) and in cages at Lago de Palmas, Lajeado in Tocantins, Brazil (right).

FEEDING PROGRAM

A commercial feeding programme, as shown in Table 3, was followed during the trial. For the initial six weeks post-hatching, the tilapia were provided with commercial feed comprising 45 percent protein, followed by a switch to a feed containing 36 percent protein from week seven to nine.

As the tilapia continued to grow, this diet was further adjusted to one containing 32 percent protein, starting from week ten.

Table 3. Commercial feeding programme with the feed characteristics and feeding rate for different sizes of fish.

Fish weight from lowest to highest (g)		Feed characteristics (protein content, pellet size)		Feeding rate (% of biomass)
1	4	45%	0.8 mm	14.20%
>4	11	45%	1.8 mm	11.70%
>11	21	45%	1.8 mm	10.40%
>21	34	45%	2-3 mm	9.70%
>34	54	45%	2-3 mm	9.00%
>54	77	45%	2-3 mm	8.10%
>77	106	36%	3-4 mm	7.10%
>106	137	36%	3-4 mm	7.00%
>137	176	36%	3-4 mm	6.50%
>176	217	32%	4-6 mm	6.00%
>217	260	32%	4-6 mm	5.50%
>260	309	32%	4-6 mm	5.10%
>309	361	32%	4-6 mm	4.80%
>361	413	32%	4-6 mm	4.40%
>413	465	32%	4-6 mm	4.00%
>465	518	32%	4-6 mm	3.70%
>518	574	32%	6-8 mm	3.50%
>574	627	32%	6-8 mm	3.20%
>627	683	32%	6-8 mm	3.10%
>683	739	32%	6-8 mm	3.50%
>739	858	32%	6-8 mm	3.20%
>858	973	32%	6-8 mm	2.80%
>973	1085	32%	6-8 mm	2.40%
>1085	1189	32%	6-8 mm	2.20%
>1189		32%	6-8 mm	2.00%

FEED CONVERSION RATIO



Due to the nature of the trial, it was not possible to differentiate the feed conversion ratio (FCR) for GenoMar 1000 and the local strain of tilapia separately. Therefore, the FCR for the combined group is presented in Figure 10 to demonstrate that the FCR in the trial was within normal parameters.

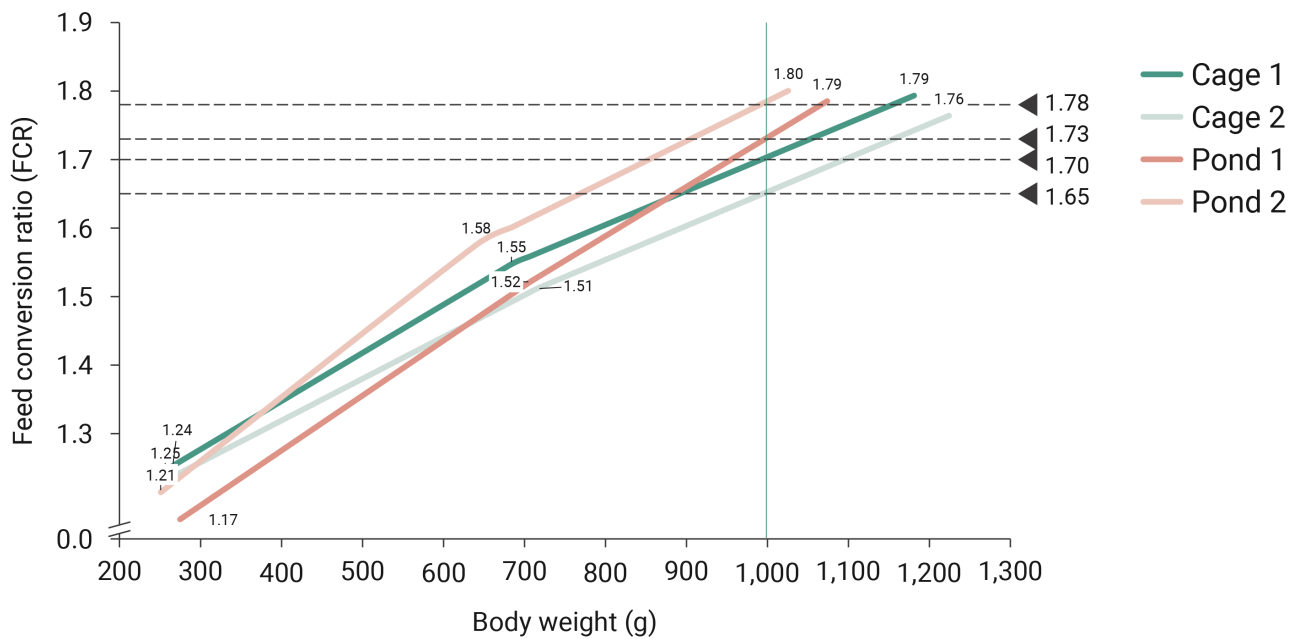


Figure 10. Combined feed conversion ratio (FCR) of the production systems at different average body weight of the fish in each cage and pond. The values listed on the right-hand side with inverted triangles represent the predicted FCR when the fish are around 1 kg in each production environment.

TEMPERATURE AND DISSOLVED OXYGEN

The temperature and dissolved oxygen levels in all cages and ponds during the common garden grow-out were monitored and recorded throughout the experiment and are presented in Figure 11.

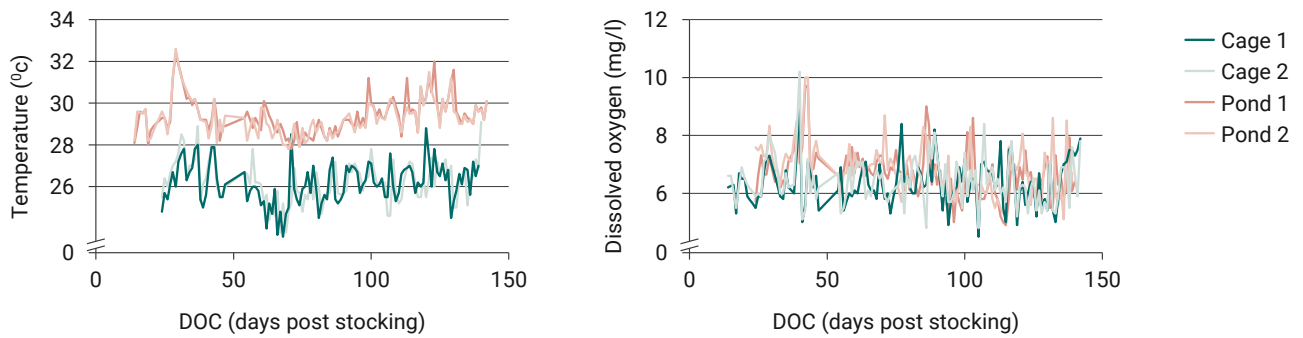


Figure 11. Charts showing the temperature and dissolved oxygen in different ponds and cages during the grow-out period of the experiment.

IMPLICATIONS FOR BRAZILIAN FARMERS

A switch to GenoMar 1000 tilapia can be a very beneficial decision for Brazilian tilapia farmers, impacting productivity, profitability, sustainability, and animal welfare:

- **GenoMar 1000 grow approximately 30 percent faster and have higher survival rate and uniformity compared to a local commercial strain, leading to an annual increased profitability of approximately 31-36 percent.**
- **Faster growth and increased survivability lead to better productivity, significantly reducing the cost of production and environmental risk.**
- **Higher survival rates reflect improved health and animal welfare.**

How does GenoMar 1000 achieve such improved production performance? The answer lies in selective breeding and the use of advanced scientific technology. GenoMar 1000 was developed over many generations by carefully selecting fish with the best growth, survival, and fillet yield traits, resulting in a product that is genetically predisposed to grow quickly and efficiently.

Availability of GenoMar 1000 fingerlings to Brazilian tilapia farmers

First sales of such high performing premium GenoMar 1000 fingerlings were made to a selected group of key customers and large tilapia producers of Brazil in early 2024. They are now available to all Brazilian tilapia farmers.

ADDITIONAL STATISTICAL INSIGHTS



This section provides a concise summary of the statistical analyses for both growth and survival, offering readers a clear understanding of the performance comparison between GenoMar 1000 and the local commercial strain of tilapia.

Statistical analysis for growth

Linear statistical model was used to separate the effect of environment (ponds and cages) with the effect of strain (GenoMar 1000 and local strain). The linear model can be defined as:

$$Y = \beta_0 + \beta_1 \cdot \text{Environment} + \beta_2 \cdot \text{Strain} + \epsilon$$

Where:

- Y represents the response variable (body weight at harvest).
- β_0 is the intercept term.
- β_1 and β_2 are the coefficients corresponding to the main effects of the environment and strain, respectively.
- Environment and strain are categorical variables representing the different levels of the environment (ponds and cages) and strain (GenoMar 1000 and local strain).
- ϵ is the error term.

Thus, fish from GenoMar 1000 were found to have 29% ($300.120/1028.227 \times 100$) higher body weight at harvest ($p < 0.001$).

	Coefficients	Estimate	Standard error	P value
	Intercept	1028.227	4.808	<0.001
Strain	Local strain	Reference		
	GenoMar 1000	300.120	4.577	<0.001
Environment	Cage 1	Reference		
	Cage 2	39.139	5.985	<0.001
	Pond 1	-105.073	6.527	<0.001
	Pond 2	-154.465	6.567	<0.001



Statistical analysis for survival

Hazard ratio was used for the statistical analysis for survival. To model the hazard ratio and separate the effects of environment (ponds and cages) from the effects of strain (GenoMar 1000 and local strain), we used a Cox proportional hazards model.

The Hazard ratio (HR) comparing the effect of one level of the environment or strain to another can be calculated as the exponential of the coefficient:

$$HR = \exp(\beta)$$

The hazard function can be defined as:

$$h(t|X) = h_0(t) \cdot \exp(\beta_1 \cdot \text{Environment} + \beta_2 \cdot \text{Strain})$$

Where:

- $h(t|X)$ is the hazard function at time t given the covariates X .
- $h_0(t)$ is the baseline hazard function.
- β_1 and β_2 are the coefficients corresponding to the effects of the environment and strain, respectively.
- Environment and strain are categorical variables representing the different levels of the environment (ponds and cages) and strain (GenoMar 1000 and local strain).

This model allows us to estimate the hazard of an event (e.g., mortality) over time while controlling for the effects of both the environment and the strain.

$HR > 1$ indicates an increased risk of death whereas, $HR < 1$ indicates a decreased risk.

At any time, the risk of death is significantly decreased ($p < 0.001$) by 49% in GenoMar 1000, compared to the local strain of tilapia.

	Coefficients	Hazard ratio (HR)	Range	P value
Strain	Local strain	Reference		
	GenoMar 1000	0.49	0.42-0.58	<0.001
Environment	Cage 1	Reference		
	Cage 2	1.48	1.22-1.78	<0.001
	Pond 1	0.97	0.77-1.22	0.775
	Pond 2	1.03	0.82-1.29	0.801



Always one generation ahead

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