Performance of an aquabusiness regarding the cultivation of *Symphysodon* sp. in a conventional system and a smart system

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Abstract. This study aims to analyze the effect of different cultivation system applications for discus (*Symphysodon* sp.) on the aquabusiness performance. The research design was a Factorial Completely Randomized Design (CRD) with two factors: stocking density and cultivation system. The stocking densities were 400, 600, and 800 fish m^{-3}, and the cultivation systems were conventional (CS) and smart system (SS), with each treatment repeated three times. The parameters observed in this study included production performance (growth, survival rate - SR, and length coefficient of variation - CV), oxygen consumption rate (OCR), quality index (Grade A and Grade B), morphology, blood glucose levels, business performance (profit, break-even Point - BEP, revenue cost ratio (R/C Ratio), and payback period - PP), investment criteria analysis (net present value - NPV, internal rate of return - IRR, and net benefit cost ratio - Net B/C), and sensitivity analysis. The results revealed that stocking density significantly affected CV, SR, OCR, Grade A, Grade B, blood glucose levels, profit, BEP unit, R/C ratio, PP, NPV, IRR, and Net B/C Ratio. The use of different cultivation systems significantly affected ΔL, CV, Grade A, blood glucose levels, profit, BEP unit, R/C ratio, PP, NPV, IRR, and Net B/C Ratio. The interaction between the two only significantly affected CV, Grade A, PP, and IRR. Meanwhile, the observation of morphology parameters showed that neither stocking density nor cultivation system, nor their interaction, significantly affected the morphology of discus fish. Additionally, the sensitivity analysis with the variable of demand reduction showed high sensitivity, with a significant impact on NPV and Net B/C Ratio. Intensive cultivation of discus with high stocking density in both CS and SS systems can improve aquabusiness performance and is feasible for development. Even in the case of decreased demand, the aquabusiness remains viable, especially at a stocking density of 800 fish m^{-3} with the conventional system.

Key Words: aquaculture, discus fish, financial analysis, ornamental fish, stocking density.

Introduction. Indonesia has significant potential as a global ornamental fish producer. In 2021, Indonesia ranked 5th in the global ornamental fish market share with 8.65% and experienced an average annual increase in global ornamental fish demand of 4.35% from 2017 to 2021 (KKP 2022). This trend indicates that ornamental fish have become a valuable economic commodity in the fisheries sector, making ornamental fish farming a promising aquabusiness. Aquabusiness encompasses both on-farm and off-farm activities, including the procurement of production facilities, production processes, post-harvest processing, marketing, and other supporting activities. Aquabusiness is closely related to various cultivation systems, including intensive cultivation systems. This system is an aquaculture method aimed at maximizing productivity and profitability by applying efficient management practices and increasing stocking density (Costa-Pierce et al 2010; Oké & Goosen 2019; Saha et al 2022).

Stocking density in cultivation systems directly affects survival, growth, behavior, health, feed efficiency, and water quality (Fotedar 2016; Aliabad et al 2022; Mugwanya et al 2022). High stocking density can disrupt the physiological processes and behavior of fish, leading to reduced growth, survival, and health status. On the other hand, too low stocking density can reduce the efficiency and profitability of an aquabusiness (Ghofur & Harianto 2018). Several studies on intensification in fish regarding stocking density aim to find the optimal density for production performance and aquabusiness efficiency. Previous studies on ornamental fish such as *Corydoras aeneus* (Diatin et al 2014; Diatin et al 2015;

Diatin et al 2019), *Barbonymus balleroides* (Arifin et al 2017), zebra pleco *Hypancistrus* sp. (Reis et al 2020), koi *Cyprinus carpio* (Nica et al 2020), silver rasbora *Rasbora argyrotaenia* (Budi et al 2020), and clown loach *Chromobotia macracanthus* (Puluhulawa et al 2021) have shown that stocking density affects the growth and survival of fish.

The ornamental discus fish (*Symphysodon* sp.) is a potential commodity for the application of intensified cultivation systems. This ornamental fish is a freshwater species originating from the Amazon River environment (Mathews et al 2016; da Silva Ladislau et al 2021; Ng et al 2021). Several species of discus fish have been successfully developed in various countries such as Brazil, China, Malaysia, Korea, and Germany, including *S. discus*, *S. tarzoo*, *S. haraldi*, and *S. aequifasciata* (Pirhonen et al 2014; Liu et al 2019).

Intensified cultivation of ornamental discus fish requires greater inputs. In traditional or conventional systems, discus fish farming requires more care compared to other ornamental fish species (Kusrini & Priono 2011; Wen et al 2018). On the other hand, intensification with increased stocking density can lead to a decline in water quality, which impacts production performance (Dupont et al 2018). Another issue is related to the concentration of cortisol hormones, which is closely related to the stress levels of the fish and can reduce the quality of fish production (Mota et al 2014). Similarly, intensified cultivation of discus fish can affect the growth and survival (Tibile et al 2016).

An alternative solution to address these issues is to utilize modern technology (Yue & Shen 2022). The use of smart systems, such as the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), computer vision (CV), sensors, and similar technologies, can present solutions (Vaidya et al 2018; Biazi & Marques 2023). Smart systems in aquaculture represent a current trend in the development of aquaculture science (Sapin et al 2022).

Smart systems can include tools for monitoring and controlling various factors such as water quality, temperature, and digital-based feeding schedules (Hu et al 2020; Kaseem et al 2021). The integration of this technology will enhance the efficiency of aquaculture operations, enable remote monitoring and control, reduce the need for constant manual intervention, and increase the overall productivity and profitability of fish farming businesses (Teja et al 2020; Kassem et al 2021; Vo et al 2021). Therefore, this study aims to evaluate stocking density with different cultivation system applications on the aquabusiness performance of intensive discus fish farming.

Material and Method

Description of the study sites. This study will be conducted from February to May 2023 at the AW Discus fish farming unit in Jakarta. Stress response and chromatophore cell analyses were carried out at the Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, Indonesia.

Animal and test container preparation. The preparation stage involves the preparation of containers, feed, and test animals. The containers used are aquariums with dimensions of 50×40×40 cm^3, which were first cleaned with detergent and rinsed with clean water. Each aquarium contains 50 L of water. The feed used was commercial feed with 60% protein. The test animals used were healthy fish, specifically Red Melon discus fish with an average length of 3.00 cm, sourced from the AW Discus fish farming unit.

Maintenance. The discus fish were maintained for 90 days. During the maintenance period, the fish were fed pellets with a feeding frequency of three times a day (06:00, 12:00, and 18:00) ad libitum. The proximate analysis is presented in Table 1. During the maintenance stage, a 100% water change was performed every 3 days. After 90 days of maintenance, harvesting was done on days 91 to 93. The harvesting process involves sorting the fish based on size and quality (shape and color intensity) for sale.

Research design. The research design was a factorial completely randomized design (CRD) with treatment density factors of 400, 600, and 800 fish m^{-3}. The cultivation systems were the conventional system (CS) and the smart system (SS). Each treatment was repeated three times. The SS experiment in this study was based on an automatic water-quality control system. This system was built using the Milwaukee MC122 pH controller + baking soda injection to maintain pH and the Elitech STC-1000 thermocontroller + Sobo stainless steel 25-watt heater to maintain temperature. The research design can be seen in Table 2.

Table 1

Proximate composition of the feed used

Composition	*Percentage (%)*
Moisture	8.1%
Protein	60.0%
Crude fat	12,4%
Crude fiber	<2%
Crude ash	<15%
Calcium	2.7%
Phosphorus	2%

Table 2

Experimental design

Treatment	*Description*
CS-400	Conventional system with a density of 400 fish m^{-3}
CS-600	Conventional system with a density of 600 fish m^{-3}
CS-800	Conventional system with a density of 800 fish m^{-3}
SS-400	Smart system with a density of 400 fish m^{-3}
SS-600	Smart system with a density of 600 fish m^{-3}
SS-800	Smart system with a density of 800 fish m^{-3}

Observation parameters. The observed parameters determined were production performance, oxygen consumption rate (OCR), quality index or fish grade, morphology or defect rate, blood glucose levels, and financial analysis. The observed production performance includes absolute length growth, survival rate (SR), and length variation coefficient. OCR and blood glucose level observations were conducted on days 0 (D0), 30 (D30), 60 (D60), and 90 (D90) of maintenance. The quality index parameter was determined by categorizing the fish into Grade A and Grade B. Fish morphology was observed by noting any morphological defects. The financial analysis includes business performance, investment criteria analysis, and sensitivity analysis. The business analysis parameters are profit, break-even point (BEP), revenue cost ratio (R/C Ratio), and payback period (PP). The observed investment criteria parameters are net present value (NPV), internal rate of return (IRR), and net benefit cost ratio (Net B/C). Sensitivity analysis was conducted using the switching value method to determine how variable changes can result in the NPV being zero and the Net B/C Ratio being 1. The switching value analysis was performed on variables considered to mostly affect business feasibility. In this study, these variables were revenue decreases of 50, 60, 70, 80, and 90%. These variables were chosen because they directly impact the overall business revenue.

Data analysis. The obtained data were analyzed quantitatively using SPSS 20 software. If the analysis of variance (two-way ANOVA) showed significant differences ($p<0.05$), further testing was conducted with Duncan's test at a 95% confidence interval.

Results and Discussion. The production performance of discus fish maintained for 90 days across all treatments is presented in Table 3. Stocking density significantly affected ($p<0.05$) the coefficient of variation (CV) and SR. The culture system significantly affected ($p<0.05$) final length (FL), absolute length (ΔL), and CV. Meanwhile, the interaction between stocking density and culture system only significantly affected ($p<0.05$) the CV.

Table 3

Initial length, final length, absolute length, coefficient of variation, and survival rate of discus fish over 90 days of maintenance based on conventional and smart systems with different stocking densities

Stocking densities	*Parameters*				
(A)	*L0 (cm)*	*Lt (cm)*	*ΔL (cm)*	*KK (%)*	*TKH (%)*
400	3	5.17±0.02^{b}	2.17±0.03^{b}	3.97±0.15^{b}	74.17±1.28^{b}
600	3	5.16±0.02^{ab}	2.16±0.03^{ab}	4.29±0.15^{ab}	68.89±1.28^{a}
800	3	5.08±0.02^{a}	2.08±0.03^{a}	4.64±0.15^{a}	75.42±1.28^{b}
		Aquaculture system (B)			
CS	3	5.08±0.02	2.08±0.02	4.77±0.12	71.48±1.04
SS	3	5.19±0.02	2.19±0.02	3.82±0.12	74.17±1.04
		Two Way Anova			
A	NS	p<0.05	p<0.05	p<0.05	NS
B	NS	NS	NS	P<0.05	p<0.05
A x B	NS	NS	NS	P<0.05	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

The OCR of discus fish maintained for 90 days across all treatments is presented in Table 4. Stocking density significantly affected ($p<0.05$) the OCR at day 60 (D60). However, the culture system and their interaction did not significantly affect ($p>0.05$) the OCR. The quality index of discus fish maintained for 90 days across all treatments is presented in Table 5. Stocking density significantly affected ($p<0.05$) both Grade A and Grade B. The culture system and their interaction only significantly affected ($p<0.05$) Grade A. The morphology of discus fish maintained for 90 days across all treatments is presented in Table 6. Stocking density, culture system, and their interaction did not significantly affect ($p>0.05$) the morphology of discus fish.

The blood glucose levels of discus fish maintained for 90 days across all treatments are presented in Table 7. Stocking density and culture system significantly affected ($p<0.05$) the blood glucose levels on day 0 (D0), 30 (D30), 60 (D60), and 90 (D90). The interaction between the two did not significantly affect ($p>0.05$) blood glucose levels. The blood glucose levels of discus fish at the start (D0) ranged from 63.51±0.87 to 72.35±0.87 mg dL^{-1}, on day 30 (D30) ranged from 68.59±1.30 to 75.67±1.30 mg dL^{-1}, on day 60 ranged from 63.59±1.14 to 74.40±1.14 mg dL^{-1}, and at the end (D90) ranged from 73.77±0.81 to 82.47±0.81 mg dL^{-1}.

The business performance of discus fish farming maintained for 90 days across all treatments is presented in Table 8. The overall investment cost for the stocking density treatments was 100.59 USD. Meanwhile, in the culture system group, the lowest investment cost was for CS at 61.83 USD, and the highest for SS, at 139.37 USD. The lowest total cost occurred for the stocking density of 400 fish m^{-3} at 20.59 USD. In the culture system group, the lowest fixed cost was for CS at 19.98 USD, and the highest for SS at 30.96 USD. In the culture system group, the highest production was for SS with 21 fish, and for CS with 20 fish. The highest revenue was for the stocking density treatments with 800 fish m^{-3} at 92.04 USD. In the culture system group, the highest revenue was for SS at 67.9 USD, and for CS at 65 USD. Stocking density and culture system significantly affected ($p<0.05$) profit, BEP unit, R/C ratio, and PP of discus fish farming. The interaction between the two only significantly affected ($p<0.05$) the PP. The highest profit was for the stocking density of 800 fish m^{-3} at 61.85 USD. In the culture system group, the highest profit was for CS at 45.1 USD, and for SS at 36.87 USD. The lowest BEP unit for stocking density was for 800 fish m^{-3} at 4.99 fish. In the culture system group, the lowest BEP unit was for CS at 2.55 fish, and for SS at 7.59 fish. The highest R/C ratio for stocking density was for 800 fish m^{-3} at 3.14. In the culture system group, the highest R/C ratio was for CS at 3.19, and for SS at 2.15. The lowest PP for stocking density was for 800 fish m^{-3} at 0.42

years. In the culture system group, the lowest PP was for CS at 0.39 years, and for SS at 1.12 years.

Table 4
Oxygen consumption levels of discus fish during 90 days of maintenance based on conventional and smart systems with different stocking densities

Stocking densities (A)	*Oxygen consumption levels (mg O^2 g^{-1} h^{-1})*			
	D0	*D30*	*D60*	*D90*
400	0	2.72 ± 0.28^{a}	1.16 ± 0.18^{a}	1.53 ± 0.06^{a}
600	0	2.61 ± 0.28^{a}	1.73 ± 0.18^{b}	1.61 ± 0.06^{a}
800	0	2.34 ± 0.28^{a}	1.88 ± 0.18^{b}	1.68 ± 0.06^{a}
Aquaculture system (B)				
CS	0	2.39±0.23	1.52±0.15	1.60±0.05
SS	0	2.72±0.23	1.65±0.15	1.61±0.05
Two Way Anova				
A	NS	NS	NS	NS
B	NS	NS	$p<0.05$	NS
A x B	NS	NS	NS	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); D0 - day 0; D30 - day 30; D60 - day 60; D90 - day 90; 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

Table 5
Quality index of discus fish over 90 days of maintenance based on conventional system and smart system with different stocking densities

Stocking densities (A)	*Quality index*		
	Grade A	*Grade B*	*Ratio A/B*
400	8 ± 0.46^{a}	5.83 ± 0.60^{a}	1.41 ± 0.13^{a}
600	10.83 ± 0.46^{b}	8.50 ± 0.60^{b}	1.32 ± 0.13^{a}
800	16 ± 0.46^{c}	13.00 ± 0.60^{c}	1.27 ± 0.13^{a}
Aquaculture system (B)			
CS	11±0.38	9.33±0.49	1.29±0.11
SS	12.22±0.38	8.89±0.49	1.38±0.11
Two Way Anova			
A	$p<0.05$	NS	NS
B	$p<0.05$	$p<0.05$	NS
A x B	$p<0.05$	NS	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

The results of the NPV and IRR analysis for discus fish farming based on CS and SS with different stocking densities are presented in Table 9. The overall NPV values are positive ($NPV>0$). Meanwhile, the IRR value exceeds the cost of capital ($IRR>i$). The conditions of NPV and IRR suggest that the business is viable for development. The results of the net B/C ratio analysis for discus fish farming based on CS and SS with different stocking densities are presented in Table 10. The stocking density treatment and farming system have a significant effect ($p<0.05$) on the net B/C ratio. However, their interaction does not have a significant effect ($p>0.05$). The net B/C ratio in this study is ≥1, indicating that the business is worthwhile.

The results of the sensitivity analysis regarding the decrease in revenue for discus fish farming based on CS and SS with different stocking densities against the NPV and net B/C ratio are presented in Table 11. The decrease in revenue significantly affects the NPV and net B/C ratio. A 10% reduction in revenue shows that the farming business is still feasible. A 20% reduction indicates that only stocking densities of 600 and 800 fish m^{-3}, as well as CS, are viable. A 30% reduction shows that only the 800 fish m^{-3} density and

CS are feasible. With a revenue decrease of 40 to 50%, the farming business is no longer viable.

Table 6
Morphology of discus fish over 90 days of maintenance based on CS and SS with different stocking densities

Stocking densities (A)	*Morphology*
400	1±0.30^{a}
600	1.33±0.30^{a}
800	1.33±0.30^{a}
Aquaculture system (B)	
CS	1.22±0.25
SS	1.22±0.25
Two Way Anova	
A	NS
B	NS
A x B	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

Table 7
Blood glucose levels of discus fish over 90 days of maintenance based on CS and SS with different stocking densities

Stocking densities (A)	*Blood glucose levels*			
	D0	*D30*	*D60*	*D90*
400	63.51±0.87^{a}	68.59±1.30^{a}	63.59±1.14^{a}	73.77±0.81^{a}
600	67.36±0.87^{b}	73.52±1.30^{b}	68.51±1.14^{b}	75.99±0.81^{a}
800	72.35±0.87^{c}	75.67±1.30^{b}	74.40±1.14^{c}	82.47±0.81^{b}
Aquaculture system (B)				
CS	70.61±0.71	74.40±1.06	71.00±0.93	78.54±0.66
SS	64.87±0.71	70.78±1.06	66.67±0.93	76.29±0.66
Two Way Anova				
A	$p<0.05$	$p<0.05$	$p<0.05$	$p<0.05$
B	$p<0.05$	$p<0.05$	$p<0.05$	$p<0.05$
A x B	NS	NS	NS	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); D0 - day 0; D30 - day 30; D60 - day 60; D90 - day 90; 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

Table 8
Economic parameters for discus fish maintenance based on CS and SS with different stocking densities

Parameters	*400*	*600*	*800*	*CS*	*SS*
Investment costs (USD)	100.85	100.85	100.85	61.87	139.83
Fixed costs (USD)	10.97	10.96	10.97	5.45	16.49
Variable costs (USD)	9.64	14.56	19.36	14.53	14.51
Total costs (USD)	20.61	25.52	30.33	19.98	31
Production (fish)	14	19	29	20	21
Total revenue (USD)	44.97	62.47	92.22	65.16	67.95
Profit (USD)	24.36	36.95	61.89	45.18	36.96
BEP unit (fish)	5.04	5.18	4.99	2.55	7.59
R/C ratio	2.32	2.56	3.14	3.19	2.15
PP (years)	1.12	0.72	0.42	0.39	1.12

Note: 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system.

Table 9

NPV and IRR of discus fish farming based on CS and SS with different stocking densities

Years	*NPV (USD)*					*IRR (%)*				
	400	*600*	*800*	*CS*	*SS*	*400*	*600*	*800*	*CS*	*SS*
1	-11.99^a	36.4^b	132.29^c	108.9	-4.41	19.55^a	79.92^b	197.25^c	192.1	5.72
2	73.94^a	166.72^b	350.58^c	268.2	125.9	81.77^a	148.95^b	274.08^c	269.6	66.96
3	152.78^a	286.28^b	550.84^c	414.4	245.5	103.11^a	168.55^b	290.74^c	286.1	88.8
4	225.1^a	395.96^b	734.57^c	548.5	355.2	111.59^a	175.21^b	295.17^c	290.4	97.64
5	291.45^a	496.59^b	903.13^c	671.6	455.9	115.39^a	177.80^b	296.53^c	291.6	101.6
6	352.33^a	588.91^b	1057.77^c	784.5	548.2	117.25^a	178.91^b	296.99^c	291.9	103.5
7	408.17^a	673.61^b	1199.65^c	888	632.9	118.23^a	179.42^b	297.16^c	292.0	104.5
8	459.41^a	751.32^b	1329.8^c	983.1	710.6	118.77^a	179.67^b	297.22^c	292.1	105.0
9	506.42^a	822.61^b	1449.22^c	1070	781.9	119.08^a	179.79^b	297.24^c	292.1	105.3
10	549.54^a	888.01^b	1558.77^c	1150	847.4	119.26^a	179.85^b	297.25^c	292.1	105.5
11	589.11^a	948.01^b	1659.27^c	1224	907.4	119.38^a	179.89^b	297.25^c	292.1	105.6
12	625.4^a	1003.06^b	1751.48^c	1291	962.4	119.44^a	179.90^b	297.25^c	292.1	105.6
13	658.7^a	1053.56^b	1836.08^c	1353	1013	119.48^a	179.91^b	297.25^c	292.1	105.7
14	689.25^a	1099.9^b	1913.69^c	1409	1059	119.51^a	179.91^b	297.25^c	292.1	105.7
15	717.28^a	1142.4^b	1984.89^c	1461	1102	119.53^a	179.92^b	297.25^c	292.1	105.7
16	743^a	1181.4^b	2050.21^c	1509	1141	119.54^a	179.92^b	297.25^c	292.1	105.7
17	766.59^a	1217.18^b	2110.14^c	1553	1177	119.54^a	179.92^b	297.25^c	292.1	105.7
18	788.23^a	1250^b	2165.12^c	1593	1209	119.55^a	179.92^b	297.25^c	292.1	105.7
19	808.08^a	1280.11^b	2215.56^c	1630	1240	119.55^a	179.92^b	297.25^c	292.1	105.7
20	826.3^a	1307.74^b	2261.84^c	1663	1267	119.55^a	179.92^b	297.25^c	292.1	105.7

Note: 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; NPV - net present value; IRR - internal rate of return.

Table 10

Net B/C Ratio of discus fish farming based on CS and SS with different stocking densities

Stocking densities (A)	*Net B/C Ratio*
400	1.32±0.07^{a}
600	1.56±0.07^{b}
800	2.14±0.07^{c}
Aquaculture system (B)	
CS	2.19±0.06^{a}
SS	1.15±0.06^{a}
Two Way Anova	
A	$p<0.05$
B	$p<0.05$
A x B	NS

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

Table 11

Sensitivity analysis of a 10, 20, 30, 40, and 50% reduction in revenue for discus fish farming based on CS and SS with different stocking densities on the net present value (NPV) and net benefit cost (B/C) ratio values

Parameters	*400*	*600*	*800*	*CS*	*SS*
10% reduction in revenue					
NPV	624.55^{a}	1020.22^{b}	1822.34^{c}	1349.93	961.47
Net B/C Ratio	1.09^{a}	1.30^{b}	1.83^{c}	1.87	0.94
20% reduction in revenue					
NPV	460.35^{a}	792.11^{b}	1485.60^{c}	1112.02	713.35
Net B/C Ratio	0.86^{a}	1.05^{b}	1.51^{c}	1.55	0.72
30% reduction in revenue					
NPV	296.14^{a}	564.00^{b}	1,148.85^{c}	874.10	465.24
Net B/C Ratio	0.62^{a}	0.79^{b}	1.20^{c}	1.24	0.51
40% reduction in revenue					
NPV	131.93^{a}	335.89^{b}	812.11^{c}	636.18	217.12
Net B/C Ratio	0.40^{a}	0.53^{b}	0.88^{c}	0.92	0.29
50% reduction in revenue					
NPV	-32.27^{a}	107.79^{b}	475.37^{c}	398.26	-31.00
Net B/C Ratio	0.20 ^{a}	0.28^{b}	0.57^{c}	0.60	0.10

Note: data (mean ± SE) in the same column followed by different superscripts indicate significant differences at the 5% level (Duncan's test); 400 - density of 400 fish m^{-3}; 600 - density of 600 fish m^{-3}; 800 - density of 800 fish m^{-3}; CS - conventional system; SS - smart system; A - stocking densities; B - aquaculture system; A x B - interaction of A and B; NS - not significant.

Discussion. The efficiency of aquaculture business in fish farming is closely related to the farmer's goal of maximizing profits through improved production performance (Tajerin et al 2011). Growth is an important component in aquaculture as it can determine the price of ornamental fish commodities (Alam et al 2016). Based on Two-Way ANOVA, the interaction between stocking density and farming system does not have a significant effect ($p>0.05$) on the growth (Lt and ΔL) of discus fish. The stocking density treatments in this study were found to have no significant effect ($p>0.05$) on the Lt and ΔL of discus fish. This condition differs from the findings of Tibile et al (2016), who found that stocking density can affect the growth of discus fish. However, several other studies revealed that stocking density does not influence growth, such as the research by Alhassan et al (2012) and Ronald et al (2014) on Nile tilapia (*Oreochromis niloticus*) raised at different stocking densities, which showed no significant effects on growth. The application of the farming system group in this study had a significant effect ($p<0.05$) on the growth of discus fish, with the SS group showing higher growth compared to CS. The SS-based farming system has been known to enhance growth, as shown in the study of Ullman et al (2019) on the farming of shrimp (*Penaeus vannamei*) using AQ1 systems (SS feeding application), which produced higher growth compared to the standard feeding protocol of CS.

The CV is also an important indicator in aquaculture business activities. A smaller CV value results in better fish quality and higher market value. Based on Two-Way ANOVA, the interaction between stocking density and farming system does not have a significant effect ($p>0.05$) on the CV of discus fish. The stocking density treatment has a significant effect ($p<0.05$) on CV. The CV condition in this study differs from that obtained by Tibile et al (2016), who found that stocking density did not affect the CV of discus fish. However, it is consistent with the research of Zhang et al (2016), which found that stocking density affects the CV of hybrid catfish (*Pelteobagrus fulvidraco* ♀ x *P. vachelli* ♂). The application of the farming system group in this study had a significant effect ($p<0.05$) on the CV of discus fish, with the SS group showing a lower CV compared to CS. So far, there have been no reports indicating that SS-based technology interventions can reduce CV in fish or shrimp. Conversely, the study by Paspatis & Boujard (1996) revealed that manual feeding resulted in a lower CV compared to automatic feeder system interventions in salmon (*Salmo salar*). This study is the first report indicating that the utilization of technology (SS) can reduce the CV in fish.

The SR is a key parameter in aquaculture businesses, as it can indicate the success of fish farming (Astari et al 2023). Based on Two-Way ANOVA, the interaction between stocking density and farming system does not have a significant effect ($p>0.05$) on the SR of discus fish. The stocking density treatment in this study significantly affects ($p<0.05$) the SR of discus fish. This is consistent with the findings of Tibile et al (2016), who found that stocking density can influence the SR of discus fish. The application of the farming system group in this study did not show a significant effect ($p>0.05$) on the SR of discus fish. However, the results show that the SR of the SS group is higher than that of CS. The SS-based farming system has been known to improve SR, as evidenced by the findings of Tsai et al (2022), who developed and applied an IoT-based Smart Aquaculture System (ISAS) for shrimp, achieving a higher SR compared to CS without ISAS.

Oxygen is also an important factor in aquaculture production. Based on Two-Way ANOVA, the interaction between stocking density and farming system does not have a significant effect ($p>0.05$) on the OCR of discus fish. The stocking density treatment in this study had a significant effect ($p<0.05$) on the OCR at D60 for discus fish. When stocking density is high, fish may experience increased stress and competition for food and space, leading to increased oxygen consumption (Seo & Park 2022). Prihadi et al (2022) found similar results in mahseer fish (*Tor soro*). However, our study also found that stocking density did not have a significant effect ($p>0.05$) on OCR at D30 and D90. This indicates that the oxygen source can meet the oxygen needs of discus fish, even at high stocking densities (Said et al 2021). The application of the farming system group in this study did not show a significant effect ($p>0.05$) on the OCR of discus fish. Although SS is known to supply oxygen, as demonstrated in the study by Dzulqornain et al (2018), the results for OCR in the SS group in this study were not better than those in the CS group. This also suggests that the oxygen source can meet the oxygen needs of discus fish, similar to the treatment with stocking density.

The quality index of fish is also an important indicator in aquaculture business. The quality index aims to classify ornamental fish quality into grades (Diatin et al 2017). According to data from AW Discus (the aquaculture unit where the research was conducted), Grade A has a quality index value >1.3, while Grade B has a value <1.3. Based on Two-Way ANOVA, the interaction between stocking density and farming system significantly affects ($p<0.05$) the Grade A of discus fish. Meanwhile, Grade B and the A/B ratio do not have a significant effect ($p>0.05$). The stocking density treatment in this study significantly affected ($p<0.05$) both Grade A and Grade B. Furthermore, the application of the farming system in this study had a significant effect ($p<0.05$) on Grade A of discus fish. No previous research has examined the quality index of fish, especially for discus fish. Essentially, the quality index parameter is the ratio of the height and length of the discus fish, making growth (length and height) a benchmark. While stocking density has been shown to affect growth, in this study, stocking density did not have a significant effect ($p>0.05$) on growth, as seen in the studies by Alhassan et al (2012) and Ronald et al (2014) on Nile tilapia. This is similarly observed with differences in farming systems. Overall, SS produces a better quality index than CS. The utilization of SS in this study resulted in better growth than CS, as indicated by Ullman et al (2019) on the farming of shrimp (*Penaeus vannamei*) using AQ1 systems (SS feeding application).

The morphological condition of fish is also an important indicator in aquaculture business. The morphology parameter includes deformities, meaning shape abnormalities or defects. The presence of defects can hinder aquaculture production activities (Chandra et al 2024). Furthermore, defective fish will lead to a decrease in selling price (Waode & Mahyudin 2016). Based on Two-Way ANOVA, the interaction between stocking density and farming system does not have a significant effect ($p>0.05$) on the morphology of discus fish. The stocking density treatment, which had no significant effect ($p>0.05$) on morphological conditions, is consistent with the findings of Taylor et al (1997), who found that stocking density did not significantly affect juvenile oyster (*Pinctada maxima*) deformities. The application of the farming system in this study did not show a significant effect ($p>0.05$) on the morphological condition of discus fish. The morphological condition of discus fish in both CS and SS farming systems showed the same value, 1.22±0.25. This marks the first study revealing the impact of SS on the morphological condition of fish, as there has been no prior research addressing this issue.

Blood glucose levels are also an important factor, as they serve as an indicator of stress, which subsequently affects the production performance of fish (Chowdhury & Saikia 2020; Dawood et al 2020). Based on Two-Way ANOVA, the interaction between stocking density and farming system did not show a significant effect ($p>0.05$). However, the stocking density treatment had a significant effect ($p<0.05$) on blood glucose levels. High stocking density is known to affect blood glucose levels in fish. For example, Odhiambo et al (2020) found that stocking density significantly influences the blood glucose of Nile tilapia. The application of the farming system also had a significant effect ($p<0.05$) on blood glucose levels. The SS group showed lower glucose levels compared to the CS group. The use of SS is known to reduce blood glucose in fish, as demonstrated by de Mattos et al (2022), who found that an automatic feeding sensor-based SS produced lower blood glucose levels in tambaqui (*Colossoma macropomum*) compared to self-feeder-based CS. The blood glucose levels of discus fish at the start (D0) ranged from 63.51±0.87 to 72.35±0.87 mg dL^{-1}. On day 30 (D30), they ranged from 68.59±1.30 to 75.67±1.30 mg dL^{-1}, on day 60, from 63.59±1.14 to 74.40±1.14 mg dL^{-1} and at the end (D90), they ranged from 73.77±0.81 to 82.47±0.81 mg dL^{-1}. These ranges remain within the normal range for discus fish, which is 32.82 to 82.8 mg dL^{-1} (Swain et al 2019; Sanaya 2022).

Business analysis can determine the efficiency of an aquaculture business (Astari et al 2023). The stocking density treatment in this study did not increase investment costs. The total investment cost for the stocking density treatment was 100.85 USD. Meanwhile, in the farming system groups, the investment cost for CS (61.87 USD) was lower than for SS (139.83 USD). The increase in investment for SS was due to the need to invest in building an SS, resulting in a higher total cost for SS (31 USD) compared to CS (19.98 USD). The total cost for the stocking density treatment also increased as stocking density increased. The lowest total cost was found in the low stocking density treatment of 400 fish m^{-3} (20.61 USD). Conversely, the highest total cost was for the high stocking density treatment of 800 fish m^{-3} (30.33 USD). This aligns with the findings of Astari et al (2023), which found that increasing stocking density can raise the total cost of rearing beautiful grouper (*E. fuscoguttatus* × *E. microdon*).

The revenue from an aquaculture venture must exceed production costs for it to be considered successful (Safrita 2020). The highest revenue from the stocking density treatment was observed at 800 fish m^{-3}, amounting to 92.22 USD per production cycle. In the farming system groups, the highest revenue was for SS, 67.95 USD per production cycle. The transition from conventional farming systems to more advanced systems is known to result in higher revenue. Research by Astari et al (2021) showed that revenue from CS was significantly lower than that from recirculating and recirculating + bioremediation systems.

Profit is defined as net income after deducting production costs. Based on Two-Way ANOVA, the interaction between stocking density and farming system only showed a significant effect ($p>0.05$) on PP. However, both stocking density and farming system had a significant effect ($p<0.05$) on profit, BEP per unit, R/C ratio, and PP. The best conditions for profit, BEP per unit, R/C ratio, and PP in the stocking density treatment were observed at a density of 800 fish m^{-3}, with a profit of 61.89 USD per cycle, a BEP of 4.99 fish, an R/C ratio of 3.14, and a PP of 0.42 years. In the farming system groups, the best results for profit, BEP per unit, R/C ratio, and PP were achieved with the CS system, yielding a profit of 45.18 USD per cycle, a BEP of 2.55 fish, an R/C ratio of 3.19, and a PP of 0.39 years.

It is known that stocking density can influence profit, BEP per unit, R/C ratio, and PP, as found by Puluhulawa et al (2021) in ornamental botia fish (*C. macracanthus*). Meanwhile, the SS-based farming system should theoretically yield better business analysis results than CS, as one of its advantages is the ability to reduce fixed costs (Mustafa et al 2016). However, in this study, the fixed costs for SS were still higher than those for CS. This does not imply that SS is ineffective for development, but rather that the fish production was relatively low, at 21 fish, which did not differ significantly from CS. Additionally, the stocking density treatment in this study has not yet identified the optimal density. Notably, a stocking density of 800 fish m^{-3} yielded better results than lower densities. Therefore, if production can be increased through higher stocking densities, there is potential for improving the efficiency of SS-based aquaculture.

Nevertheless, considering the R/C ratio criteria, the SS-based discus fish aquaculture with an R/C ratio of 2.15 is deemed worthy of development. It is known that an R/C ratio greater than 1 indicates that the venture is profitable or feasible for further development (Karimba et al 2014). Furthermore, the PP for SS in this study, with a value of 1.12 years, is considered very good, meaning the company could recoup its investment in 2 years and 7 months. This indicates that SS still has potential for further development.

Investment criteria analysis is also an important factor in determining the efficiency of an aquaculture business (Artiana et al 2019). The application of different systems and technologies in fish farming yields varying financial values (Diatin et al 2021), making the selection of the appropriate system a crucial factor in increasing farmer income. This study's results indicate that stocking density and farming system have a significant effect ($p<0.05$) on NPV, IRR, and net B/C ratio in discus fish farming. The interaction between these factors significantly affects only the IRR ($p<0.05$). It is known that intensive farming can influence NPV, IRR, and net B/C ratio, as seen in the intensive farming of vannamei shrimp at PT. Lautan Emas Situbondo, East Java (Muqsith et al 2021). NPV, IRR, and net B/C ratio are important metrics for evaluating aquaculture business performance (Arifa et al 2022; Samat et al 2024). The NPV of the discus fish aquaculture in this study was >0, $IRR>i$, and net B/C ratio ≥ 1, indicating that the venture is viable.

Sensitivity analysis is also an important factor to observe as it measures changes affecting the feasibility of the aquaculture business. This analysis serves as a scenario to assess the impact of variable changes on the running farming venture. The findings of this study show that a decrease in revenue is very sensitive in the discus fish aquaculture business, significantly impacting the NPV and net B/C ratio. Similar findings were reported in the scenario of reduced revenue in intensive shrimp farming at PT. Lautan Emas Situbondo, East Java (Muqsith et al 2021). A 10% reduction in revenue shows that the farming business is still feasible. An 20% reduction indicates that only stocking densities of 600 and 800 fish m^{-3}, as well as CS, are viable. A 30% reduction shows that only the 800 fish m^{-3} density and CS are feasible. Meanwhile, with a revenue decrease of 40 to 50%, the farming business is no longer viable. Therefore, intensive discus fish farming at a density of 800 fish m^{-3} based on the CS system is considered a feasible aquaculture business, as it is not overly sensitive to revenue reductions.

Conclusions. Intensive cultivation of discus fish with high stocking density in CS and SS systems can enhance aquaculture performance, making it feasible for development. If there is a decrease in demand, the aquaculture business remains viable, especially with a stocking density of 800 fish m^{-3} using a CS.

Acknowledgements. We are grateful to the 12 technicians from AW Discus fish farming who significantly assisted in data collection for this study. Their help and cooperation were invaluable in ensuring that every step of data collection was conducted smoothly and accurately. Their participation not only included providing the necessary information but also offering valuable insights based on their experience and expertise in discus fish farming. We greatly appreciate their time, dedication, and willingness to share their knowledge, which greatly contributed to the success of this research.

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 22 July 2024. Accepted: 09 September 2024. Published online: 08 November 2024.

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How to cite this article:
Arisyanto A., Diatin I., Effendi I., Hadiroseyani Y., 2024 Performance of an aquabusiness regarding the cultivation of *Symphysodon* sp. in a conventional system and a smart system. AACL Bioflux 17(6):2427-2442.