University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 15, Issue 1 (2026) PP 421-430
https://jam.utq.edu.iq/index.php/main https://doi.org/10.541/ebsx5618

Effect of stocking densities in floating cages on growth indicators and chemical composition of common carp muscles *Cyprinus carpio* L.

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Abstract

The effects of different rearing densities of common carp *Cyprinus carpio* were studied to determine the optimal stocking density in the Euphrates River in Thi-Qar Governorate, southern Iraq, coordinates 46°18'13.09"E 31° 0'42.14"N, during a period of 180 days from October 2025 to March 2026, with an average initial weight of 65.6 g, with two replicates for each treatment. The experiment included three stocking densities: 31, 41, and 52 fish/m³ (750, 1000, and 1250 fish for treatments T1, T2, and T3, respectively). The results showed significant differences ($p \leq 0.05$) between treatments in growth indicators, with treatment T1 exhibiting the highest final weight, weight gain, and specific growth rate. The highest feed conversion ratio was recorded in T3 and the lowest in T1. Fish in treatment T1 had significantly higher feed conversion efficiency than those in treatments T2 and T3, and protein efficiency ratios were significantly higher in treatment T1 compared to treatments T2 and T3. No significant differences were observed in the chemical composition of protein, moisture, ash, and carbohydrates. However, significant differences were found in fat content, which was higher in T3 compared to T1 and T2.

Keywords : ***Stocking density, Floating cages, Common carp, Growth performance, FCR, Chemical analysis***

I. Introduction:

Fish farming in floating cages is a modern production system that has gained increasing attention in the field of aquaculture, due to its efficiency in using water resources and the possibility of intensive production within natural water bodies (Yeboh and Tanoh, 2018). Stocking density is a crucial factor that directly affects fish growth, physiological behavior, and health (Mugwanya *et al*., 2022). Increasing the number of fish within a given volume leads to increased competition for food, oxygen, and space, as well as the accumulation of organic waste and higher levels of environmental stress within the cages (Naslund and Johnson, 2016). This is a key factor controlling growth performance, feed conversion efficiency, and overall fish production in aquaculture systems. Exceeding the optimal density leads to increased mortality rates, reduced feed efficiency, and the emergence of health disorders resulting from stress and deteriorating water quality. Conversely, adopting appropriate and specific densities, determined according to the fish species, feed type, and environmental factors, contributes to improved growth rates and increased productivity, thus achieving greater sustainability and efficiency in cage aquaculture systems (Aura *et al*., 2025; Awal *et al*., 2025). Common carp (*Cyprinus carpio*) is one of the most important farmed fish species in the world due to its high adaptability to different environmental conditions, relatively rapid growth rate, and tolerance to various feed types. It represents a suitable model for studies related to stocking density and environmental stress, as it is sensitive to changes in water quality and competition levels within farming units (Al-Shaban *et al*., 2021; Jalil *et al*., 2025). The importance of studying the effect of stocking density in floating cages lies in its contribution to determining optimal production standards, improving the quality of fish products, and reducing economic losses resulting from poor management (Chattopadhyay *et al*., 2013). Therefore, this study aims to determine the optimal stocking density for common carp (Cyprinus carpio L.) in floating cages to achieve the best growth and feed efficiency while maintaining the quality of muscle chemical composition.

II. Materials and Methods

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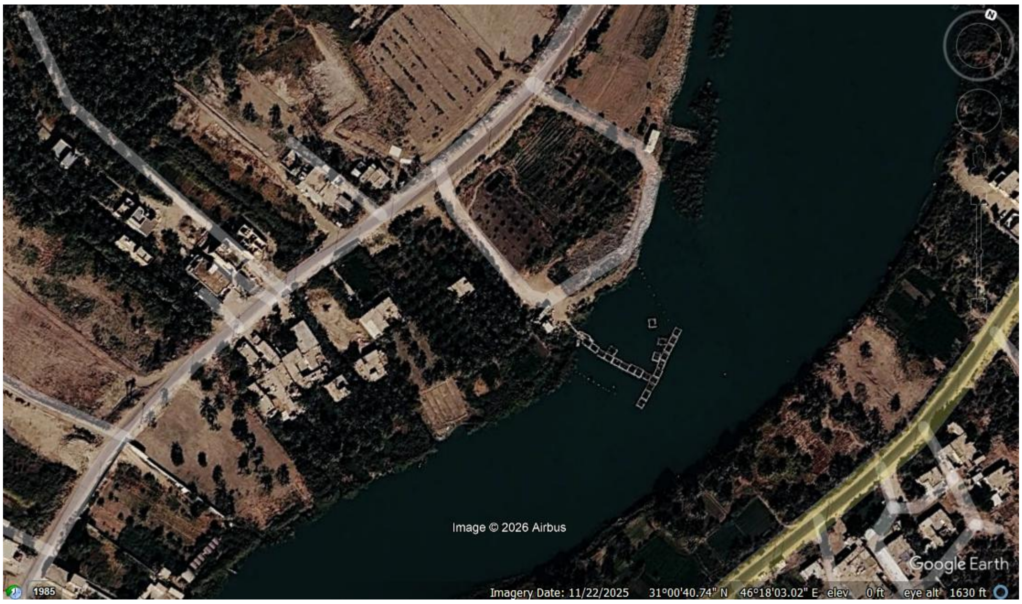
Experiment Site

The study was conducted in Nasiriyah, Dhi Qar Governorate, at a private farm on the Euphrates River in the Al Bu Azm area, 5 km from the highway bridge. The study lasted six months, from October 2025 to March 2026. The farm consists of 20 floating cages used for raising common carp. The site is characterized by several advantages, most notably that the cages are securely fixed to the riverbank, personnel are present to monitor the fish, the cages are made of galvanized iron and cork and are in good condition, and the location is considered secure from theft.

Fig 1: Map showing the location of sampling in the middle reaches of the Euphrates River in Thi-Qar Province.



Fieldwork

I received 6000 common carp Cyprinus carpio L from a private hatchery in the city of Hilla, with an average weight of 65.6 ± 0.11 g. They were distributed among the six experimental cages at three stocking densities: Treatment 1 T1 = 31 fish/m3, Treatment 2 T2 = 41 fish/m3, and Treatment 3 T3 = 52 fish/m3, with two replicates for each treatment. Treatment 1 had 750 fish per tank, Treatment 2 had 1000 fish per tank, and Treatment 3 had 1250 fish per tank. The dimensions of the cages were 4 × 3 × 2 m. A floating feed of Saudi origin was used at a feeding rate of 3% of the fish weight twice daily, morning and evening. The amount of feed was gradually increased as the fish weight increased.

Table (1) Chemical Analysis of the Feed Used in Fish Feeding

Material	Percentage %
Protein	27.37
Fat	5.89
Moisture	5.47
Ash	7.98
Carbohydrate	28.3

Fish weights were measured monthly using a Chinese-made single-pan digital scale. The fish were extracted using a manual net and transported outside the cages to be weighed for the purpose of calculating growth parameters according to the following equations:

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Total weight gain (g) = Final weight (g) – Initial weight (g)

Specific growth rate (g/day) = natural logarithm of final weight – natural logarithm of initial weight / time period between weights × 100.

Feed conversion ratio = Amount of feed consumed (g) / Weight gain (g).

Feed conversion efficiency = (Weight gain g / Value of feed consumed g) × 100.

Protein efficiency ratio = weight gain (g) / protein intake (g).

The physical and chemical properties of the water were measured, including temperature, which was measured using a mercury thermometer graduated from 0-100. The process took place in the morning for accuracy of reading, pH measurement using a pH meter, and dissolved oxygen measurement using an oxygen meter.

Turbidity was measured using a Turbid meter, total dissolved solids using a TDS meter, and electrical conductivity using a conductivity meter. Total suspended solids were measured by filtering 100 ml of the water sample through filter paper after it had been accurately weighed before drying. This paper was then dried in an oven at a temperature of (103-105)°C for 24 hours. It was weighed after drying and calculated using the following equation:

Total suspended solids mg/L = Weight after drying - Weight before drying × 1000 / Total sample volume.

Laboratory work

At the end of the experiment, fish samples of different densities were collected for the purpose of dissecting them and taking a muscle sample to conduct chemical analysis on them using standard methods (A.O.A.C, 2000). The moisture content was measured using an electric oven at a temperature of 105°C. Until the weight stabilized, the Kjeldal technique was used to estimate the protein content by multiplying the resulting nitrogen content by a factor of 6.25. The percentage of fat was measured using the Soxhlet Apparatus by weighing the dry sample and placing it in the Soxhlet beaker. An organic solvent (petroleum ether) was used for 16 hours with continuous heating. The organic solvent was evaporated in an electric oven at a temperature of 105°C for half an hour. The sample was weighed and the percentage of crude fat was calculated. The ash content was measured by burning the sample in an electric furnace at a temperature of 550°C. The process continued until the weight stabilized. In addition, the carbohydrate content was estimated according to the equation:

Carbohydrate % = 100 – (Moisture % + Protein % + Crude Fat % + Ash %).

Statistical analysis:

The fully randomized design (CRD) was used for the statistical analysis of one factor with three coefficients, and the significant differences between the means were tested using the Revised Least Significant Differences (RLSD) using the SPSS statistical software (2021) (V.26) to compare the experimental coefficients at a significance level of ($P \leq 0.05$).

III. Results and Discussion:

1- Body weight, weight gain, and specific growth rate

Table (2) shows the results of the average body weight, total weight gain, and specific growth rate according to the experimental densities. It is noted that there are no significant differences between the rearing density treatments in the initial weight of the fish, while significant differences were found between the rearing densities for the final weight of common carp (Cyprinus carpio), as the first treatment T1 was superior and reached 686.7 g compared to the rearing treatments T2 and T3, which reached 619.8 g and 594.2 g respectively at six months of age.

The weight gain results in Table 2 indicate significant differences between the rearing densities T1, T2, and T3. Treatment T1, at 621.0 kg, outperformed treatments T2 and T3, at 554.2 kg and 528.7 kg, respectively, during the period from 0 to 180 days. The superiority of treatment T1 reflects the ability of fish at lower densities to utilize food more

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efficiently and direct energy towards growth rather than using it to adapt to unfavorable environmental conditions, as occurs at higher densities. The results for the specific growth rate (SGR) in Table 2 show that the T1 rearing treatment was significantly higher, reaching 1.30, compared to the T2 and T3 treatments, which reached 1.25 and 1.21, respectively. The higher SGR in treatment T1 can be explained by the fact that this indicator depends on the efficiency of energy and protein utilization in the body. At lower densities, digestion and absorption are more efficient, and energy loss is lower, leading to higher SGRs. Conversely, higher densities lead to reduced nutrient utilization efficiency due to stress and competition. The superiority of the first treatment (T1) in final weight is attributed to the lower density providing a more favorable growth environment, with reduced competition for food and oxygen. Under these conditions, the fish are able to consume sufficient feed more efficiently, and stress levels are lower, thus improving feed conversion efficiency. This study is consistent with (Hayat *et al*., 2018).

Low and medium stocking densities (50–100 fish/m³) achieve the best performance in terms of weight gain and specific growth rate, while high densities (125 fish/m³) lead to a decline in these indicators. Stocking density is a vital factor in fish farming due to its direct impact on production, physiological functions, and growth (Debnath *et al*. 2022; Mollah *et al*. 2015). This is attributed to the fact that fish in high densities cannot obtain a sufficient amount of the feed provided to them due to overcrowding and competition for feed (Anderson *et al*., 2002).

Table (2): Effect of rearing densities on body weight, total weight gain and relative growth rate of common carp *Cyprinus carpio* cultured in floating cages (mean ± standard deviation)

Tretmention	Initial weight	Final weight	Total weight gain	qualitative growth rate
1T	65.7 ± 0.16	686.7 ± 1.15 a	621.0± 1.01 a	1.30± 0.0006 a
2T	65.6 ± 0.087	619.8 ± 3.04 b	554.2± 3.02 b	1.25 ± 0.0030 b
3T	65.5 ± 0.082	594.2 ± 9.98 c	528.7 ± 9.91 c	1.21 ± 0.0391 b
moral	N.S	*	*	*

* Horizontal differences between treatments indicate significant differences ($P \leq 0.05$)

N.S. No significant differences between treatments.

2- Feed conversion ratio, feed conversion efficiency, and protein efficiency ratio

Table 3 shows the effect of stocking densities on feed conversion ratio, feed conversion efficiency, and protein efficiency ratio of common carp (Cyprinus carpio) cultured in floating cages. The feed conversion ratio recorded the highest significant value in the third treatment T3, which reached 3.369, compared to both the first treatment T1, which reached 3.271, and the second treatment T2, which reached 3.339. Significant differences were observed between the breeding densities treatments for feed conversion efficiency, as the first treatment T1 was superior and reached 30.569 compared to breeding treatments T2 and T3, which reached 29.947 and 29.681 respectively. The results of the protein efficiency ratio showed a significant advantage for the T1 breeding treatment, which reached 1.12, compared to the T2 and T3 breeding treatments, which reached 1.09 and 1.09 respectively.

This result is consistent with the study (Fahad and Shuhaib, 2021) which showed a significant difference in total weight gain, feed conversion ratio, feed conversion efficiency, and protein efficiency ratio between breeding density coefficients.

Table (3): Effect of rearing densities on feed conversion efficiency and protein efficiency ratio of common carp (Cyprinus carpio) cultured in floating cages (mean ± standard deviation)

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Tretmention	Feed Conversion Rate	Feed Conversion Efficiency	Protein Efficiency Ratio
T1	3.271 ± 0.0012 c	30.569 ± 0.008 a	1.12 ± 0.001 a
T2	3.339 ± 0.0036 b	29.947 ± 0.030 c	1.09 ± 0.0012 b
T3	3.369 ± 0.012 a	29.681 ± 0.103 b	1.08 ± 0.0037 c
moral	*	*	*

* Horizontal differences between treatments indicate significant differences (P≤0.05)

N.S. No significant differences between treatments.

3- Chemical composition of fish muscles

Table 4 shows the effect of rearing densities on the chemical composition of common carp *Cyprinus carpio* cultured in floating cages. It is noted that there are no significant differences between rearing densities in terms of moisture content, total protein, ash, and carbohydrates, while significant differences were found between different rearing densities with respect to crude fat. The third treatment, T3, which reached 6.64, outperformed the two treatments, T1 and T2, which reached 6.23 and 6.29 respectively.

The results of the study indicate that there are no significant differences in most components of the chemical composition of carp muscles between different rearing densities, which demonstrates the fish's ability to maintain their muscle structure within a stable physiological range under suitable environmental conditions, especially density stress conditions. In contrast, the fat percentage showed a significant increase in high density, which is attributed to the decrease in motor activity and the increase in energy storage as a result of limited space and high crowding intensity, leading to fat accumulation in muscle tissue. Higher densities may lead to a change in feeding behavior such as competition for food, which drives some fish to consume relatively larger quantities when feed is available, thus increasing the deposition of fat percentages because it is not used as an energy source (Al-Shablawi, 2021; John and Ronald, 2002; Lall and Tibbetts, 2009; Prabu *et al*., 2017; Leibold and Hammerschmidt, 2015).

Table (4) Effect of rearing densities on the chemical composition of the muscles of common carp (Cyprinus carpio) cultured in floating cages (mean ± standard deviation)

Tretmention	moisture %	crude protein%	crude fat %	ash %	carbohydrates %
T1	0.38 ± 74.60	0.08 ±16.2	0.05 ±6.23^{b}	0.37±2.19	0.30±0.77
T2	0.19 ± 74.50	0.06 ±16.1	0.09 ±6.29^{ab}	0.21±2.06	0.17±0.97
T3	0.17 ±74.49	0.18±16.02	0.28 ±6.64^{a}	0.32±2.03	0.30 ±0.82
moral	N.S	N.S	*	N.S	N.S

* Horizontal differences between treatments indicate significant differences (P≤0.05)

N.S. No significant differences between treatments.

4- Physical properties of water

Table 5 shows the physical properties of the water during the months of the experiment. The results showed significant differences between the months of the experiment. The lowest water temperature was recorded in January at 17°C and the highest value in October at 25°C. The lowest air temperature was recorded in January at 14°C and the highest value in October at 33°C.

The results showed a seasonal difference in temperatures, reaching its highest point in autumn and its lowest point in winter. This difference is due to changes in the seasons, the length of daylight hours, the angle of the sun's rays, and the difference in the times of sample collection. This is consistent with (Paul *et al*., 2019; Garner

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et al., 2014; Benyahya *et al*., 2007). Fish growth and feed consumption are also affected by several environmental factors, most notably water temperature, dissolved oxygen concentration, pH level, electrical conductivity, and other factors (Flajshans and Hulata, 2007).

The results also recorded the lowest turbidity value in January, reaching NTU 2.67, and the highest value in December, reaching NTU 34.67. As for TSS levels, the highest value was recorded during December at 66.33 mg/L, and the lowest value during January at 14 mg/L. The significant increase in turbidity and total suspended solids (TSS) values is attributed to increased surface runoff coinciding with the start of the rainy season, which carries large quantities of sediment and resuspends it in the water column. Conversely, the decrease in these two indicators is attributed to the stabilization of hydrological conditions and the decline in runoff rates, creating favorable conditions for the sedimentation of suspended particles and thus improving water clarity. This is consistent with(Li *et al*., 2024; Kim *et al*., 2025; and Lu *et al*., 2023).

Table (5): Measurement of the physical properties of water during the months of the experiment (mean ± standard deviation)

Month/Examination	Water temperature °C	Air temperature °C	Turbidity NTU	TSS mg/L
October	$1.00{\pm}25^{a}$	$0.58{\pm}33.67^{b}$	$0.15{\pm}17.17^{c}$	1.00 ± 32^{e}
November	1.00 ± 22^{b}	1.00 ± 18^{c}	1.00 ± 25^{b}	1.00 ± 57^{b}
December	1.00 ± 18^{c}	1.00 ± 16^{d}	$0.15{\pm}34.67^{a}$	$0.58{\pm}66.33^{a}$
January	1.00 ± 17^{c}	1.00 ± 14^{e}	$0.01{\pm}2.67^{e}$	1.00 ± 14^{d}
February	$0.58{\pm}21.33^{bc}$	$1.00{\pm}17^{cd}$	$0.15{\pm}25.77^{b}$	1.00 ± 52^{c}
March	1.00 ± 22^{b}	$0.58{\pm} 25.67^{b}$	$0.005{\pm} 6.21^{d}$	$0.58{\pm}14.33^{d}$
Morality	*	*	*	*

* Different letters horizontally between the coefficients indicate the presence of significant differences (P≤0.05)

Table 6 shows the physical properties of water during the months of the experiment, which included total dissolved solids (TDS) and electrical conductivity (EC). The results showed significant differences between the values of total dissolved solids and electrical conductivity, as total dissolved solids reached its highest value during February at 2148 mg/L and its lowest value during October at 1458 mg/L. Electrical conductivity (EC) recorded its highest value during February at 3159.67 mS/cm and its lowest value during October at 2386.33 mS/cm. Although high values of total dissolved solids (TDS) and electrical conductivity (EC) are usually associated with periods of drought due to increased concentration, their increase during the rainy season can be explained by increased surface runoff which contributes to the transfer of dissolved salts and minerals from the soil and surrounding sources into the aquatic environment, leading to increased concentrations of dissolved ions. These ions are the main factor in increasing the electrical conductivity of water (Mohammad, 2017; Kim *et al*., 2022; Kent and Belitz, 2004).

There is a direct relationship between total dissolved solids (TDS) and electrical conductivity (EC), as the latter reflects the ability of water to conduct electricity as a result of the presence of dissolved ions. Therefore, increasing the concentration of these ions leads to an increase in both TDS and EC (Rusydi, 2018; Thirumalini and Joseph, 2009; Dewangan and Shrivastava, 2024).

Table (6): Measurement of the physical properties of water during the months of the experiment (mean ± standard deviation)

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Month/Examination	Total dissolved solids (TDS) mg/L	Electricalconnection (E.C.) millisiemens/cm
October	1.00±1458^{f}	7.64±2386.33^{e}
November	2.00±1676^{e}	0.58±2617.33^{d}
December	1.53±1689.67^{d}	1.53±2819.33^{b}
January	1.00±1778^{c}	2.00 ± 2776^{c}
February	1.00±2148^{a}	1.53 ±3159.67^{a}
March	1.53±1837.67^{b}	1.00±2828^{b}
Morality	*	*

* Different letters horizontally between the coefficients indicate the presence of significant differences (P≤0.05)

5- Chemical properties

Table 7 shows the chemical properties of the water during the months of the experiment, including dissolved oxygen and pH. The results showed significant differences between the months of the experiment. Dissolved oxygen recorded its highest value during January at 9.50 mg/L and its lowest value during March at 5.53 mg/L.

The increase in dissolved oxygen concentration is attributed to the decrease in water temperature, which increases the solubility of gases, in addition to decreased biological activity and improved aqueous mixing. Conversely, the decrease in dissolved oxygen concentration is attributed to the gradual increase in temperature and the increased oxygen consumption resulting from biological activity and the decomposition of organic matter. This aligns with(Kramer, 1987; Kulkarni ,2016; Sanchez *et al*. (2007).

The pH values showed significant differences, reaching a high of 7.82 in March and a low of 6.69 in December. The decrease in pH is attributed to increased surface runoff and decomposition of organic matter, leading to higher carbon dioxide concentrations and the formation of carbonic acid in the water. Conversely, the increase in pH is attributed to increased photosynthetic activity of aquatic organisms, which contributes to carbon dioxide consumption and a decrease in its concentration, thus raising the pH. This aligns with Raven *et al*, 2020 ; Hall *et al*. (2020).

Table (7) Measurement of the chemical properties of water during the months of the experiment (mean ± standard deviation).

Month/Examination	Dissolved oxygen mg/L	pH
October	0.15±7.63^{d}	0.41±7.47^{bc}
November	0.10±8.60^{c}	0.39±7.25^{c}
December	0.02±9.01^{b}	0.09±6.69^{d}
January	0.10±9.50^{a}	0.22±7.26^{c}
February	0.01±9.01^{b}	0.06±7.74^{a}
March	0.15±5.53^{e}	0.05±7.82^{a}
Morality	*	*

* Different letters horizontally between the coefficients indicate the presence of significant differences (P≤0.05)

IV. Conclusions

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The results of this study showed that stocking densities in floating cages significantly affect the productive performance of common carp (Cyprinus carpio). High densities led to a significant decrease in growth indicators and feed conversion efficiency. In contrast, no significant differences were recorded in most components of the fish muscle's chemical composition between the different treatments, with the exception of fat content, which showed statistically significant changes. This can be explained by the fact that high density and the associated physiological stress selectively affected fat metabolism and accumulation pathways, without extending its effect to other muscle chemical components, indicating a specific metabolic response to different rearing conditions.

V. Recommendations

It is recommended to adopt low stocking densities in the culture of common carp in floating cages, as they achieved significant superiority in growth performance and feed conversion efficiency. High stocking densities should be avoided due to their negative impact on productive performance, despite their association with increased lipid deposition in fish muscle.

Management and feeding programs should be optimized in accordance with low stocking densities to ensure efficient feed utilization and minimize waste. The elevated lipid content observed under high stocking densities should be considered a specific metabolic response, warranting careful evaluation of flesh quality from both health and market perspectives. Further studies are recommended to elucidate the mechanisms of lipid deposition under different stocking densities and to relate them to physiological and environmental factors. The findings should be supported by economic analyses to determine the optimal balance between growth performance, product quality, and economic return.

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