Research on Integrated Agro-Aquaculture Ecological Farming Technology

Ning XU[1], Xiaoguang ZU[2], Chanjuan CHEN[1], Tiegang LIU[1], Bingkun YANG[1], Yanhui LIU[1]*

1. Jilin Provincial Fisheries Research Institute, Changchun 130033, China; 2. Changchun Agricultural Technology Extension Station, Changchun 130033, China

Abstract [**Objectives**] To establish an integrated agro-aquaculture ecological farming model by combining in-pond cage fish farming, water circulation systems, and rice cultivation on bio-floating beds, and compared it with traditional pond farming. [**Methods**] The research was carried out in 3 test ponds and 3 control ponds. A 6 m × 9 m × 2.5 m cage was set every 667 m^2 in the test pond, and water circulator and microporous oxygenation equipment were installed. Ecological floating beds were set on both sides of the pond. Common aeration equipment was used for control ponds. The same number and size of crucian carp, and the same number, proportion and size of silver carp and bighead carp were raised in both the test and control groups. Total nitrogen, ammonium nitrogen, total phosphorus and phosphate content was determined every 15 d, and growth indicators and feed conversion ratios of fish were measured at the end of the experiment. [**Conclusions**] The content of total nitrogen, ammonium nitrogen, total phosphorus and phosphate in the experimental group decreased by 50.69%, 69.12%, 62.62% and 54.20%, respectively, compared with the control group. Compared with the control group, the harvest size, survival rate and yield per unit area of crucian carp in the experimental group increased by 5.25%, 7.58% and 13.28%, respectively, and the feed conversion ratio decreased by 4.72%. [**Results**] The integrated agro-aquaculture model demonstrated significant advantages in mitigating eutrophication, improving yield, and enhancing feed efficiency.

Key words Integrated agro-aquaculture, Ecological farming, Traditional farming, Nutrient removal, Water purification

0 Introduction

As a traditional aquaculture method in China, intensive pond farming still widely relies on increasing fry stocking and feed input to pursue high yields. However, this practice has led to aggravated pond eutrophication, deterioration of water quality, frequent fish diseases, increased drug usage, and declining aquaculture efficiency[1]. Additionally, untreated drainage water from aquaculture ponds easily causes pollution in receiving water bodies. Given these issues, transforming and upgrading pond aquaculture models toward ecological and green development has become an urgent need. Based on the concept of ecological healthy aquaculture, researchers proposed dividing traditional aquaculture ponds into aquaculture areas and water purification areas[2]. High-density cage culture is adopted in aquaculture areas, while water purification areas utilize ecological floating beds for rice planting and filter-feeding species like silver carp and bighead carp to improve water quality. Through the action of water circulator, the water body and residual feed and feces in the aquaculture area are pushed to the water purification area, forming a microcirculation of water within the pond. The rice and silver carp, bighead carp in the water purification area can effectively reduce the content of nutrients such as nitrogen and phosphorus in the water, thus achieving clean aquaculture with significant ecological and environmental advantages[3]. This model also achieves "zero water exchange" aquaculture, which is an important innovation compared to traditional pond aquaculture models[4]. However, as an emerging aquaculture model, it still requires further enrichment and improvement in practical application.

Therefore, we conducted further research on multi-dimensional ecological aquaculture technology in agriculture and aquaculture, with the aim of providing a scientific reference for the application of diversified ecological aquaculture technology in agriculture and aquaculture.

1 Materials and methods

1.1 Test materials The experimental site is Jilin Jinlongyu Aquaculture Cooperative. There were 6 experimental ponds, each with an area of 5.0 × 667 m^2 and a maximum water depth of 3.2 m; 15 seamless polyethylene cages were used, with a mesh size of 3.0 cm and dimensions of 6 m × 9 m × 2.5 m, and the cage frames were welded from 3/4 inch steel pipes, and the floats were cylindrical plastic barrels; fully automatic feeders were used for feeding in both ponds and cages; the water circulator equipment was a submersible flow-pushing aerator; the microporous aeration system consisted of a high-pressure vortex blower and microporous aeration tubes; the spring fingerling sizes were as follows: Allogynogenetic crucian carp "Zhongke 5" (64.70 ± 4.32) g, bighead carp (1 054.88 ± 114.56) g, and silver carp (937.77 ± 97.58) g; the feed was a special feed for crucian carp provided by Tongwei Feed Company, with a crude protein content of 32%; the floating plate harvest size was 3.8 m × 1.45 m, 90 wells per floating plate; the diameter of the fixed cup was 11.0 cm, matching the size of the floating plate hole; the culture substrate was pond sediment, and the rice variety was "Hongke 67".

1.2 Experimental design Both the experimental and control

Received: December 19, 2024 Accepted: February 19, 2025

Supported by Jilin Provincial Key Research and Development Project (20230202070NC).

Ning XU, agronomist, research fields: pond aquaculture.

* Corresponding author. Yanhui LIU, researcher, research fields: fish pathology studies.

groups were set up with 3 replicates. Each experimental group had 5 cages installed in the pond, while the control group had no cages. The stocking density per unit area was identical for both groups: 2 200 crucian carp, 40 silver carp, and 20 bighead carp per 667 m^2. In the experimental group, the main cultured crucian carp were placed in the cages. Each cage was equipped with an automatic feeder, microporous aeration equipment at the bottom, and a submersible flow-pushing aerator on the outside to drive water circulation and create internal pond flow. The experimental group used floating beds covering 20% of the pond surface area for rice cultivation. The control group had one automatic feeder and two paddlewheel aerators per pond, with all other conditions identical to the experimental group. Water quality parameters were monitored every 15 d starting from June 10. At the end of the trial, survival rate, average body weight, and yield per unit area were measured for all fish species. Feed utilization was calculated based on the weight gain of the main cultured fish and the total feed input.

1.3 Daily management Both experimental and control groups were fed 4 times daily, with feeding amounts equivalent to 3% – 4% of the total fish biomass. The experimental group operated microporous aeration equipment 24/7, with submersible flow-pushing aerators activated twice daily (4:00 – 6:00 AM and 18:00 – 20:00 PM) to establish internal water circulation. The experimental group replenished water losses from evaporation and leakage without performing water exchange. The control group replenished evaporation/leakage losses and conducted partial water exchanges based on water quality monitoring. Pond inspections were conducted before and after each feeding to monitor fish behavior, feeding activity, disease signs, and equipment function. Dead fish were promptly removed and weighed. Hydrochemical parameters (*e. g.*, dissolved oxygen, pH, ammonia) were monitored at regular intervals.

1.4 Index monitoring

1.4.1 Hydrochemical index. Starting from June 10, total nitrogen (TN), ammonium nitrogen (NH_4^+-N), total phosphorus (TP) and phosphate (PO_4^{3-}-P) were measured every 15 d. The sampling time was 10:00 – 10:30 AM every day. 5 to 6 sampling points were selected in the pond. The sampling water depth was 50 to 60 cm. 500 mL of water samples were collected from each point. After the water samples from each sampling point were mixed, 1 000 mL of solution was taken as a mixed sample and stored in a refrigerator at 4 ℃ and measured within 24 h.

1.4.2 Fish growth index. At the beginning and end of the experiment, the weight of main fish and intercultured fish was accurately measured, the average body weight of various fish was measured, the number and survival rate of various fish after the experiment were calculated, and the feed conversion ratio was calculated according to the feeding amount and weight gain of fed fish.

Number of fish at the end of the test (N_t) = W_t/W

Survival rate (SR, %) = N_t/N_0

Feed conversion ratio (FCR) = $W_{feed}/(W_t + W_{dead} - W_0)$

where N_0 is the stocking quantity; N_t is the harvested quantity; W_0 is the fish weight when stocked per unit area (g); W_t is the harvested fish weight per unit area (g); W is the average fish body weight at harvest (g); W_{feed} is the weight of feed per unit area (g); W_{dead} is the weight of dead feeding fish per unit area (g).

1.5 Data Analysis The data were statistically analyzed by Excel software, and the data were expressed as ($X \pm \sigma$), and the significance test was carried out by one-way ANOVA. Differences between groups were analyzed using multiple comparisons.

2 Results and analysis

2.1 Changes of N in aquaculture water Fig. 1 reflects the change of TN. During the experimental period, the TN variation ranges of the experimental group and control group were 1.87 – 3.19 mg/L and 2.39 – 6.02 mg/L, respectively. The TN of the experimental group increased gradually from the initial value of 2.24 mg/L to the peak of 3.19 mg/L on July 10, then declined slowly to the lowest value of 1.87 mg/L by the end of the experiment on September 8. The TN of the control group rose steadily from the initial minimum of 2.39 mg/L, peaked at 6.02 mg/L on August 24, and then decreased to 4.65 mg/L by the end of the experiment. Except for June 10, the TN of the experimental group was consistently significantly lower than that of the control group ($P < 0.05$), with an average reduction of 50.69%. At the end of the experiment, the TN of the experimental group was 1.87 mg/L.

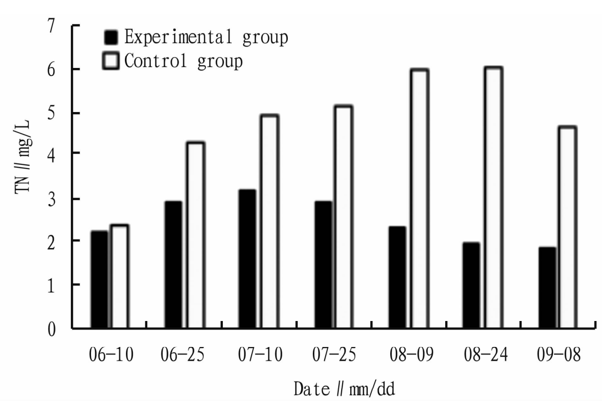

Fig. 1 Changes of TN content in the experimental group and the control group

Fig. 2 illustrates the NH_4^+-N dynamics: the experimental group fluctuated stably between 0.81 and 0.91 mg/L from June 10 to July 10, followed by a gradual decline to the lowest value of 0.33 mg/L by September 8. The control group exhibited fluctuating trends (rise, fall, rise, and fall) after the experiment began, starting at the minimum of 0.87 mg/L and peaking at 3.01 mg/L on August 24. Except for the initial date (June 10), the NH_4^+-N of the experimental group was significantly lower than that of the control group ($P < 0.05$), with an average reduction of 69.12%. By the end of the experiment, the NH_4^+-N of the experimental group was 0.33 mg/L, representing an 84.51% reduction compared to the control group.

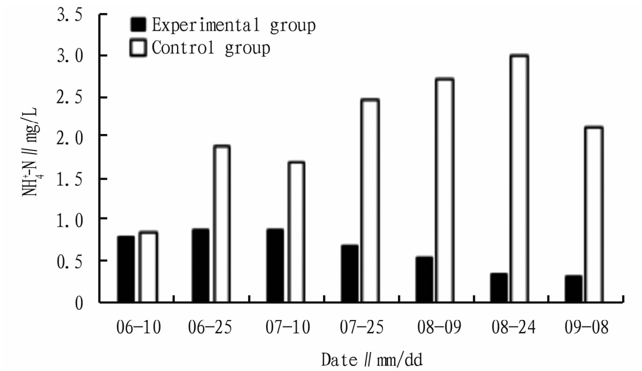

Fig. 2 Changes of NH_4^+-N content in the experimental group and the control group

2.2 Changes of P in aquaculture water Based on the TP variation in Fig. 3 and PO_4^{3-}-P changes in Fig. 4, the experimental group showed similar trends for both TP and PO_4^{3-}-P: a gradual rise followed by a slow decline after the experiment began. The peak values of TP (0.22 mg/L) and PO_4^{3-}-P (0.13 mg/L) both occurred on July 10. The lowest TP value in the experimental group (0.09 mg/L) was observed on June 10 at the start of the experiment, while the lowest PO_4^{3-}-P value (0.05 mg/L) occurred on September 8 at the end of the experiment. The TP of the control group exhibited minor fluctuations during its upward trend, with two peaks observed. The highest TP value (0.64 mg/L) was recorded on August 24, and the lowest (0.11 mg/L) on June 10 at the experiment's start. The PO_4^{3-}-P of the control group continuously increased from the experiment's start, reaching a maximum of 0.28 mg/L on August 24, then declining to 0.14 mg/L by the end. Except for June 10, the TP and of the experimental group were significantly lower than the control group ($P<0.05$), with average reductions of 62.62% and 54.20%, respectively. At the end of the experiment, the TP and PO_4^{3-}-P of the experimental group decreased by 77.19% and 64.29% respectively compared with the control group, and the TP was only 0.13 mg/L.

2.3 Growth and feed utilization of cultured fish At the end of the experiment, the harvest size, yield per unit area, and survival rate of the experimental and control groups are shown in Table 1. According to Table 1, there were no significant differences in the survival rates of silver carp and bighead carp, as well as the harvest size and yield per unit area of bighead carp between the experimental and control groups ($P>0.05$). The experimental group showed significantly higher harvest size, survival rate, and yield per unit area for crucian carp compared to the control group by 5.25%, 7.58%, and 13.28%, respectively ($P<0.05$). The harvest size and yield per unit area of silver carp in the experimental group were significantly lower than those of the control group by 17.18% and 18.15%, respectively ($P<0.05$).

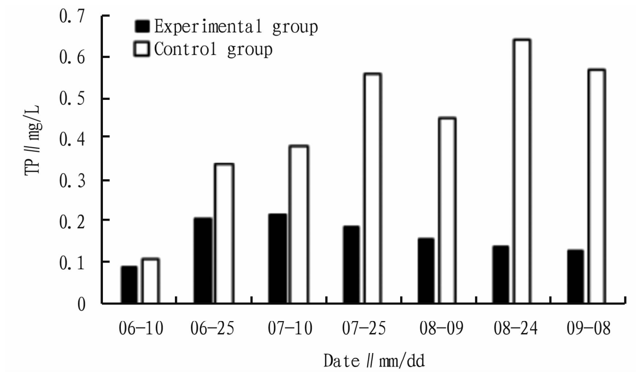

Fig. 3 Changes of TP in the experimental group and the control group

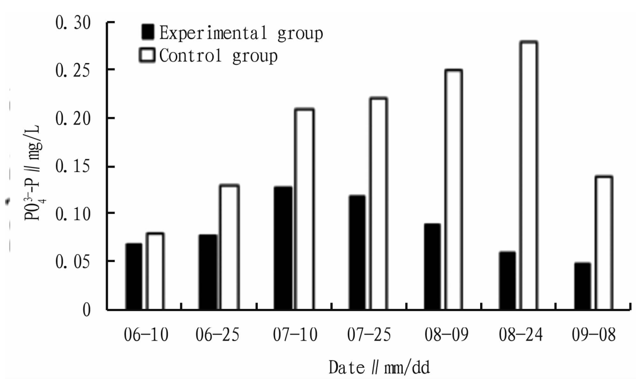

Fig. 4 Changes of PO_4^{3-}-P in the experimental group and the control group

Table 1 Fish growth and feed utilization

Group		Experimental group	Control group
Harvest size // g	Crucian carp	$413.62^a \pm 7.06$	$392.97^b \pm 5.43$
	Silver carp	$2211.84^b \pm 94.58$	$2\,429.02^a \pm 44.58$
	Bighead carp	$2\,454.24^a \pm 180.14$	$2\,411.88^a \pm 96.22$
Yield per unit area // kg/667 m^2	Crucian carp	$834.32^a \pm 11.06$	$736.49^b \pm 8.34$
	Silver carp	$87.59^b \pm 7.12$	$95.87^a \pm 10.15$
	Bighead carp	$49.26^a \pm 4.38$	$48.27^a \pm 2.20$
Survival rate // %	Crucian carp	$91.64^a \pm 1.08$	$85.18^b \pm 1.58$
	Silver carp	$99.00^a \pm 0.82$	$98.67^a \pm 0.47$
	Bighead carp	$99.33^a \pm 0.94$	$99.67^a \pm 0.47$
Weight gain of crucian carp // kg/667 m^2		$691.98^a \pm 11.06$	$569.34^b \pm 8.34$
Mortality rate of crucian carp // kg/667 m^2		$5.12^b \pm 0.62$	$24.81^a \pm 1.53$
Feed input // kg/667 m^2		980.00	915.00
FCR		$1.41^b \pm 0.02$	$1.48^a \pm 0.02$

NOTE Different superscript letters within the same row indicate significant differences ($P<0.05$), while identical letters denote no significant differences ($P>0.05$).

The weight gain per unit area, mortality weight, and feed input for crucian carp in both groups at the end of the experiment are listed in Table 1. The experimental group exhibited a 21.54% increase in weight gain per unit area and a 4.73% reduction in feed conversion ratio compared to the control group ($P<0.05$).

3 Discussion and conclusion

3.1 Effects of integrated agro-aquaculture on different nitrogen forms in aquaculture water Eutrophication of aquaculture water is one of the main issues affecting water quality, with nitrogen primarily originating from residual feed, feces, and metabolic waste[5]. Aquaculture water eutrophication leads to excessive levels of ammonium nitrogen (NH_4^+-N) and nitrite nitrogen (NO_2^--N)[6], which can inhibit fish growth or even cause mortality in severe cases. Fig. 1-3 show that at the experiment's start, low feed input and underdeveloped rice roots resulted in no significant differences in TN and NH_4^+-N between experimental and control groups on June 10 ($P>0.05$). As the experiment progressed, rising water temperatures combined with water circulation in the experimental group dispersed residual feed and feces evenly. Enhanced nitrogen absorption by rice roots reduced TN and NH_4^+-N to 1.87 mg/L and 0.81 mg/L, respectively, by the experiment's end. In the control group, TN and NH_4^+-N continuously increased, peaking on August 24, then gradually declined as water temperatures dropped. By the experiment's conclusion, TN levels were 1.87 mg/L (experimental group) and 4.65 mg/L (control group). The TN of the experimental group met China's primary discharge standard for aquaculture tailwater[7], demonstrating the significant nitrogen reduction effect of integrated agro-aquaculture. The research on integrated agro-aquaculture mostly focuses on aquatic plants and water vegetables in ponds. Yang Jun *et al.*[8] used water spinach, *calamus* and *Lythrum salicaria* to purify aquaculture water quality in pond captivity experiments, and the TN of water samples in captivity buckets was 1.23 - 1.87 mg/L, which was always lower than the first-class discharge standard of pond aquaculture tail water in China. He Yong *et al.* demonstrated TN and NH_4^+-N removal rates of 70.15 - 82.7% and 29.6 - 35.8% in shrimp-vegetable integrated systems, highlighting effective water purification[9]. From the perspective of water purification effect, various aquatic plants had different nitrogen removal effects on aquaculture water quality, which was related to the nitrogen content in aquaculture water, aquatic plant species and planting area. In this study, 20% rice cultivation area reduced TN by 50.69% compared to the control group, showing exceptional nitrogen removal efficiency.

3.2 Effects of integrated agro-aquaculture on different phosphorus forms in aquaculture water Phosphorus is another key factor in aquaculture water eutrophication. In intensive high-density ponds, it primarily originates from residual feed, feces, and organic debris[10]. Although phosphorus has no direct toxicity to fish, it is the primary driver of eutrophication, with total phosphorus (TP) being the limiting factor[11]. In the experimental group, TP and PO_4^{3-}-P slightly increased from June 10 to July 10, then gradually declined until the experiment's end. In contrast, the TP and PO_4^{3-}-P of the control group initially rose and only began to decline near the conclusion. The experimental group's phosphorus reduction was driven by enhanced nutrient absorption by rice roots, resulting in a final TP level of 0.13 mg/L, below China's primary discharge standard[7]. The control group relied solely on phytoplankton to absorb phosphorus, which could not offset external inputs from feed. TP rose until late August and then declined with reduced feeding and temperature, ending at 0.57 mg/L (exceeding discharge standards)[7]. Sun Zhiping[12] studied the effect of rice planting in ponds on nutrient regulation in aquaculture water. The results showed that the average TP concentration in rice-growing ponds was 0.20 mg/L, which was significantly reduced by 61.5% compared with the average TP concentration in ponds without rice-growing ponds of 0.52 mg/L. The study results of Chen Jiazhang *et al.*[13] showed that the TP removal rate was 33.33% - 45.10% when 20% water spinach was planted in floating bed, and the study results of Li Wenxiang *et al.*[14] showed that the TP removal rate was 21.68% when 20% *Aponogeton lakhonensis* was planted in floating bed. These results indicate that phosphorus removal efficiency varies significantly with plant species and cultivation density. In this study, the floating bed area of rice was 20%, and the TP removal rate of aquaculture water was 62.62%.

3.3 Effects of integrated agro-aquaculture on fish growth and feed utilization The growth of farmed fish is influenced by multiple factors. Controllable variables include feed nutrition, feeding methods, quantity, frequency, and water environment management. In this experimental group, the integrated application of circulating water in pond, water quality purification in rice ecological floating bed, and bottom microporous aeration were used, and all indexes such as TN, NH_4^+-N, TP, PO_4^{3-}-P were obviously reduced, which created a good ecological environment for fish growth, and played a significant role in improving fish survival rate and promoting fish growth. The experimental group showed 7.58%, 5.25%, and 13.28% higher survival rate, harvest size, and yield per unit area for crucian carp compared to the control group. Bighead carp in the experimental group exhibited marginally higher survival, size, and yield than the control group, but without statistical significance. Silver carp in the experimental group had similar survival rates but 17.18% and 18.15% lower harvest size and yield than the control group. In the experimental group, due to the competitive relationship between floating bed rice and phytoplankton in the utilization of nutrients, rice absorbed a lot of nutrients in aquaculture water through its developed root system, which reduced the nutrients in aquaculture water and affected the growth of phytoplankton. At the same time, the shading effect of floating bed rice on the aquaculture water surface is also an important reason to inhibit the growth of phytoplankton[15]. Rice can inhibit the growth and reproduction of phytoplankton while purifying water quality, so the natural bait of silver carp was relatively insufficient, resulting in the slow growth of silver carp, and the harvest size and yield of silver carp were far lower than those of the control group. Overall, the experimental group achieved 10.28% higher total yield than the control group.

In terms of feed utilization, due to the relatively low hydrochemical factor of fish growth limiting in the experimental group, the feed utilization rate of crucian carp was relatively improved. The yield of crucian carp in the experimental group increased by 21.54% and the feed conversion ratio decreased by 4.73%.

According to the comprehensive test results, integrated agro-aquaculture can not only effectively control the eutrophication of aquaculture water bodies, increase the yield per unit area and reduce the feed consumption rate, but also expand the rice planting area and increase the grain yield, showing significant economic and ecological benefits.

References

[1] ZHANG Q, HOU J, YANG J, *et al.* Effects of pond captivity density on growth performance and health status of largemouth bass[J]. Acta Hydrobiologica, 2022, 46(5): 671-678. (in Chinese).

[2] XIA NL. A "zero water exchange" engineered recirculating aquaculture model in ponds[J]. Hebei Fisheries, 2020(4): 16-17, 62. (in Chinese).

[3] HE XG, HOU J. Research progress on pond captivity models[J]. Journal of Huazhong Agricultural University, 2021, 40(3): 21-29. (in Chinese).

[4] HE XG. "Zero discharge" green and high-efficiency captivity technology in ponds[J]. Scientific Fish Farming, 2019(9): 16-17. (in Chinese).

[5] FENG JF, LI FB, WU DX, *et al.* Remediation effects and application prospects of rice cultivation systems on eutrophication in freshwater aquaculture ponds[J]. Acta Ecologica Sinica, 2014, 36(16): 4480-4487. (in Chinese).

[6] ZHANG GZ, ZHAO WW, LI H, *et al.* A brief discussion on bio-floating bed technology[J]. Aquaculture, 2022, 43(2): 72-73, 76. (in Chinese).

[7] SC/T 9101-2007. Discharge requirements for freshwater pond aquaculture water[S]. 2007.

[8] YANG J, AI J, DU QS, *et al.* Experiment on culturing Hemibarbus maculatus in "zero water exchange" captivity ponds[J]. Aquaculture, 2020, 41(3): 19-24, 30. (in Chinese).

[9] HE Y, DENG SM, HONG B, *et al.* Application of shrimp-vegetable integrated system in pond captivity models[J]. Scientific Fish Farming, 2023(8): 43-44. (in Chinese).

[10] LIU Y H, LIU TG, YANG BK, *et al.* Construction of water-saving ecological aquaculture models in northern ponds[J]. Agriculture and Technology, 2023, 43(13): 117-121. (in Chinese).

[11] SONG C, CHEN JZ, GE XP, *et al.* Control of nitrogen and phosphorus in tilapia aquaculture ponds by floating bed cultivation of water spinach [J]. Chinese Agricultural Science Bulletin, 2011, 27(23): 70-75. (in Chinese).

[12] SUN ZP. Regulatory effects of rice planting in ponds on nutrients and oxygen in aquaculture water[D]. Zhejiang University, 2018. (in Chinese).

[13] CHEN JZ, MENG SL, HU GD, *et al.* Effects of water spinach floating bed cultivation on water quality in intensive fish ponds[J]. Journal of Ecology and Rural Environment, 2010, 26(2): 155-159. (in Chinese).

[14] LI WX, LI W, LIN ML, *et al.* Nutrient removal efficiency of water spinach floating beds in aquaculture water[J]. Acta Scientiae Circumstantiae, 2011, 31(8): 1670-1675. (in Chinese).

[15] WANG L, WANG GX, TANG XY, *et al.* Inhibitory effects of different types of aquatic plant communities on cyanobacteria and green algae[J]. Chinese Journal of Ecology, 2009, 28(12): 2567-2573. (in Chinese).

(From page 47)

(ii) Rational planning of liabilities. For publicly listed companies within the feed industry, it is imperative to strategically manage their liabilities and enhance their debt paying ability. Enterprises should assess their specific circumstances to effectively regulate the scale of their liabilities and adjust their debt structures, to optimize their overall debt paying ability.

(iii) Improving company governance. Companies can enhance asset management by improving the management of accounts receivable and implementing regular collection practices. Furthermore, it is essential to strengthen internal management to bolster the operational ability of the company. This can be achieved through the optimization of the governance structure and the enhancement of employee training, aimed at improving the overall operational ability of the company.

References

[1] MENG LH. Research on countermeasures of digital economy enabling high-quality development of feed industry under Chinese-style modernization[J]. Feed Research, 2024, 47(1): 188-192. (in Chinese).

[2] LIU HZ. The transformation and upgrading path of the feed industry under the background of digital economy[J]. China Feed, 2024(8): 149-152. (in Chinese).

[3] SONG YC, YAN P, WANG RR. (2024). Research on the coupling and coordination relationship between digital economy and high quality development of feed industry[J]. China Feed, 2024(10): 168-171. (in Chinese).

[4] SHI ZZ. Research on the transformation and upgrading of feed industry driven by the synergy of scientific and technological innovation and innovation and entrepreneurship[J]. China Feed, 2024(18): 113-116. (in Chinese).

[5] HAO YH. Research on financial performance evaluation of listed feed companies based on AHP-DEA model[J]. Feed Research, 2022, 45(4): 123-127. (in Chinese).

[6] XIA JZ. Financial performance evaluation of China's feed listed companies based on entropy multi-layer TOPSIS[J]. Feed Research, 2021, 44(12): 113-117. (in Chinese).

[7] YANG L. Application of factor analysis method in financial performance evaluation of feed listed companies[J]. China Feed, 2020(10): 135-138. (in Chinese).

[8] LUO J, SHI XY, LIU JW. Growth analysis of listed Baijiu companies based on principal component analysis[J]. Liquor-Making Science & Technology, 2024(4): 133-137. (in Chinese).

[9] LU D, WANG GH. Research on financial risk early warning of agricultural listed companies: Based on factor analysis and cluster analysis[J]. Friends of Accounting, 2019(24): 79-83. (in Chinese).

[10] YE CY, GUAN X, YANG L, *et al.* Research on comprehensive performance evaluation of pharmaceutical manufacturing listed companies: Based on factor analysis and cluster analysis[J]. Communication of Finance and Accounting, 2021(12): 127-130, 163. (in Chinese).