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Study of technological aspects of *Procambarus clarkii* cultivation in terms of ensuring their welfare

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Abstract. A crucial element in improving aquaculture performance, including the crayfish farming sector, is enhancing and developing cultivation technologies for new species, whose potential can rapidly supply the market with commercial products. This study aimed to analyse the impact of dietary modifications on the growth performance of *Procambarus clarkii* when fed a vitamin-amino acid complex, “Chicktonic”, at rates of 1.0 mL/kg (Group 2) and 2.0 mL/kg (Group 3). The study employed theoretical (analysis, systematisation, comparison), experimental (laboratory), and standard aquaculture research methods. Results indicated that crayfish fed diets supplemented with “Chicktonic” exhibited higher growth rates throughout the experimental period. For instance, Groups 2 and 3 demonstrated a 3.9 and 4.3-fold increase in weight, reaching 13.70 ± 1.10 g and 16.24 ± 1.30 g, respectively. In the control Group 1, which received feed without the vitamin supplement, the lowest weight gain was recorded, increasing by a factor of 3.7, reaching 13.93 ± 1.89 g by the end of the study period. No significant differences in body length were observed among all groups; however, in experimental Group 3 (2.0 mL/kg), this indicator was 8.34 ± 0.22 cm, compared to 7.83 ± 0.42 cm in Group 1 and 7.83 ± 0.18 cm in Group 2. It was found that the introduction of the vitamin-amino acid supplement into the crayfish diet accelerated the sexual maturation of females

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in experimental Groups 2 and 3, where the first specimens with eggs were recorded. The effect of vitamin intake was also noted in the visual assessment of the colour of the crayfish's external chitinous covering. Group 3 (2.0 mL/kg) exhibited a bright red hue, whereas the control group had a pale red, sometimes pale orange, carapace colour. The results obtained may be used to optimise the artificial cultivation of *Procambarus clarkii* and suggest the use of vitamin supplements to improve their welfare and well-being

Keywords: aquaculture; cultivation; weight; length; survival; red swamp crayfish; feeding

Introduction

Given the global challenges and the current state of the crayfish farming industry, there is a pressing need to identify crustacean species with high economic potential that can fill the market gap with high-quality products. To fully explore the possibilities of cultivating new species, efforts should be directed towards optimising or improving methods for their industrial farming. Among the species with high cultivation potential, the red swamp crayfish, *Procambarus clarkii* (Girard, 1852), also known as the Louisiana crawfish or red swamp crayfish, is particularly interesting. According to the criteria of Article 4(3) of Regulation (EU) No. 1143/2014 of the European Parliament (2019), *Procambarus clarkii* is a species widely distributed in Europe and cannot be eradicated by economically feasible means. According to the DAISIE invasive species checklist (Roy *et al.*, 2020), this species is registered as having significant invasive potential at the biogeographic level. In a study of this species outside its native range, A. Ballinger (2022) describes the invasive situation of this species on all continents, highlighting the problem of rapid introduction and spread of this species in natural water bodies throughout Europe and other countries. According to A. Nota *et al.* (2024), such a high level of introduction is attributed to the species' high adaptive capacity to various artificial and natural environments, a result of its evolutionary development. This leads to significant imbalances in local ecosystems, driven by consumer pressure on the trophic structure

and the dominance of *Procambarus clarkii*. The authors' assumptions were confirmed by a study conducted near the Mediterranean Sea, where individuals of the species were found in close proximity to the coastline at depths of about 1.5 m, with the nearest freshwater sources located 0.5-1.7 km away (note: the salinity of the Mediterranean Sea varies from 36.0 to 39.5‰). The influence of salinity as a limiting factor for the survival and distribution of the species was previously studied by A.J.M. Dörr *et al.* (2020), who found that this parameter has a temporary adverse effect, especially on females, causing a moderate disruption to the redox process, thus not limiting the adaptive abilities of the species.

Overall, the biological characteristics of *Pr. clarkii* provide this species with a significant competitive advantage in terms of cultivation technology and economics. For this reason, when inventorying alien species used for aquaculture and related activities, D. Savini *et al.* (2010) included it in the list of the 27 most popular alien species introduced in Europe. An analysis of crayfish products on the Ukrainian fish market has shown the presence of frozen red swamp crayfish imported from Spain for over 8 years. Statistical data on import volumes and demand for this product are either absent or inaccessible, but the duration of supply indicates an existing economic benefit. Products grown by Ukrainian producers could provide a worthy competitor to imports and replace frozen products with fresh ones. Moreover, the controlled cultivation of *Procambarus clarkii*, particularly

in industrial settings, would reduce pressure on wild crayfish populations in Ukraine, allowing time for their recovery and stabilisation (given a combination of optimal factors), while at the same time guaranteeing a stable supply of crayfish products to the fish market.

However, an analysis of available information sources reveals a significant lack of new data or recommendations concerning the cultivation technology for *Procambarus clarkii*. The vast majority of methods for producing commercial products are based on so-called ecological aquaculture, involving cultivation in earthen ponds. Some farms employ elements of intensive technology, building on the results of individual studies. For instance, in their study, M. Zhao *et al.* (2024) investigated the impact of different types of shelters for crayfish, establishing that under their experimental conditions, PVC pipes demonstrated the highest protective efficacy; researchers reached this conclusion based on improved growth indicators of the crayfish. The growth and development of the red swamp crayfish were studied by J. Wang *et al.* (2023) based on the assessment of an ecological growth and development index; based on a set of biological characteristics, the researchers established a trend towards an improvement in the index with the appearance of a greater amount of nutrients in the crayfish diet. In turn, the crayfish diet was investigated by A. Kaliszewicz *et al.* (2022), studied the possibility of using fatty acids to improve the survival and growth of *Procambarus clarkii*, establishing improved survival rates when palmitic acid was introduced into the diet. X. Chen *et al.* (2024) conducted a large-scale study investigating the influence of different feeding and maintenance conditions on the correlation between carapace colour and astaxanthin content. Thus, groups of crayfish whose diet contained a higher content of β -carotene and were kept at a higher water temperature (30.0°C) had a higher level of astaxanthin, which formed a saturated bright red colouration of the crayfish carapace.

Considering the above information, the search for methods to improve the growth and survival rates of crayfish in the context of developing an artificial cultivation technology for *Procambarus clarkii* is of great relevance. In this regard, the use of vitamin-amino acid supplements is of particular interest, with positive experiences in their application reported for other promising aquaculture species, as described in the research of B. Kovalenko *et al.* (2021), I. Kononenko *et al.* (2023), and I. Kononenko & B. Kovalenko (2023). This issue also becomes relevant in the context that the use of various technological techniques in feed production at different levels can lead to the destruction or alteration of the activity of certain unstable components. Measures aimed at increasing the digestibility of carbohydrates or reducing the negative effects of non-starch polysaccharides can, in some cases, cause the destruction of 35-40%, and sometimes even 50-70% of vitamins and other nutrients.

This study aimed to analyse the impact of feeding *Procambarus clarkii* on the effectiveness of changing their biological and fishery parameters when the vitamin-amino acid complex “Chicktonic” was introduced into the feed.

Materials and Methods

To assess the impact of the vitamin-amino acid complex “Chicktonic” on the growth and welfare of *Procambarus clarkii*, individuals aged 2.5-3.0 months were used. The study involved three groups of subjects: Group 1 – control, which received feed without vitamin supplementation, and two experimental groups: Group 2 received feed with the preparation at a rate of 1.0 mL/kg, and Group 3 – 2.0 mL/kg of feed. The initial number of individuals in each group was 10. Groups were formed by random selection. In total, 30 red swamp crayfish were used in the experiment. The crayfish were kept in 100-litre aquariums.

Water conditioning was carried out using an external JBL CristalProfi e902 greenline

filter, creating a closed water circulation system designed for a volume of 90-300 litres. Water heating was provided by an Atman AT-100W heater. Water temperature and dissolved oxygen content were measured daily using a portable AZ-86021 oximeter.

Compound feeds for trout fish were used for feeding individuals of all groups: Alltech Coppens Advance 1.0 mm (protein content 54.0%, vitamins: vitamin A – 12,000 IU/kg, vitamin D3 – 738 IU/kg) and Alltech Coppens Supreme – 22 3.0 mm (protein content 43.8%, vitamins: vitamin A – 9,138 IU/kg, vitamin D3 – 1,198 IU/kg). The feeds were supplemented with a combined vitamin-amino acid complex, “Chicktonic”, which contained (per 1 mL): vitamin A – 2,500 IU, vitamin D3 – 500 IU, alpha-tocopherol – 3.75 mg, vitamin B1 – 3.5 mg, vitamin B2 – 4.0 mg, vitamin B6 – 2.0 mg, vitamin B12 – 0.01 mg, sodium pantothenate – 15.0 mg; vitamin K3 – 0.250 mg, choline chloride – 0.4 mg, biotin – 0.002 mg, inositol – 0.0025 mg, D, L-methionine – 5 mg, L-lysine – 2.5 mg, histidine – 0.9 mg, arginine – 0.49 mg, aspartic acid – 1.45 mg, threonine – 0.5 mg, serine – 0.68 mg, glutamic acid – 1.16 mg, proline – 0.51 mg, glycine – 0.575 mg, alanine – 0.975 mg, cystine – 0.15 mg, valine – 1.1 mg, leucine – 1.5 mg, isoleucine – 0.125 mg, tyrosine – 0.34 mg, phenylalanine – 0.81 mg, tryptophan – 0.075 mg, and a filler.

The required vitamin dosage was measured using a single-channel LLG micropipette with a measurement volume of 100-1,000 µL. The compound feed was treated with the vitamin-amino acid preparation “Chicktonic” using a spray-drying method. This involved spraying and subsequent drying of a vitamin emulsion, which was prepared using distilled water at room temperature at a rate of 100 mL of water per 1.0 kg of feed. The compound feed was spread out in a single layer on a tray. During the spraying process, the feed was continuously mixed to ensure maximum uniformity of the mixture distribution across the feed surface.

To minimise the loss of activity, the compound feed was treated in small batches: 0.1-0.5 kg, adjusted according to the growth of the individuals and changes in their diet. Treated feed was used within 4-5 weeks to prevent significant vitamin losses during prolonged storage. The treated feed was stored in individual zip-lock bags placed in containers, which were kept in a cupboard away from direct sunlight. The daily feeding rate for *Procambarus clarkii* was determined based on their total biomass and varied from 2.0 to 5.0% of their total biomass at different stages of individual development. The experimental groups were fed twice daily: the determined feed ration was divided into two portions in a 30:70 ratio – the first portion was introduced in the morning, and the second in the evening. The feed was placed in two feeding stations located on opposite sides of the aquarium.

Intermediate measurements of crayfish length and mass, as two primary fish-biological parameters, were conducted every 10 days. The daily feed ration was adjusted based on the data obtained. The study duration was 2 months. Measurements of mass and body length were performed following general fish-biological recommendations using a vernier calliper, measuring tape, and a TVE-0.21 laboratory balance with a minimum increment of 0.02 g. The conditions for keeping, feeding, and caring for the crayfish complied with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (1986) and adhered to the bioethical standards of good animal welfare as outlined in the Regulation “On the Protection of Animals Used for Scientific or Educational Purposes at the National University of Life and Environmental Sciences of Ukraine” (2023).

Results and Discussion

Daily monitoring of the water’s hydrochemical parameters during the cultivation of *Procambarus clarkii* over the study period showed

that, with the experimental temperature set at 25.0°C in all aquariums, the actual temperature readings fluctuated from 25.9°C at the beginning of the study (October) to 24.8°C at the end (December), but remained within the optimal range for the species. The dissolved oxygen content varied within the optimal range for this species: from

6.1 mgO₂/L to 7.1 mgO₂/L; pH – 7.9-8.3. Thus, from the standpoint of hydrochemical parameters, the aquatic environment was within the optimal range.

The results of measurements of biological and fishery parameters, specifically the weight and length of *Procambarus clarkii*, during the study period, are presented in Table 1.

Table 1. Biological and fishery parameters of *Procambarus clarkii* over the study period

Date	Mean mass, g (M±m)			Mean length, cm (M±m)		
	Group 1 (control) max/min*	Group 2 (1.0 mL/kg) max/min*	Group 3 (2.0 mL/kg) max/min*	Group 1 (control) max/min*	Group 2 (1.0 mL/kg) max/min*	Group 3 (2.0 mL/kg) max/min*
	μ**	μ**	μ**	μ**	μ**	μ**
06.10.23	2.60/4.90	2.00/4.70	2.90/4.30	4.50/6.50	4.50/6.00	5.00/5.50
	3.74±0.24	3.50±0.28	3.78±0.15	5.40±0.19	5.25±0.16	5.30±0.09
16.10.23	3.70/6.00	3.10/6.00	4.3/6.1	6.00/6.50	5.00/6.20	5.50/7.00
	4.55±0.28	4.80±0.29	4.79±0.18	5.56±0.16	5.57±0.13	6.30±0.15
25.10.23	4.50/8.80	3.80/10.70	6.2/9.3	5.50/7.00	3.20/7.70	6.2/7.5
	6.17±0.59	6.79±0.75	7.44±0.43	6.46±0.20	6.21±0.52	6.84±0.17
08.11.23	6.40/13.60	8.10/13.60	8.2/12.8	6.00/7.50	6.50/8.00	6.30/7.50
	9.21±1.00	9.73±0.90	10.53±0.71	6.79±0.23	7.22±0.23	7.21±0.20
15.11.23	8.10/14.20	8.20/14.90	8.8/14.1	6.50/8.10	6.50/8.50	6.80/7.80
	11.37±1.12	10.52±1.06	11.97±0.76	7.25±0.31	7.25±0.31	7.43±0.16
22.11.23	9.60/15.70	10.50/15.50	10.00/16.20	6.50/8.00	7.00/8.20	7.50/8.50
	12.82±1.22	11.73±0.84	13.71±0.82	7.25±0.27	7.33±0.21	7.96±0.15
06.12.23	9.50/21.50	16.10/17.00	12.7/21.60	7.00/9.50	7.50/8.500	7.70/9.00
	13.93±1.89	13.70±1.10	16.24±1.30	7.83±0.42	7.83±0.18	8.34±0.22

Note: * – minimum and maximum values of the measured parameter; ** – mean value of the measured parameter

Source: authors' development

It was established that through random selection, three experimental groups of *Procambarus clarkii* were formed with relatively homogeneous initial mass and body length. At the beginning of the study, the mean body mass of the control Group 1 was 3.74 ± 0.24 g with a minimum and maximum value in this group of 2.60 and 4.90, respectively. Individuals in the experimental Group 2 were characterised by a mean body mass of 3.50 ± 0.28 g with a minimum mass of 2.00 g and a maximum of 4.70 g. In the experimental Group 3, the studied mean body mass was 3.78 ± 0.15 g

with a minimum and maximum value of 2.90 and 4.30 g, respectively.

The most intense increase in body mass in all three groups was observed during the first month of cultivation – it was during this period that each group experienced a “mass jump” (Fig. 1). At the same time, the mass gain in the control group increased by an average of 1.35 times at each measurement stage. Thus, during the first month of cultivation, the average mass of individuals in the control group was 9.21 ± 1.00 g, increasing the mass gain by an average of 5.47 g. The average mass of crayfish

in experimental Group 2 (1.0 mL/kg) increased by 1.39 times, and the average gain of 1 individual was 6.23 g. The mass of individuals in experimental Group 3, which received the vitamin

at a dose of 2.0 mL/kg, increased by 1.45 times during the first month of cultivation, reaching 10.53 ± 0.71 g, which is 6.75 g more compared to the initial mass.

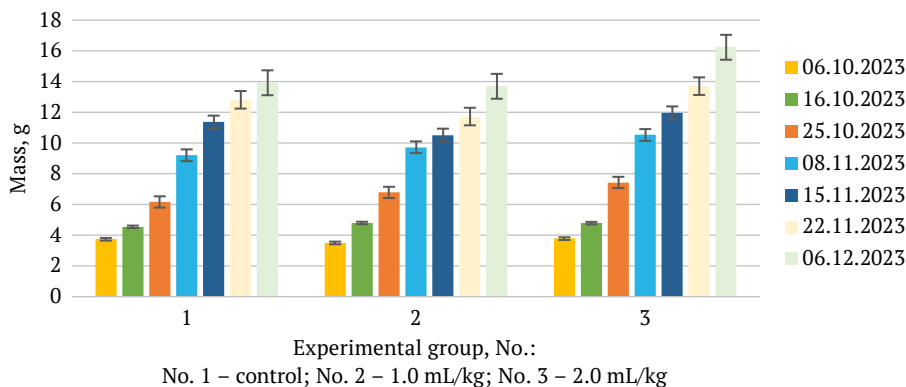


Figure 1. Weight gain of crayfish over the study period

Source: authors' development

Further analysis of mass during the second month of cultivation did not reveal any significant differences in the growth rate among the three experimental groups. On average, the mass gain of individuals in the control Group 1 increased by 1.15 times (by 4.72 g), compared to the first month of cultivation. For individuals in experimental Groups 2 (1.0 mL/kg) and 3 (2.0 mL/kg), this figure increased by 1.14 and 1.16 times, respectively (by 3.97 and 5.71 g). Overall, during the second month of cultivation, there was a trend towards a similar growth rate for individuals in all groups. However, it is essential to emphasise that the use of the vitamin supplement in Groups 2 and 3 during the first month of feeding effectively “kick-started” their growth, providing a solid foundation for weight gain that was maintained throughout the remainder of the study period.

Overall, the final mass of crayfish in the control Group 1 increased 5.36 times compared to the initial mass, reaching 13.93 ± 1.89 g, with an average mass gain of 10.20 g. In experimental Group 2, the initial mass of individuals increased 6.85 times, reaching an average of

13.70 ± 1.10 g with a gain of 10.20 g. The highest average mass was obtained in experimental Group 3 – 16.24 ± 1.30 g, where the initial mass increased by 12.46 g, which is 5.60 times greater compared to the initial mass.

Regarding the linear growth of crayfish in all groups, analysis of the obtained data did not show a significant difference in the growth rate intensity, not only in the first month of cultivation but also throughout the entire study period. Linear growth occurred with a relatively constant intensity throughout the entire study period (Fig. 2). On average, the body length of crayfish in the control Group 1 increased by 2.43 cm compared to the initial length (5.40 ± 0.19 cm), reaching 7.83 ± 0.42 cm. In crayfish of experimental Group 2 (1.0 mL/kg), no significant differences in linear growth rates were found compared to the control group. Thus, on average, the body length of individuals in Group 2 increased by 2.58 cm, reaching 7.83 ± 0.18 cm at the end of the study period. The highest results of linear growth were established in individuals of experimental Group 3 (2.0 mL/kg),

which reached 8.34 ± 0.22 cm after two months of the study, increasing body length

by 3.04 cm compared to the initial length (5.30 ± 0.09 cm).

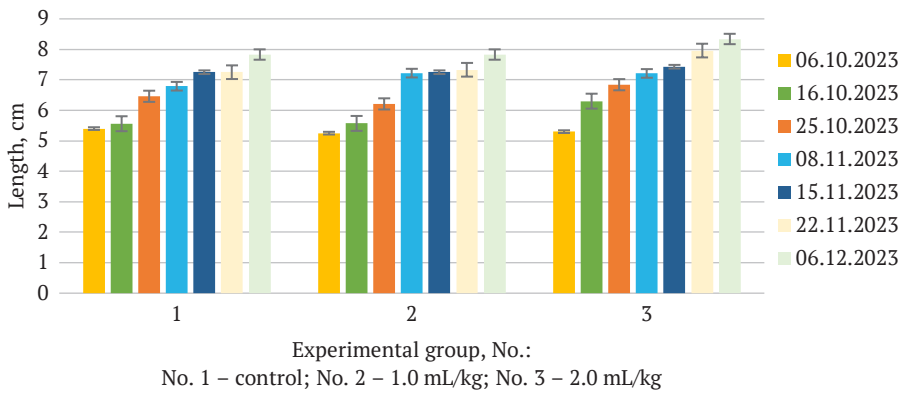


Figure 2. Linear growth of crayfish over the study period

Source: author's development

This study does not assess the welfare and well-being of *Procamburus clarkii* in terms of survival, as all recorded deaths in each experimental group were caused by cannibalism and are indicative of a behavioural rather than a physical issue. This aspect will be examined in

a subsequent study investigating the use of different shelter designs and configurations. The following table (Table 2) provides an overview of the changes in the number of *Procamburus clarkii* individuals in the experimental groups throughout the study period.

Table 2. Changes in the number of individuals in experimental groups over the study period

Age, months	Number of specimens, n		
	Group 1 (control)	Group 2 (1.0 mL/kg)	Group 3 (2.0 mL/kg)
2.5-3.0	10	10	10
3.0-3.5	10	10	9
3.5-4.0	7	8	7
4.0-4.5	7	6	7
4.5-5.0	6	6	7
5.0-5.5	6	6	7
5.5-6.0	6	6	7
% survival	60	60	70

Source: authors' development

The first recorded mortality occurred in experimental Group 3 on the ninth day of the study, coinciding with the first instance of moulting in this group, which triggered a behavioural response – cannibalism. Overall, survival rates for the control Group 1 and experimental Group 2 were 60%. In experimental Group 3,

survival was 70%, which is 10% higher than the control and experimental Group 2. While not significant, this result could also be linked to the use of feed with a higher vitamin and amino acid complex content (2.0 mL/kg of feed).

The enrichment of feed with the vitamin-amino acid complex “Chicktonic” during

feeding also had an effect on the colour of the chitinous exoskeleton of *Procambarus clarkii* in the experimental groups. Visual assessment of colour intensity showed that experimental Group 3, which consumed feed supplemented with 2.0 mL/kg of the vitamin, had a bright red colouration of the carapace (Fig. 3), while crayfish in the control Group 1, which received feed without the vitamin, had a pale red, and in some cases even pale orange, the colouration of the carapace (Fig. 4). The colour difference was clearly noticeable and did not require the use of any additional measurement methods.



Figure 3. Individuals from Group 3

Source: authors' material



Figure 4. Individuals from the control group

Source: authors' material

Analysis of the use of “Chicktonic” in the feeding of the red swamp crayfish showed that the first females with eggs were recorded in experimental Groups 2 and 3, i.e., those that consumed compound feed supplemented with

the vitamin-amino acid complex “Chicktonic” at doses of 1.0 and 2.0 mL/kg, respectively. This indicates one advantage of introducing this preparation into the diet. By the end of the second month of the study, when the females were 5.0-5.5 months old, fully developed ovaries capable of participating in the reproductive process had formed.

When assessing the behavioural responses of *Procambarus clarkii* during measurements of aquaculture biological indicators and aquarium maintenance (such as water changes and cleaning shelters), it is believed that the studied subjects were temporarily in conditions of sub-optimal welfare. This was indicated by their experiencing minimal negative impacts from all manipulations, as their basic needs for optimal management were met (including the absence of physical stress, prompt execution of tasks, careful handling, and the provision of comfortable conditions). Active behaviour in the subjects was observed for a while after their return to the rearing environment; however, the crayfish quickly returned to their usual state and responded positively to feeding.

Analysis of the results from the first month of rearing *Pr. clarkii* showed that the ratio of vitamins and amino acids in the diet of the study subjects in all three groups had little impact on their biological and fishery parameters during the early stages of rearing. This finding is corroborated by research conducted by J. Wang *et al.* (2023), where the research group assessed the morphological and biological characteristics of *Procambarus clarkii* by comparing the results of feeding with diets containing protein and fat levels ranging from 6.0-25.0% in the experimental groups to 8.0-32.0% in the control groups. For the first 20 days, the studied parameters were at a reference level in all groups, and a significant difference was recorded between 40 and 80 days of the experiment. In the current experiment, a positive effect of introducing vitamins into the crayfish feed was first recorded

20 days after the start of the experiment, when, after relatively stable indicators in all groups, a significant increase in average body weight of 1.9 g was observed in Group 3 (2.0 mL/kg) compared to the previous measurement. In contrast, Group 1 (control) showed an increase of 0.8 g and Group 2 (1.0 mL/kg) an increase of 0.7 g. However, starting from the 30th day of rearing, a stable increase in weight gain was recorded, with this trend continuing until the end of the experiment, also in experimental Group 2. Thus, the groups that received the additional vitamin-amino acid complex had more distinct results compared to the control group. A similar effect of the “Chicktonic” preparation was established by B. Kovalenko *et al.* (2021) when studying the effect of this preparation on the fish farming parameters of the African sharptooth catfish. In that study, the weight gain of fish that received an additional vitamin-amino acid preparation was activated on days 20-30 of rearing in older individuals, and after day 30 of rearing in juveniles (Muzzarelli, 2013; Lyko, 2017).

It can be assumed that the high growth rates of the crayfish after the first month of rearing, especially in the experimental groups that consumed compound feed supplemented with vitamins, are associated with the well-known fact of the optimal impact of vitamin consumption in the early stages of development when complex morpho-physiological transformations occur in the organism, as detailed by M. Yevtushenko (2015). The created feeding conditions ensured the optimal course of metabolic processes, in particular, plastic and energy metabolism, due to the sufficient amount of nutrients, including vitamins, and the optimal redistribution of feed energy. A similar result was described in the study of B. Kovalenko *et al.* (2021) when feeding young African sharptooth catfish with “Chicktonic” revealed faster absorption and conversion of nutrients into linear weight gain. Additionally, likely, the decrease in weight gain intensity in the experimental groups during the second

month of the study was caused by reaching sexual maturity in *Procambarus clarkii*, which is associated with rapid growth and development of gametes and a preferential allocation of energy from plastic or energy metabolism towards reproductive metabolism (Amine *et al.*, 2008; Yevtushenko, 2015). However, a decrease in the mass of individuals in the experimental groups with the onset of sexual maturity and the development of reproductive products was not recorded, suggesting that the additional intake of nutrients allows the body to compensate for energy expenditures on different levels of metabolism and maintain high results (Niu *et al.*, 2014; Wade *et al.*, 2017).

Furthermore, the results obtained in this study coincide with the data on the use of the vitamin-amino acid preparation “Chicktonic” in the feeding of African sharptooth catfish and tilapia, as described in the scientific studies of B. Kovalenko *et al.* (2021), I. Kononenko *et al.* (2023) and I. Kononenko & B. Kovalenko (2023). For example, the results of the research by I. Kononenko *et al.* (2023) also show the effectiveness of introducing the vitamin-amino acid complex “Chicktonic” into the diet of tilapia, the effectiveness of which was especially evident when creating unfavourable environmental conditions. In addition to the overall increase in fish body weight, this contributed to maintaining high survival rates in groups that consumed feed with the vitamin at a level of 90.0% compared to 60.0% in the control group.

In the study by I. Kononenko & B. Kovalenko (2023), when feeding African sharptooth catfish with feed containing the “Chicktonic” preparation at doses of 1.0 and 2.0 mg/kg (Groups 2 and 3, respectively), no significant difference in biological and fishery parameters was found between the experimental and control groups. However, a positive effect of the preparation on survival was established in the experimental groups, which increased by an average of 2.0-4.0%. Additionally, similar results improving survival rates to 67% ± 13

were obtained in the study by Kaliszewicz *et al.* (2022). However, when dietary supplements with fatty acids, particularly palmitic acid, were introduced into the diet of young *Procambarus clarkii*. The results obtained in the current study indicate a positive effect of vitamins in the diet of the red swamp crayfish on its survival, which was at the level of 70.0% in Group 3, which is 10.0% higher than in the control and experimental Group 2.

Analysis of the crayfish's exoskeleton colouration showed that the groups consistently fed with vitamin-supplemented feed had a bright, saturated carapace colour compared to the pink, sometimes even pale pink, colouration of the individuals in the control group. The obtained results may indicate a higher level of carotenoids, especially astaxanthin, the gene which was identified by X. Chen *et al.* (2024), which has a direct impact on the formation of the intensity and saturation of the *Procambarus clarkii* carapace colour. The saturated colour of *Procambarus clarkii* can be a great tool to influence the consumer, making the product competitive in the fish market (Wickins & O'C Lee, 2002; Luo *et al.*, 2019).

The earlier sexual maturation observed in females from the experimental groups, compared to the control, could also be a result of the additional consumption of vitamins and the intake of beneficial substances. According to M. Yevtushenko (2015), the attainment of sexual maturity in fish is also linked to the accumulation of certain biologically active substances in the organism: vitamins, enzymes, amino acids, and fatty acids. Thus, the feeding conditions created for the experimental groups of *Procambarus clarkii*, whose diet contained an additional vitamin-amino acid complex, enhanced their organism's ability to convert additional nutrients from feed and optimally distribute the obtained resource to ensure the biological needs of growth and development, as well as physiological and behavioural activity in this system, which provides well-being

under artificial cultivation conditions. Thus, based on the conducted research, the undeniable advantage of introducing the vitamin-amino acid preparation "Chicktonic" into the diet of *Procambarus clarkii* has been established.

Conclusions

The results of this study have demonstrated the positive impact of incorporating the vitamin-amino acid complex "Chicktonic" into the diet of *Procambarus clarkii*, influencing every aspect of the research. When comparing the results of crayfish rearing, it is evident that experimental Groups 2 and 3, which consumed feed supplemented with this preparation at different doses, showed a clear advantage in terms of linear weight gain, sexual maturation, and exoskeleton colouration. Notably, crayfish in experimental Group 3 outperformed not only the control group but also experimental Group 1, which consumed feed with half the vitamin dose compared to Group 3 – 1.0 mL/kg. Analysis of linear growth indicators did not reveal any significant difference in body length among all three groups. All recorded cases of crayfish mortality in each group were exclusively linked to cannibalism and had no relation to feeding conditions, vitamin dose, or adverse welfare. Assessment of exoskeleton colouration revealed a significant difference in carapace colour between crayfish that consumed feed with the vitamin and crayfish from the control group.

Based on the conducted research, it can be concluded that the welfare of the crayfish in the experimental groups during their artificial cultivation was evident, as the results indicate that optimal conditions for the functioning of all biological systems were established. This contributed to the good growth and appearance of the crayfish, reflecting their welfare and well-being.

The results obtained have significant potential for further research in terms of studying the specific manifestations of the effects of higher concentrations of the vitamin-

amino acid complex under various conditions of artificial cultivation, as well as optimising and intensifying the cultivation technology of *Procambarus clarkii* while adhering to the principles of animal welfare. None.

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Conflict of Interest

None.

References

- [1] Amine, T.M., Aiad, A.S., & Abu El-Nile, M.O. (2008). Evaluation of chemical quality and nutrition value of fresh water cray fish (*Procambarus clarkii*). In *Proceedings 2nd International conference high institute of public health "AlexHealth 2008"*. Alexandria: High Institute of Public Health (pp. 1-13). doi: [10.21608/jhiph.2008.22496](https://doi.org/10.21608/jhiph.2008.22496).
- [2] Ballinger, A. (2022). *Procambarus clarkii* (red swamp crayfish). Wallingford: CABI. doi: [10.1079/cabicompendium.67878](https://doi.org/10.1079/cabicompendium.67878).
- [3] Chen, X., Chen, J., Huang, L., Wu, B., Wu, C., He, J. & Bai, Z. (2024). *PcASTA* in *Procambarus clarkii*, a novel astaxanthin gene affecting shell color. *Frontier in Marine Science*, 10, article number 1343126. doi: [10.3389/fmars.2023.1343126](https://doi.org/10.3389/fmars.2023.1343126).
- [4] Dörr, A.J.M., Scalici, M., Caldaroni, B., Magara, G., Scoparo, M., Goretti, E., & Elia, A.C. (2020). Salinity tolerance of the invasive red swamp crayfish *Procambarus clarkii* (Girard, 1852). *Hydrobiologia*, 847, 2065-2081. doi: [10.1007/s10750-020-04231-z](https://doi.org/10.1007/s10750-020-04231-z).
- [5] European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes. (1986). Retrieved from <https://rm.coe.int/168007a67b>.
- [6] Kaliszewicz, A., Karaban, K., Sierakowski, M., Maciaszek, R., Kur, M., Pyffel, Z., Wolny, L., Chmiel, K., Luciuk, P., Rusin, P. & Kowalczyk, K. (2022). Effect of dietary supplementation with fatty acids on growth, survival, and fatty acid patterns in *Procambarus clarkii* and *Procambarus virginialis*: The first comparison of two invasive crayfish species. *The European Zoological Journal*, 89(1), 130-141. doi: [10.1080/24750263.2022.2030420](https://doi.org/10.1080/24750263.2022.2030420).
- [7] Kononenko, I.S., & Kovalenko, B.Y. (2023). [Efficiency of the use of vitamin-amino acid preparation 'Chiktonik' under optimal growing conditions](#). In *Collection of materials based on the results of the scientific and practical conference 'Topical issues of the present and post-war restoration of agriculture and ecology: Expert and analytical components of the formation of the food strategy of Ukraine' on the occasion of the 20th anniversary of the ULABP of the NULES of Ukraine* (pp. 79-80). Kyiv: National University of Life and Environmental Sciences of Ukraine.
- [8] Kononenko, I.S., Pashkevych, O.O., & Kononenko, R.V. (2023). [Search for ways to improve the results of tilapia cultivation in artificial systems](#). In *Proceedings of the V International scientific and practical conference 'Modern problems of rational use of water biological resources*. Kyiv: Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine.
- [9] Kovalenko, B., Kovalenko, V., Sharylo, D., Polishchuk, N., Korzh, O., & Kirakosian, A. (2021). Growth and survival of Clarias catfish (*Clarias gariepinus* B., 1822) at different stages of cultivation with the addition to the fodder of "Chiktonik". *Animal Science and Food Technology*, 12(4), 26-37. doi: [10.31548/animal2021.04.003](https://doi.org/10.31548/animal2021.04.003).
- [10] Luo, L., Huang, J., Liu, D., Tan, L., Jiang, S., Zhou, F., Jiang, S., Yang, Q., & Yang, L. (2019). [Study on selection and spatial distribution of two kinds of caverns for *Procambarus clarkii*](#). *South China Fisheries Science*, 15, 76-81.
- [11] Lyko, F. (2017). The marbled crayfish (*Decapoda: Cambaridae*) represents an independent new species. *Zootaxa*, 4363, 544-552. doi: [10.11646/zootaxa.4363.4.6](https://doi.org/10.11646/zootaxa.4363.4.6).

- [12] Muzzarelli, R.A. (2013). *Chitin*. Oxford: Elsevier.
- [13] Niu, J., *et al.* (2014). Comparison effect of dietary astaxanthin and b-carotene in the presence and absence of cholesterol supplementation on growth performance, antioxidant capacity and gene expression of *Penaeus monodon* under normoxia and hypoxia condition. *Aquaculture*, 422, 8-17. doi: [10.1016/j.aquaculture.2013.11.013](https://doi.org/10.1016/j.aquaculture.2013.11.013).
- [14] Nota, A., Santovito, A., Gattelli, R., & Tiralongo, F. (2024). From fresh to salt waters: First reports of the red swamp crayfish *Procambarus clarkii* (Girard, 1852) in Mediterranean Marine Waters. *Hydrobiology*, 3, 1-10. doi: [10.3390/hydrobiology3010001](https://doi.org/10.3390/hydrobiology3010001).
- [5] Regulation (EU) No. 1143/2014 of the European Parliament and of the Council of 22 October 2014 on The Prevention and Management of The Introduction and Spread of Invasive Alien Species. (2014). Retrieved from <http://data.europa.eu/eli/reg/2014/1143/oj>.
- [16] Regulation “On the Protection of Animals Used for Scientific or Educational Purposes at the National University of Life and Environmental Sciences of Ukraine”. (2023). Retrieved from https://nubip.edu.ua/sites/default/files/u169/polozhennya_pro_zahist_tvarin_2.pdf.
- [17] Roy, D., *et al.* (2020). *DAISIE – Inventory of alien invasive species in Europe*. Brussels: Research Institute for Nature and Forest (INBO). doi: [10.15468/ybwd3x](https://doi.org/10.15468/ybwd3x).
- [18] Savini, D., Occhipinti-Ambrogi, A., Marchini, A., Tricarico, E., Gherardi, F., Olenin, S., & Gollasch S. (2010). The top 27 alien animal species intentionally introduced by European aquaculture and related activities: Stocking, sport fishery and ornamental purposes. *Journal of Applied Ichthyology*, 26(s2), 1-7. doi: [10.1111/j.1439-0426.2010.01503.x](https://doi.org/10.1111/j.1439-0426.2010.01503.x).
- [19] Wade, N.M., Gabaudan, J., & Glencross, B.D. (2017). A review of carotenoid utilisation and function in crustacean aquaculture. *Reviews in Aquaculture*, 9(2), 14-156. doi: [10.1111/raq.12109](https://doi.org/10.1111/raq.12109).
- [20] Wang, J., Wang, Z., Wang, Q., & Zhou, Zh. (2023). Ecological index analysis of growth and development of *Procambarus Clarkii* based on biological characteristics. *Journal of Sea Research*, 192, article number 102363. doi: [10.1016/j.seares.2023.102363](https://doi.org/10.1016/j.seares.2023.102363).
- [21] Wickins, J.F, & O’C Lee, D. (2002). *Crustacean farming: Ranching and culture*. London: Blackwell Science.
- [22] Yevtushenko, M.Y. (2015). *Ecological physiology and biochemistry of aquatic organisms*. Kyiv: Publishing centre of the National Academy of Sciences of Ukraine.
- [23] Zhao, M., Feng, G., Wang, H., Shen, C., Fu, Y., Zhang, Y., Zhang, H., Yao, Y., Chen, J., & Xu, W. (2024). The influence of shelter type and coverage on crayfish (*Procambarus clarkii*) Predation by Catfish (*Silurus asotus*): A controlled environment study. *Animals*, 14, article number 1147. doi: [10.3390/ani14081147](https://doi.org/10.3390/ani14081147).

Вивчення технологічних аспектів вирощування раків *Procambarus clarkii* у розрізі забезпечення їх благополуччя

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Анотація. Важливим елементом підвищення показників аквакультури, в тому числі сектору раківництва, є удосконалення та розробка технологій вирощування нових видів, потенційні можливості яких у короткі терміни здатні забезпечити ринок товарною продукцією. Мета роботи полягала в аналізі впливу особливостей годівлі *Procambarus clarkii* на їх рибницько-біологічні показники при введенні у корми вітамінно-амінокислотного комплексу «Чиктонік» у кількості 1,0 мл/кг корму (група № 2) та 2,0 мл/кг (група № 3). В ході експерименту використано теоретичні (аналіз, систематизація, порівняння), експериментальні (лабораторні) та загальноприйняті у рибництві методи досліджень. Встановлено, що групи раків, що споживали корми з препаратом «Чиктонік», характеризувалися вищими показниками лінійно-вагового приросту протягом всього досліджуваного періоду. Так, у групах № 2 та № 3 маса збільшилася у 3,9 та 4,3 рази, досягнувши $13,70 \pm 1,10$ г та $16,24 \pm 1,30$ г відповідно. У контрольній групі № 1, яка отримувала корм без добавки вітаміну, зафіксоване найнижчі показники збільшення маси – у 3,7 рази, що в кінці досліджуваного періоду становило $13,93 \pm 1,89$ г. Значних відмінностей у довжині тіла серед всіх груп досліду не зафіксовано, однак у дослідній групі № 3 (2,0 мл/кг) даний показник становив $8,34 \pm 0,22$ см, порівняно з $7,83 \pm 0,42$ см у групі № 1 та $7,83 \pm 0,18$ см у групі № 2. Виявлено, що введення вітамінно-амінокислотного препарату у раціон раків стимулювало швидше статеве дозрівання самиць у дослідних групах № 2 та № 3, де першими зафіксовані екземпляри із ікрою. Вплив споживання вітаміну виявлено також при візуальній оцінці кольору зовнішнього хітинового покриву раків – група № 3 (2,0 мл/кг) характеризувалася забарвленням яскраво-червоного кольору, водночас контрольна група мала блідо-червоний, подекуди блідо-оранжевий колір панциря. Отримані результати можуть бути використані для оптимізації штучного вирощування *Procambarus clarkii* та запровадити використання вітамінних комплексів для підвищення показників їх благополуччя та добробуту

Ключові слова: аквакультура; культивування; маса; довжина; виживаність; червоний каліфорнійський рак; годівля