

Characteristics of the growth rate, fatty acid profile, and shell content of the freshwater snail *Viviparus contectus* (Millet, 1813)

by

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Abstract

Freshwater snails are a nutritious food source, providing vital amino acids, minerals, and protein with low lipid levels. Hence, the adaptation ability, growth rate, fatty acid (FA) profile, and shell content of *Viviparus contectus* were determined. Biometric measurements were recorded for 6 months. Over the 6-month cultivation period, specific growth rates were recorded as $0.32\% \cdot \text{day}^{-1}$ for shell length and $0.92\% \cdot \text{day}^{-1}$ for body weight. The FA profile of the freshwater snail included a total of 32 compounds with saturated, monounsaturated, and polyunsaturated FAs represented by 13, 10, and 9 types, respectively. Monounsaturated fatty acids (MUFAs) exhibited the highest concentration, followed by saturated fatty acids (SFAs) at 35.14% and polyunsaturated fatty acids (PUFAs) at 14.57%. Stearic acid (C18:0), erucic acid (C22:1 n-9), and arachidonic acid (C20:4 n-6) were determined as the most abundant FAs within the saturated, monounsaturated, and polyunsaturated FAs classes, respectively. The energy-dispersive X-ray spectroscopy spectra analysis revealed that the shell powder composition consisted of the elements, such as carbon, oxygen, calcium, iron, manganese, and silicon. Overall, *V. contectus* showed a clear increase in growth over the cultivation period, and future studies are needed to obtain the best culture conditions and intensive production of the species.

Key words: freshwater snail, *Viviparus contectus*, growth, culture, fatty acid, shell

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1. Introduction

V. contectus is a freshwater gastropod of the Viviparidae family, commonly recognized by the vernacular name river snail. It features a semi-transparent shell with dark green coloration and brown spiral bands. *V. contectus* is a common gastropod species distributed in numerous regions. According to Lu et al. (2014), species within the Viviparidae family inhabit regions throughout Asia, the Americas, Europe, Africa, and Australia. However, they also noted the existence of numerous Viviparidae species and significant gaps in taxonomic records. These snails inhabit depths ranging from 0 m to 20 m and respire through gills. Reproduction typically occurs in the coastal area during the spring season, with male individuals being smaller than females. The shell of the snail may reach dimensions of up to 40 mm in height and 30 mm in width (Kutluyer Kocabaş & Kocabaş, 2023).

The species inhabits marshes, pools, rivers, and lakes, feeding primarily on detritus while contributing to water filtration (Chiu et al., 2002). The elevated content of vital amino acids, taurine, and minerals, such as calcium, iron, and zinc, makes it a popular dietary supplement in China (Cao & Yao, 2005). It is processed into various foods, either canned or freshly cooked, for use as a sauce. Additionally, treatment of alcohol-induced toxicity and liver dysfunctions in traditional practices of China and Korea has relied on *V. contectus*. Recent studies have demonstrated various pharmacological effects of extracts from the same Viviparidae family, such as *Cipangopaludina chinensis*, including anticancer activity, heart-protective effects against injuries, and *in vivo* hepatoprotective effects (Cui & Zhao, 1989; Jiang et al., 2013).

The influence of global food systems is causing traditional foodstuffs to be substituted with convenient, mass-produced products (Cunningham et al., 2021; Ghosh et al., 2002). Furthermore, the ecological degradation resulting from increasing urbanization has adversely affected the natural populations of numerous animal species and the associated traditional knowledge, including snails. Therefore, maintaining the sustainability of food resources such as snails requires careful consideration of agricultural practices. To expand protein-rich food production, various countries have turned to snail cultivation. Although snail farming has attracted increasing attention as a sustainable alternative protein source (Cunningham et al., 2021; Forte et al., 2016; Ghosh et al., 2002), information regarding

growth performance, nutritional composition, and shell characteristics of many freshwater snail species remains limited. Studies on the cultivation performance and biochemical composition of *V. contectus* under controlled culture conditions are scarce. Such information is necessary to evaluate the potential of this species as a sustainable food resource and for future aquaculture applications. Therefore, the current study aimed to evaluate the growth rate, fatty acid (FA) profile, and shell content of *V. contectus* in a controlled cultivation environment.

2. Material and methods

2.1. Animals and housing conditions

Specimens of *V. contectus* were gathered from their natural environment at Demirköprü Dam Lake (Manisa, Türkiye) using metal scoops, shovels, and rakes, and subsequently transported to the laboratory for further analysis. Snail rearing was conducted in six glass tanks of 20 L capacity (40 cm × 25 cm × 20 cm), housed in a temperature- and humidity-controlled environment. Each was stocked with 10 individuals of *V. contectus* ($n = 60$). The rearing environment was maintained at $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$, with a photoperiod of 16 hr light followed by 8 hr darkness. No mortality was observed during the 6-month culture period. Freshwater snails were nourished with a varied diet and provided three times a week, such as: *Chlorella vulgaris*, fresh lettuce leaves, and a commercial fish food. The commercial feed's nutritional breakdown was 36% protein, 14% fat, 3% fiber, 12% calcium, 2.96% phosphorus, and 1.60% sodium. The water underwent partial renewal every 3 days, with a complete renewal conducted once a week. Freshwater snails (shell lengths [SLs]: $11.22 \text{ mm} \pm 4.29 \text{ mm}$, weight: 0.42 ± 0.40) were randomly selected for cultured trials.

2.2. Growth rate

The development and growth rate of the freshwater snails were documented for six months using a calliper ($\pm 0.01 \text{ mm}$). During each monthly sampling, the following parameters were recorded: total body weight (W , g), shell width and length (SW and SL , mm), aperture length and width (AL and AW , mm), body whorl height (BWH , mm), and spiral height (SPH , mm). The growth performance, expressed as specific growth rate (specific growth rate [SGR] % ·

day⁻¹), was calculated according to Chatterji et al. (1984). The time interval ($t_2 - t_1$) corresponded to the duration between successive measurements (30 days for monthly SGR calculations and 180 days for the overall cultivation period):

$$\text{SGR}_L(\%) : [(\ln L_2 - \ln L_1) / (T_2 - T_1)] \times 100$$

$$\text{SGR}_W(\%) : [(\ln W_2 - \ln W_1) / (T_2 - T_1)] \times 100$$

SGR: Specific growth rate

L_1 : Mean shell lengths at time t_1

L_2 : Mean shell lengths at time t_2

W_1 : Mean freshwater snail weights at time t_1

W_2 : Mean freshwater snail weights at time t_2

$t_2 - t_1$: 180 days

2.3. Elemental analysis of shell

The surface morphology and elemental composition of the shell samples were investigated using a Hitachi SU3500 scanning electron microscope (Hitachi High-Tech Corporation, Tokyo, Japan) (SEM) coupled with an Oxford Instruments INCA energy-dispersive X-ray spectroscopy (EDS) system. Shells from 10 randomly selected individuals were thoroughly cleaned with distilled water, air-dried, ground into a fine powder using an agate mortar, and homogenized to obtain a representative composite shell sample, following sample preparation procedures commonly adopted for molluscan shell powder characterization. Before scanning electron microscope-energy-dispersive X-ray spectroscopy (SEM-EDS) (Oxford Instruments plc, Abingdon, Oxfordshire, UK) analysis, the homogenized shell powder was sputter-coated with a thin layer of gold to improve electrical conductivity and minimize charging effects during imaging. Elemental analyses were performed using the Oxford INCA X-ray spectrometer, while AZtec and INCA software were used for instrument control, spectral acquisition, and data processing. EDS measurements were conducted at an accelerating voltage of 20 kV, with count rates ranging between 1000 and 2000 counts $\cdot$ s⁻¹. Element identification was based on characteristic X-ray peaks, and elemental composition was determined using the standardless quantitative analysis procedure provided by the software. The reported elemental composition (wt%) represents the elemental analysis of the homogenized

composite shell powder and is expressed as relative elemental percentages.

2.4. FA profile

The FA composition of freshwater snail tissues was determined following a modified method of Hara and Radin (1978). Briefly, tissue samples (1 g) were homogenized in 10 mL of a hexane-isopropanol mixture. The homogenates were centrifuged at 8000 rpm for 10 min, and the organic phase containing total lipids was collected. FA methyl esters (FAMES) were prepared by transesterification using 2% sulfuric acid in methanol. The reaction mixture was incubated at 55°C for 15 hr. After cooling to room temperature, 5% sodium chloride solution was added and mixed using a vortex mixer. FAMES were extracted with 5 mL hexane, followed by the addition of 5 mL KHCO₃ solution (2%) to facilitate phase separation. The hexane phase was evaporated under a stream of nitrogen, and the lipid extract was re-dissolved in 1 mL heptane before being transferred into 2-mL autosampler vials (Christie, 1992). FAME analysis was performed using a Shimadzu GC-17 gas chromatograph. Samples were injected into a Macherey-Nagel capillary column (25 m $\times$ 0.25 mm i.d., 0.25 μ m film thickness). The oven temperature was initially held at 120°C for 1 min, increased to 200°C at a rate of 5°C $\cdot$ min⁻¹, then to 220°C at a rate of 4°C $\cdot$ min⁻¹, and finally maintained at 220°C. The injector and detector temperatures were set at 280°C and 240°C, respectively. FA identification was achieved by comparing retention times with those of a Supelco® 37 Component FAME Mix standard (Sigma-Aldrich, Merck KGaA, Darmstadt, Germany) analyzed under identical chromatographic conditions. Chromatographic data were processed using Class GC 10 software (version 2.01) (Shimadzu Corporation, Kyoto, Japan). FA composition was expressed as the relative percentage of total identified FAs and calculated using external standard calibration and area normalization methods.

2.5. Statistics

Statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Data are presented as mean $\pm$ standard deviation (SD). Principal component analysis (PCA) was performed separately for the morphometric and FA datasets. The morphometric PCA included shell height (SH/SPH), SL, SW, aperture length (AL), AW, BWH, and body weight (W). The FA PCA was conducted using the relative percentages of the identified FAs obtained from the muscle tissue of 30 freshwater snails ($n = 30$) to evaluate variation in FA composition and



Table 1

Monthly variation in morphometric parameters and SGR of *V. contectus* over a 6-month period.

Time (Month)	SL	SW	Aperture length (AL)	AW	BWH	Weight (W) (g)	SGR _L (%)	SGR _W (%)
0	11.22 ± 2.49	8.24 ± 2.68	8.38 ± 1.79	6.25 ± 1.70	12.62 ± 2.36	0.42 ± 0.40	-	-
1	14.37 ± 2.86	9.62 ± 2.61	8.76 ± 1.68	7.22 ± 1.71	13.90 ± 2.83	0.69 ± 0.53	0.82	1.65
2	15.25 ± 2.41	10.86 ± 2.81	9.72 ± 2.01	7.99 ± 1.72	14.75 ± 2.39	0.73 ± 0.55	0.20	0.19
3	16.39 ± 2.32	12.05 ± 1.79	10.23 ± 1.52	8.84 ± 1.28	15.88 ± 2.32	1.19 ± 0.54	0.24	1.63
4	17.21 ± 1.81	12.32 ± 2.11	10.24 ± 1.62	8.91 ± 1.53	16.72 ± 1.83	1.23 ± 0.56	0.16	0.11
5	18.09 ± 2.24	13.56 ± 1.83	11.50 ± 1.23	9.75 ± 1.34	17.39 ± 2.16	1.61 ± 0.64	0.17	0.90
6	19.84 ± 1.82	14.98 ± 1.12	12.20 ± 0.94	10.85 ± 0.68	19.34 ± 1.82	2.21 ± 0.58	0.31	1.05

AW, aperture width; BWH, body whorl height; SGR, specific growth rate; SL, shell length; SW, shell width.

identify the FAs contributing most strongly to sample differentiation. Components with eigenvalues greater than 1.0 were retained for interpretation.

3. Results

3.1. Growth rate

Monthly variation in morphometric parameters and SGR are presented in Table 1. The mean ($\pm$ SD) initial values for SL, SW, AL, AW, SPH, BWH, and W of *V. contectus* were measured as 11.22 mm $\pm$ 2.49 mm, 8.24 mm $\pm$ 2.68 mm, 8.39 mm $\pm$ 1.79 mm, 6.25 mm $\pm$ 1.70 mm, 0.60 mm $\pm$ 0.16 mm, 12.62 mm $\pm$ 2.36 mm, and 0.425 g $\pm$ 0.40 g, respectively. At the end of 6 months, the mean ($\pm$ SD) final values for SL, SW, AL, AW, SPH, BWH, and W were measured as 19.84 mm $\pm$ 1.82 mm, 14.98 mm $\pm$ 1.12 mm, 12.20 mm $\pm$ 0.94 mm, 10.85 mm $\pm$ 0.68 mm, 0.65 mm $\pm$ 0.01 mm, 19.34 mm $\pm$ 1.82 mm, and 2.21 g $\pm$ 0.58 g, respectively. After 6 months of cultivation, the specific growth rates were calculated as 0.32% $\cdot$ day⁻¹ for SL and 0.92% $\cdot$ day⁻¹ for body weight, respectively, indicating a gradual decrease in length growth efficiency and a more variable pattern of biomass accumulation over the experimental period.

As illustrated in Fig. 1, the first principal component (PC1) explained 98.13% of the total variance, while the second principal component (PC2) accounted for 1.28%, together representing 99.41% of the cumulative variance. The high proportion of variance explained by PC1 indicates that most of the morphological variation is primarily explained by a single dominant factor. The strong and consistent loadings of all morphometric variables on PC1 suggest that the observed variation primarily reflects an overall size effect rather than independent shape-related variation among traits.

3.2. Profile of FA composition

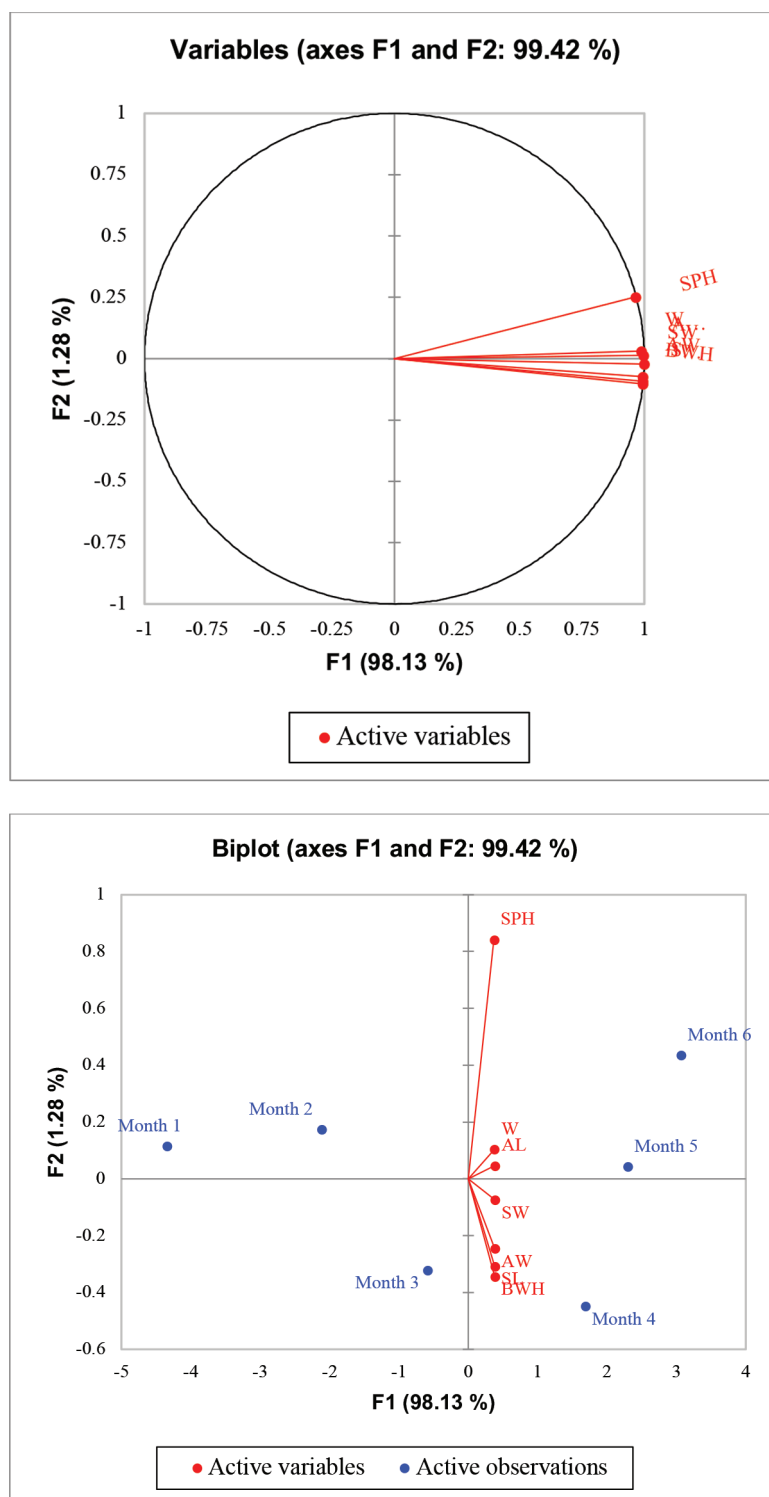
The FA profiles of tissues after 6 months of cultivation are presented in Table 2. Analysis of the tissue revealed the presence of 13 saturated FAs (SFAs), 10 monounsaturated FAs (MUFAs), and 9 polyunsaturated FAs (PUFAs). MUFAs were the most abundant at 44.12%, followed by SFAs at 35.14%, and PUFAs at 14.57%. The predominant MUFA was C22:1 n9 while the major PUFA detected in the tissue was arachidonic acid (C20:4 n-6).

PCA reveals variations in the FA composition. As shown in Fig. 2, A cumulative variance of 66.06% was explained by the PC1 (36.42%) and the PC2 (29.64%) and C6:0, C8:0, C11:0, C14:1, C17:0, C18:0, C18:3 n-3, C20:2, C22:1 n-9, C20:5 n-3, C24:0 and C24:1 have negative scores featuring 6 months. A positive relationship was identified between PC1 and the FAs C16:1 n-7, C18:3 n-6, C20:0, and C22:5 n-3.

3.3. Shell content

SEM-EDS analysis was performed on shell samples collected at the end of the 6-month cultivation period from individuals used in the growth experiment. SEM micrographs of cross-sectional views of shells at different magnifications are presented in Fig. 3. Plate and needle-like, and polygonal-shaped crystals were irregular in size.

The elemental composition of the shell is presented in Fig. 4, and quantitative results are expressed as weight percentages (wt%). The EDS spectrum revealed that oxygen (55.0 wt%), carbon (29.9 wt%), and calcium (14.7 wt%) were the dominant elements in the shell matrix, indicating a calcium carbonate-based structure. Trace elements including iron (0.2 wt%), manganese (0.1 wt%), and silicon (0.1 wt%) were also detected in minor amounts.

**Figure 1**

PCA illustrating snail morphometric parameters: SPH, SL, W (weight), SW, AL (aperture length), AW, and BWH. AW, aperture width; BWH, body whorl height; PCA, principal component analysis; SL, shell length; SPH, spiral height; SW, shell width.



Table 2

Percentage composition of FAs in *V. contectus* under laboratory culture conditions.

FAs	Muscle (%)
SFA	
C6:0 (Caproic acid)	1.43 ± 2.66
C8:0 (Caprylic acid)	1.88 ± 0.92
C10:0 (Capric acid)	1.37 ± 0.82
C11:0 (Undecylic acid)	0.45 ± 0.45
C12:0 (Laurik asit)	0.86 ± 0.65
C13:0 (Tridecylic acid)	0.19 ± 0.36
C14:0 (Miristik asit)	1.13 ± 0.63
C15:0 (Pentadekanoik asit)	0.81 ± 0.80
C16:0 (Palmitik asit)	7.39 ± 4.41
C17:0 (Margarinik asit)	7.46 ± 4.63
C18:0 (Stearik asit)	10.86 ± 5.21
C20:0 (Arachidic acid)	0.45 ± 0.51
C24:0 (Lignocerik asit)	0.86 ± 0.94
MUFA	
C14:1 (Miristoleik asit)	1.55 ± 1.11
C15:1 (pentadekenoik asit)	1.51 ± 1.78
C16:1 n-7 (Palmitoleik asit)	1.43 ± 3.00
C17:1 (Heptadekanoik asit)	3.02 ± 4.33
C18:1 n-9t (Elaidic acid)	1.02 ± 0.67
C18:1 n-9c (Oleic acid)	5.51 ± 9.23
C18:1 n-11 (Vaccenik asit)	0.44 ± 1.04
C20:1 (Eikosanoik asit)	0.04 ± 0.11
C22:1 n9 (Erucic acid)	28.68 ± 19.94
C24:1 (Nervonik asit)	0.93 ± 0.53
PUFA	
C18:2 n-6c (Linoleik asit)	0.60 ± 1.42
C18:3 n-3 (α-Linolenik asit)	0.70 ± 0.53
C18:3 n-6 (γ-Linolenik asit)	0.23 ± 0.42
C20:2 n-6 (Eicosadienoic acid)	0.86 ± 1.07
C20:3 n-3 (Eikosatrienoik asit)	0.75 ± 1.20
C20:4 n-6 (Araşidonik asit)	9.92 ± 17.96
C20:5 n-3 (Eikosapentaenoik asit)	0.79 ± 0.65
C22:5 n-3 (Dokosapentaenoik asit)	0.30 ± 0.10
C22:6 n-3 (Dokosaheksaenoik asit)	0.45 ± 0.46
ΣSFA	35.66
ΣMUFA	44.13
ΣPUFA	14.57
Σn-3	2.96
Σn-6	11.61
n-3/n-6	0.25

FA, fatty acid; MUFAs, monounsaturated FAs; PUFAs, polyunsaturated FAs; SFA, saturated FA.

4. Discussion

4.1. Growth rate

Controlled culture studies specifically evaluating the growth performance, FA composition, and shell elemental composition of *V. contectus* are currently scarce. Therefore, previous studies on other freshwater gastropod species were used as a comparative framework for interpreting the growth performance of *V. contectus* under controlled culture conditions. Although several laboratory and culture-based studies have investigated the growth, morphometric relationships, life-history traits, stocking density, and rearing conditions of freshwater gastropods, information for *V. contectus* remains limited. Black (1976) documented the complete development of *Bedeva paivae* from egg capsule deposition to sexual maturity under laboratory conditions. Mayta (1978) reported that *Pomacea maculata* increased from 0.15 g and 2.9 mm at hatching to approximately 20 g and 50 mm after 1 year of culture, with a mortality rate of only 0.3%. Guerrero and Guerrero (1980) investigated the culture of *Pila luzonica* in flooded rice fields and *Vivipara angularis* in fertilized ponds, demonstrating that growth performance was strongly influenced by stocking density and food availability. Similarly, Catalma (1986) reported density-dependent growth in cultured *P. luzonica*, while Jakubik and Lewandowski (2007) described age-dependent growth and reproductive characteristics of *Viviparus* under field and laboratory conditions. More recently, Ghosh et al. (2022) demonstrated that elevated temperature and reduced relative humidity adversely affected the growth of juvenile *Pomacea canaliculata* in aquaculture systems. Collectively, these studies demonstrate that growth in freshwater gastropods is influenced by environmental conditions, food availability, and culture practices. However, comparable information for *V. contectus* remains very limited, particularly regarding the combined evaluation of growth performance, FA composition, and shell elemental characteristics under controlled culture conditions. Over a 6-month period, the freshwater snails in this study exhibited significant growth, increasing from an initial weight of 0.425 g and length of 11.22 mm to a final weight of 2.21 g and length of 19.84 mm. After 6 months of cultivation, the overall SGR were 0.32% · day⁻¹ for SL and 0.92% · day⁻¹ for body weight. These values indicate differential growth allocation with a relatively higher biomass accumulation compared to SL increment over time. However, these SGR values and growth trends should be interpreted cautiously and are presented here as descriptive growth performance indicators rather than mechanistic estimates, as they are based on endpoint and interval-based measurements under culture conditions. Overall, the observed growth suggests successful

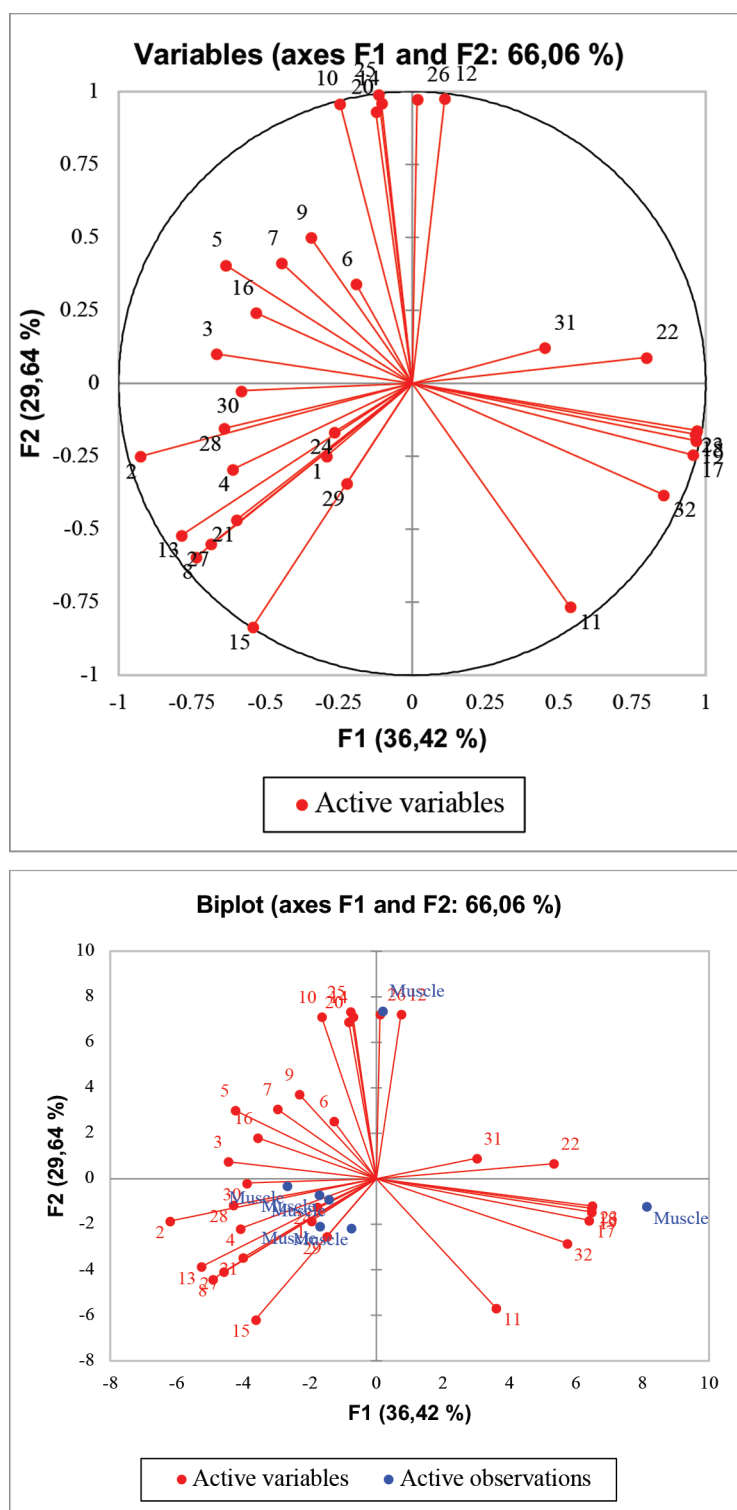
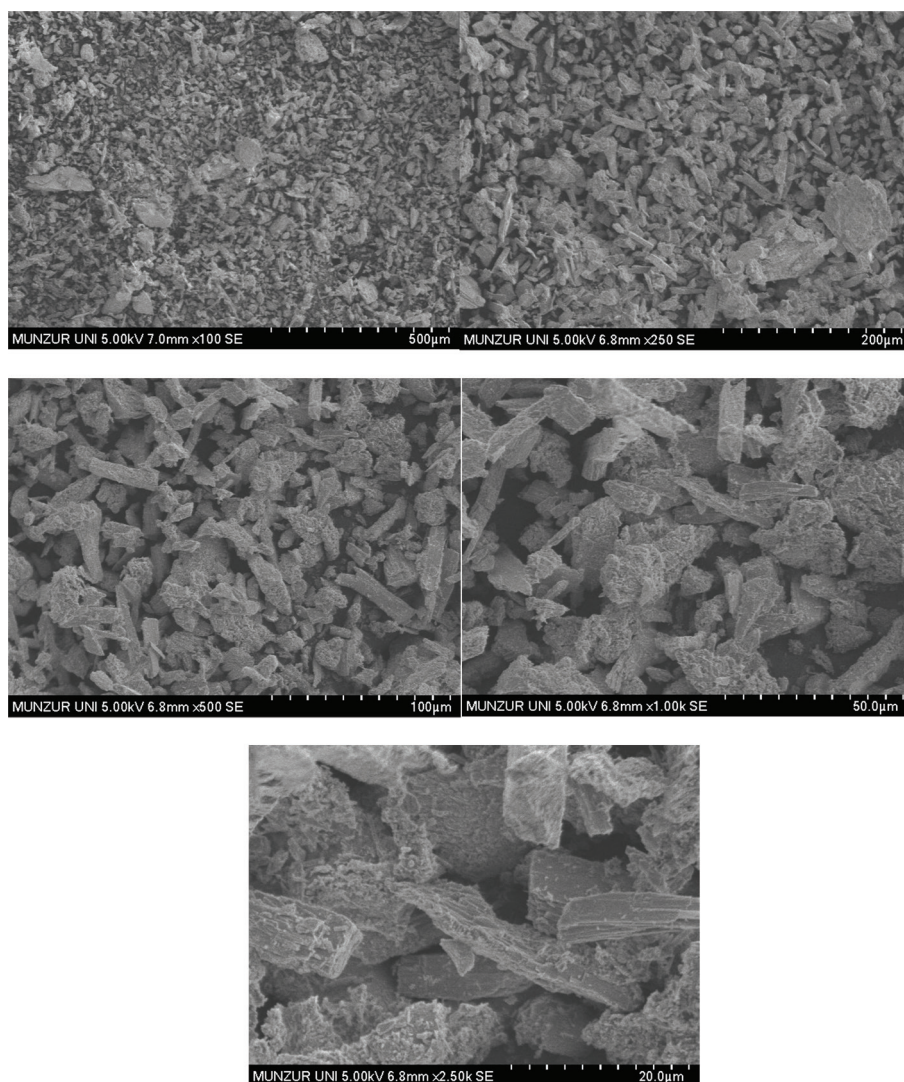
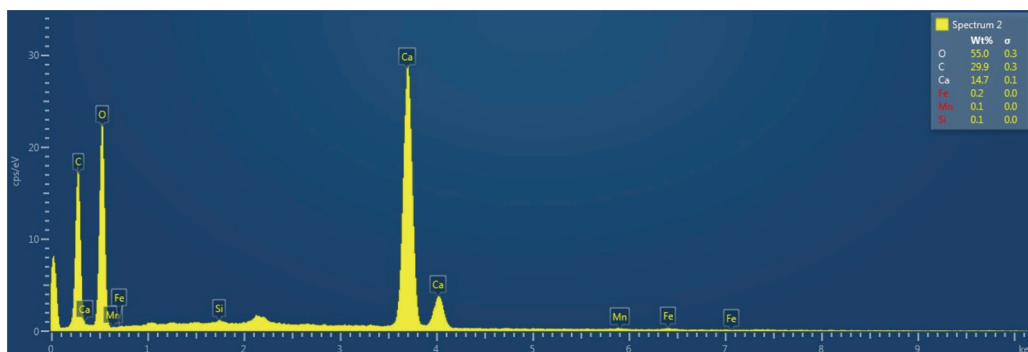
**Figure 2**

Illustration of scores (A) and loadings (B) from the PCA of FAs in freshwater snail. 1 (C6:0), 2 (C8:0), 3 (C10:0), 4 (C11:0), 5 (C12:0), 6 (C13:0), 7 (C14:0), 8 (C14:1), 9 (C15:0), 10 (C15:1), 11 (C16:0), 12 (C16:1 n-7), 13 (C17:0), 14 (C17:1), 15 (C18:0), 16 (C18:1 n-9t), 17 (C18:1 n-9c), 18 (C18:1 n-11), 19 (C18:2 n-6), 20 (C18:3 n-6), 21 (C18:3 n-3), 22 (C20:0), 23 (C20:1), 24 (C20:2 n-6), 25 (C20:3 n-3), 26 (C20:4 n-6), 27 (C22:1 n-9), 28 (C20:5 n-3), 29 (C24:0), 30 (C24:1), 31 (C22:5 n-3), 32 (C22:6 n-3). FA, fatty acid; PCA, principal component analysis.



**Figure 3**

SEM micrographs of cross-sectional view of *V. contectus* shells at different magnifications. SEM, scanning electron microscope.

**Figure 4**

The SEM-EDS of cross sectioned surface of shells *V. contectus*. SEM-EDS, Scanning electron microscope-energy-dispersive X-ray spectroscopy.

adaptation and sustained development under controlled conditions, although direct comparison with other studies should be made carefully due to methodological and species-specific differences.

4.2. Profile of FA composition

According to Felagha et al. (2020), the FA composition of wild *V. contectus* included five SFAs (myristic, palmitic, heptadecanoic, stearic, and arachidic acids) and two PUFAs (α -linolenic acid and linoleic acid). A total of 22 FAs were identified, comprising 8 saturated SFAs, 6 MUFAs, and 8 PUFAs in *V. contectus* from wild (Demirköprü Dam Lake, Manisa) by Özçiçek et al. (2023). In this study, a total of 32 FAs were identified, comprising 13 SFAs, 10 MUFAs, and 9 PUFAs in *V. contectus*. This may be related to differences in diet, environmental conditions, population-specific variation, or methodological differences among studies.

After 6 months of cultivation, *V. contectus* contained elevated levels of C16:0, C17:0, C18:0, C18:1 n-9, and C20:4 n-6. These findings agree with previous reports on *V. contectus* and various freshwater snail taxa (Ekin, 2008; Ekin et al., 2009, 2010, 2011, 2012; Felagha et al., 2020; Özçiçek et al., 2023). Comparisons with these previous studies should be considered descriptive, as differences among studies may be associated with multiple factors, including diet, season, habitat characteristics, population-specific variation, analytical methodology, sample processing.

MUFAs help regulate lipid metabolism, and they are considered important components of the nutritional profile of aquatic organisms. In the present study, MUFAs were the predominant FA group (44.12%), followed by SFAs (35.14%) and PUFAs (14.57%). Interestingly, erucic acid (C22:1 n-9) (28.68%) was identified as the most abundant FA under rearing conditions. In contrast, erucic acid was not detected in wild *V. contectus* in our previous study Özçiçek et al. (2023) or in Felagha et al. (2020). This difference may be associated with variation in dietary sources, environmental conditions, population-specific characteristics, or other methodological differences among studies. However, because the FA composition of the commercial feed and supplementary dietary items, including *C. vulgaris* and lettuce, was not determined in the present study, the origin of erucic acid cannot be established. Future studies should include FA analyses of all dietary components to clarify the potential source of this FA under culture conditions.

Arachidonic acid (ARA, C20:4 n-6) was the predominant PUFA identified in cultured *V. contectus*.

ARA is a biologically important long-chain n-6 PUFA that serves as a structural component of membrane phospholipids and as a precursor of eicosanoids involved in numerous physiological processes (Beder, 2015; Lian et al., 2022). The relatively high proportion of ARA observed in the present study is consistent with previous reports describing ARA as one of the major PUFAs in freshwater gastropods (Felagha et al., 2020; Özçiçek et al., 2023). These findings indicate that ARA constitutes an important component of the FA profile of *V. contectus*, although further studies are needed to evaluate the nutritional significance and bioavailability of this species.

4.3. Shell content

Species-specific differences contribute to variations in the mechanical properties, organic matter, and mineral composition of molluscan shells (Parveen et al., 2020). Previous studies have shown that the shells of bivalves and gastropods are predominantly composed of carbon, oxygen, and calcium, although trace elements such as Na, Si, Al, Fe, and Mn may also be detected depending on species, habitat, and shell characteristics (Jacob et al., 2008; Lakshmana et al., 2018). Kutluyer Kocabaş and Kocabaş (2023) reported that wild *V. contectus* shells contained O (50.2%), Ca (33.2%), C (12.8%), Si (2.4%), and Al (1.5%). In the present study, SEM-EDS characterization of cultured *V. contectus* shells at the end of the 6-month rearing period revealed O (55.0 wt%), C (29.9 wt%), Ca (14.7 wt%), Fe (0.2 wt%), Mn (0.1 wt%), and Si (0.1 wt%). The predominance of oxygen, carbon, and calcium is consistent with the carbonate-based composition of molluscan shells reported in previous studies. Differences observed between the present study and previously published data should be interpreted descriptively, as they may be associated with species- and population-specific variation, habitat characteristics, sample preparation, analytical methodology, or other study-specific factors.

5. Conclusion

In conclusion, the weight of freshwater snails increased more than fivefold from 0.425 g to 2.21 g while SL increased from 11.22 mm to 19.84 mm during the 6-month cultivation period. MUFAs represented the predominant FA group, followed by SFAs and PUFAs. EDS analysis indicated that the shells contained mineral components that may support their potential utilization in value-added applications rather than disposal as



waste. These findings demonstrate that *V. contectus* can successfully grow under the applied culture conditions while providing information on its FA profile and shell mineral composition. Future studies should investigate the effects of different stocking densities, substrate types, feed composition, and water quality on growth performance and biochemical composition under controlled culture conditions.

This study has some limitations that should be considered when interpreting the results. FA composition was evaluated only at the end of the culture period, and the FA composition of the commercial feed and supplementary dietary items was not analyzed. In addition, detailed water quality parameters were not monitored throughout the experiment. Therefore, the observed FA profile should be interpreted cautiously, and future studies incorporating temporal sampling, feed FA analysis, and comprehensive water quality monitoring would provide a better understanding of the effects of culture conditions on *V. contectus*.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Not applicable.

Author's contributions

Sample collection: MK, FKK, laboratory work: FKK, VK, EÖ, fatty acid analyses: ÖY, and EÖ., article writing and evaluation of data: FKK and MK.

Data availability statement

The datasets obtained and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethics approval is not applicable to this article.

References

- Beder, A. (2015). *The effects of dietary essential fatty acid enrichment on the nutrition and condition of red king crab (Paralithodes camtschaticus) larvae*. [MSc Thesis, University of Alaska Fairbanks]. Fairbanks, AK, USA.
- Black, J. H. (1976). Spawning and development of *Bedeva paivae* (Crosse) (Gastropoda: Murexidae). *Journal of the Malacological Society of Australia*, 3(4), 215–221. <https://doi.org/10.1080/00852988.1976.10673897>
- Cao, M., & Yao, X. (2005). Study on extraction technology of taurine from *Cipangopaludina chinensis*. *Journal of Yang University*, 2, 84–87.
- Catalma, E. G. (1986). A study on the culture of *Pila luzonica* in rice paddies (Philippines). *CLUS Science Journal*, 5(2), 23.
- Chatterji, A., Ansari, Z. A., Ingole, B. S., & Parulekar, A. H. (1984). Growth of the green mussel, *Perna viridis* L., in a sea water circulating system. *Aquaculture*, 40(1), 47–50. [https://doi.org/10.1016/0044-8486\(84\)90215-1](https://doi.org/10.1016/0044-8486(84)90215-1)
- Chiu, Y. W., Chen, H. C., Lee, S. C., & Chen, C. A. (2002). Morphometric analysis of shell and operculum variations in the viviparid snail, *Cipangopaludina chinensis* (Mollusca: Gastropoda), in Taiwan. *Zoological Studies*, 41(3), 321–331.
- Christie, W. W. (1992). *Gas Chromatography and Lipids*. The Oil Press.
- Cui, R., & Zhao, C. (1989). Preliminary study on the pharmacological functions of polysaccharides from three Mollusca species. *Journal of Yunnan University*, 3, 172–174.
- Cunningham, K., Turner, C., Frongillo, E. A., Constantinides, S. V., & Bhandari, S. (2021). Using a global food environment framework to understand relationships with food choice in diverse low- and middle-income countries. *Global Food Security*, 29, 100511. <https://doi.org/10.1016/j.gfs.2021.100511>
- Ekin, İ. (2008). *Güneydoğu Anadolu Bölgesi'nde dağılışı gösteren bazı yumuşakçaların yağ asidi içeriği*. [Doktora Tezi, Dicle Üniversitesi]. Fen Bilimleri Enstitüsü, Turkey.
- Ekin, İ., Başhan, M., & Şeşen, R. (2009). Fatty acid composition of freshwater snail *Bithynia tentaculata* (L., 1758) (Gastropoda: Prosobranchia) distributed in the Southeast Anatolia. *SAU Fen Bilimleri Dergisi*, 13(1), 28–33. <https://doi.org/10.16984/saufbed.64081>
- Ekin, İ., Başhan, M., & Şeşen, R. (2010). Seasonal variation in the fatty acid composition of the neutral lipid, phospholipid and total lipids of *Theodoxus syriacus* (Gastropoda: Prosobranchia). *SDU Fen Bilimleri Enstitüsü Dergisi*, 14(1), 23–31. <https://izlik.org/JA54YR56LK>
- Ekin, İ., Başhan, M., & Şeşen, R. (2011). Possible seasonal variation of the fatty acid composition from *Melanopsis praemorsa* (L., 1758) (Gastropoda: Prosobranchia), from southeast Anatolia, Turkey. *Turkish Journal of Biology*, 35(2), 203–213. <https://doi.org/10.3906/biy-0903-30>

- Ekin, İ., Kaçar, S., Başhan, M., & Şeşen, R. (2012). *Radix peregra* (Müller, 1774) tatlı su salyangozunun fosfolipit, diasilgliserol, triasilgliserol ve total lipidinin yağ aside dağılımı. *Journal of Life Sciences*, 1(2), 191–198. <https://izlik.org/JA39SN62DP>
- Felagha, I., Monanu, M. O., & Amadi, B. A. (2020). Mineral, fatty and amino acids composition of three species of mollusks (*Egeria radiata*, *Limicolaria flammea* and *Viviparus contectus*). *Asian Journal of Research in Biochemistry*, 6(2), 7–13. <https://doi.org/10.9734/ajrb/2020/v6i230112>
- Forte, A., Zucaro, A., De Vico, G., & Fierro, A. (2016). Environmental loading of Italian semi-intensive snail farming system evaluated by means of life cycle assessment. *Journal of Cleaner Production*, 125, 56–67. <https://doi.org/10.1016/j.jclepro.2016.03.045>
- Ghosh, D., Porter, E., Shen, B., Lee, S. K., Wilk, D., Drazba, J., Yadav, S. P., Crabb, J. W., Ganz, T., & Bevins, C. L. (2002). Paneth cell trypsin is the processing enzyme for human defensin-5. *Nature Immunology*, 3(6), 583–590. <https://doi.org/10.1038/ni797>
- Ghosh, S., Meyer-Rochow, V. B., & Jung, C. (2022). Farming the edible aquatic snail *Pomacea canaliculata* as a mini-livestock. *Fishes*, 7(1), 6. <https://doi.org/10.3390/fishes7010006>
- Guerrero, L. A., & Guerrero, R. D. (1980). Preliminary studies on the culture of edible freshwater snails in Central Luzon, Philippines. *CLSU Science Journal*, 1(1), 11–14.
- Hara, A. R., & Radin, N. S. (1978). Lipid extraction of tissues with a low-toxicity solvent. *Analytical Biochemistry*, 90(1), 420–426. [https://doi.org/10.1016/0003-2697\(78\)90046-5](https://doi.org/10.1016/0003-2697(78)90046-5)
- Jacob, D. E., Soldati, R., Wirth, J., Huth, U., & Wehrmeister, W. (2008). Nanostructure, composition, and mechanisms of bivalve shell growth. *Geochimica et Cosmochimica Acta*, 72(22), 5401–5415. <https://doi.org/10.1016/j.gca.2008.08.019>
- Jakubik, B. E., & Lewandowski, K. B. (2007). Size structure, age, mortality and fecundity in *Viviparus viviparus* (Linnaeus, 1758) (Gastropoda: Architaenioglossa: Viviparidae). *Folia Malacologica*, 15(3), 109–117. <https://doi.org/10.12657/folmal.015.012>
- Jiang, C., Jiao, Y., Chen, X., Li, X., Yan, W., Yu, B., & Xiong, Q. (2013). Preliminary characterization and potential hepatoprotective effect of polysaccharides from *Cipangopaludina chinensis*. *Food and Chemical Toxicology*, 59, 18–25. <https://doi.org/10.1016/j.fct.2013.05.036>
- Kutluyur Kocabaş, F., & Kocabaş, M. (2023). Morphological and microstructure analysis of the shells of *Dreissena polymorpha*, *Unio pictorum* and *Viviparus contectus*. In H. Y. Çoğun (Ed.), *Current debates on natural and engineering sciences*.
- Lakshmanan, B., Jayaraju, N., Prasad, T. L., Sreenivasulu, G., Nagalakshmi, K., Kumar, M. P., & Madakka, M. (2018). Data on molluscan shells in parts of Nellore coast, southeast coast of India. *Data in Brief*, 16, 705–712. <https://doi.org/10.1016/j.dib.2017.11.081>
- Lian, F., Siikavuopio, S. I., Harrison, S. M., Vang, B., Brunton, N. P., Esaïassen, M., & Lorentzen, G. (2022). Fatty acid profile of cooked leg meat and raw hepatopancreas of red king crab (*Paralithodes camtschaticus*) during three-month live holding without feeding at 5 and 10°C. *Journal of Food Composition and Analysis*, 105, 104206. <https://doi.org/10.1016/j.jfca.2021.104206>
- Lu, H. F., Du, L. N., Li, Z. Q., Chen, X. Y., & Yang, J. X. (2014). Morphological analysis of the Chinese *Cipangopaludina* species (Gastropoda; Caenogastropoda: Viviparidae). *Zoological Research*, 35(6), 510–527. <https://doi.org/10.13918/j.issn.2095-8137.2014.6.510>
- Mayta, L. R. B. (1978). The biology of *Pomacea maculata* Perry (Gastropoda: Ampullaridae) in the laboratory. *Anales Científicos de la Universidad Nacional Agraria La Molina*, 16(1–4), 11–14.
- Özçiçek, E., Kutluyur Kocabaş, F., Kocabaş, M., & Yılmaz, Ö. (2023). Seasonal changes in fatty acid profile of the freshwater snail *Viviparus contectus* (Millet, 1813) from lake habitat. *Molluscan Research*, 43(3–4), 173–180. <https://doi.org/10.1080/13235818.2023.2248571>
- Parveen, S., Chakraborty, A., & Chanda, D. K. (2020). Microstructure analysis and chemical and mechanical characterization of the shells of three freshwater snails. *ACS Omega*, 5(40), 25757–25771. <https://doi.org/10.1021/acsomega.0c03064>

