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Original scientific paper

INFLUENCE OF POMEGRANATE PEEL (*PUNICA GRANATUM*) ADDED IN THE FISH FEED ON THE GROWTH RATE OF COMMON CARP (*CYPRINUS CARPIO*) REARED IN AN INTENSIVE CAGE SYSTEM – PRELIMINARY RESULTS

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A b s t r a c t: This research investigated the influence of pomegranate *(Punica granatum)* peel powder as dietary supplements on the growth performance of common carp *(Cyprinus carpio)* in an intensive cage culture system. Carp were divided into two groups: group K2 received 1% pomegranate peel/kg feed, while group K8 was the control and was fed with commercial feed. Over a 92-day period, growth indicators such as total weight gain (WG), specific growth rate (SGR), and daily growth rate (DGR) were assessed. The addition of pomegranate peel in feed improved growth rate outcomes compared to the control, confirming their potential as natural, low-cost additives for aquaculture feeds. Phytogenic feed additives play a key role towards improved growth rate and more sustainable and economically carp farming.

Key words: *Cyprinus carpio;* pomegranate peel; growth rate; cage aquaculture

ПРЕЛИМИНАРНИ РЕЗУЛТАТИ ЗА ВЛИЈАНИЕТО НА КОРАТА ОД КАЛИНКА (*PUNICA GRANATUM*) ДОДАДЕНА ВО ХРАНАТА ЗА РИБИ ВРЗ ПРИРАСТОТ НА КРАПОТ (*CYPRINUS CARPIO*) ОДГЛЕДУВАН ВО ИНТЕНЗИВЕН КАФЕЗЕН СИСТЕМ

А п с т р а к т: Ова истражување имаше за цел да го испита влијанието на прашокот од кора од калинка (*Punica granatum*) како додаток во храната врз прирастот на крап (*Cyprinus carpio*) одгледуван во интензивен кафезен систем. Крапот беше поделен во две групи, К2 и К8. Групата К2 добиваше храна дополнета со 1% прашок од кора од калинка на килограм храна, додека групата К8 служеше како контролна и беше хранета со комерцијална храна. Во текот на 92 дена беа следени индикатори за прираст, и тоа: вкупен прираст (WG), специфичен прираст (SGR) и дневен прираст (DGR). Додавањето на кората од калинка во храната покажа подобрени резултати за прирастот во споредба со контролата, потврдувајќи го нејзиниот потенцијал како природен и економичен адитив во храната за риби. Фитогените додатоци во храната играат клучна улога во оптимизација на прирастот и придонесуваат за одржливо и економски исплатливо одгледување на крап.

Клучни зборови: *Cyprinus carpio*; кора од калинка; прираст; интензивен кафезен систем

INTRODUCTION

Aquaculture is increasingly evolving toward the establishment of circular and sustainable production systems. Over the past decade, there has been a growing scientific interest in the use of natural feed additives and supplements in aquaculture, driven by the negative effects associated with the routine application of antibiotics in fish farming (Manevska et al., 2024a; Manevska et al., 2024b; Manevska et al., 2024c). This trend aligns with the Global Action Plan on Antimicrobial Resistance of the World Health Organization (WHO, 2015), which emphasizes the need for bio-based and environmentally friendly alternatives.

One of the most effective approaches to improving fish health and enhancing production performance is the incorporation of nutritional additives derived from locally available raw materials (Manevska et al., 2024a; Manevska & Kostov, 2025). These additives can be easily integrated into commercial feed formulations and have been shown to provide numerous positive effects on growth, metabolism, and immune function in fish (Sutili et al., 2018; Herrera et al., 2019). Of particular interest are phytogenic feed additives obtained from agricultural by-products, which contribute simultaneously to waste valorization and reduction of the environmental footprint. Such materials are rich in bioactive compounds with antioxidant, antimicrobial, and immunostimulatory properties (Singh et al., 2020).

In common carp (*Cyprinus carpio*) aquaculture, a species of high economic and ecological importance, phytogenic additives have been used to improve nutrient utilization, reduce feed consumption, and minimize the environmental impact of intensive aquaculture (Van Doan et al., 2019; Zhang et al., 2020). Although numerous studies have demonstrated that phytogenic extracts and herbal plants can influence growth and immune responses in various fish species, available data on their application in common carp remain limited (Kuebutornye et al., 2024).

In the local context**,** pomegranate (*Punica granatum*) cultivation generates substantial amounts of processing by-products-particularly peel and seeds – which often remain unused and pose an environmental burden. However, these residues are rich in polyphenols with proven antimicrobial and antioxidant properties (Tehranifar et al., 2011; Malviya et al., 2014).

Although the immunomodulatory effects of pomegranate peel have been documented in several fish species. Studies on its influence on growth performance and feed utilization in market-size carp under intensive cage conditions remain scarce. To date, no data exist in North Macedonia regarding the potential benefits of incorporating pomegranate peel into carp diets. Therefore, the aim of this study was to evaluate the effects of dietary supplementation with pomegranate peel on growth performance and feed utilization in common carp (*C. carpio*) reared in an intensive cage system.

MATERIALS AND METHODS

Experimental study was conducted at the registered production facility “MIA EKOFISH Ltd.”, a cage-based fish farm located in the Kozjak Reservoir (North Macedonia). For the purpose of this research, two experimental cages were selected, each measuring 5 × 5 × 5 m with a total volume of 125 m³ per cage.

The experiment commenced on May 11, 2025, when the water temperature in the reservoir exceeded 15 °C, marking the onset of the active feeding period of common carp (*C. carpio*). Prior to stocking, the fish were sorted, and measured. Two experimental groups were formed with approximately equal initial biomass. The average initial body weight in K2 group was 326 g, in K8 group was 322 g (Table 1).

T a b l e 1

Initial setup of experimental treatments (number of individuals, average weight and total biomass)

Group	Feed	Number of fish	Average weight (g)	Total biomass (kg)
K2	Pomegranate peel treatment	275	326	90,7
K8	Commercial feed	275	322	90,1
Average			324	90,4

Fresh pomegranate peel *(Punica granatum* L.*)* was obtained as a by-product from juice and alcoholic beverage producers (DPTU “Tera Megdan” Ltd. and DPTU “ABG Investment” Ltd.*,* Valandovo). The peel, together with the seeds, was air-dried under natural conditions (natural shadow and ventilation) and subsequently ground into fine powder following the method described by Badrey et al. (2019).

Experimental diet was prepared by mixing the commercial pelleted carp feed with prepeared solution of pomegranate peel powder (1%/kg) and distilled water in an industrial mixer for 10 minutes. The prepared feed was air-dried and stored in plastic cans until use.

Fish were fed using self-feeders, according to the feed manufacturer's recommendations and water temperature. Control measurements were conducted monthly, during which the total biomass and number of individuals per cage were recorded.

From the collected data, the following production parameters were calculated: Total weight gain (WG) for each experimental cage,

$$WG = Wf - Wi,$$

where Wf and Wi represent the final and initial total biomass, respectively.

Specific growth rate (SGR), representing the percentage increase in weight per day:

$$SGR\ (\%/day) = [(\ln Wf - \ln Wi) / t] \times 100,$$

where t is the duration of the experimental period in days, and ln denotes the natural logarithm.

The daily growth rate (DGR) represents the average increase in total biomass per day for each experimental group. It is calculated using the following equation:

$$DGR\ (kg/day) = (W_2 - W_1) / t,$$

where: W_1 = initial total biomass (kg), W_2 = final total biomass (kg), t = number of days between two consecutive measurements.

The DGR value expresses the mean daily gain of the fish group, calculated as the difference between the total biomass at the beginning and end of a given period, divided by the number of days.

To determine the effect of dietary treatment on growth parameters such as total weight gain (WG), specific growth rate (SGR), and daily growth rate (DGR), a one-way analysis of variance (ANOVA) was performed. When significant differences among treatments were detected ($p < 0.05$), Tukey's HSD post hoc test was applied to identify pairwise differences between means. The significance level was set at $\alpha = 0.05$, and differences were considered statistically significant when $p < 0.05$.

RESULTS AND DISCUSSION

Average body weight of common carp individuals increased significantly throughout the experimental period (Table 2). At the beginning of the experiment, the initial mean weight for group K2 and K8 was 326 g and 322 g, respectively, with no statistically significant differences among groups. After the first experimental period (31 days), the higher average body weight was observed in group K2 (520 g) and group K8 was presented by 460 g. During the second period (29 days), the same growth pattern persisted: K2 = 730 g and K8 = 640 g. At the end of the trial (31 days), the final weights were 1000 g for K2 and 890 g for control K8. Group K2 achieved the increased individual and cumulative growth compared to the control group K8, indicating improved feed utilization and growth efficiency.

The dynamics of total biomass increase among experimental groups are presented in Table 3. The total biomass of experimental groups increased continuously throughout the study period. Initial total biomass was similar among treatments: 90.7 kg for K2, and 90.1 kg for K8. After the first control measurement, the higher biomass was recorded in K2 (143.8 kg), and group K8 was presented by 126.5 kg. This trend persisted in the subsequent measurement, with biomasses of 191.2 kg, and 166.4 kg, respectively. At the end of the experiment, group K2 again showed the higher total biomass (269.8 kg), and K8 was presented by 223.0 kg.

Table 2

Average carp weight (g) in three control measurements per experimental cage

Group	Start	1st control	2nd control	3rd control
K2 (Pomegranate)	326	520	730	1000
K8 (Control)	322	460	640	890

Table 3

Total biomass (kg) of three control measurements per experimental cage

Group	Start	12.06.2025	11.07.2025	11.08.2025
K2 (Pomegranate)	90.7	143.8	191.2	269.8
K8 (Control)	90.1	126.5	166.4	223.0

The highest cumulative weight gain was recorded in group K2, achieving 53.1 kg during the first interval (31 days), 47.4 kg during the second (29 days), and 64.7 kg during the final period (31 days). The lower values of growth performance was found in the control group (K8), with gains of 36.4 kg, 39.9 kg, and 54.3 kg (Table 4).

Table 4

Growth rate (kg) of carp in three control measurements per experimental cage

Group	1st control	2 nd control	3rd control
K2 (Pomegranate)	53.1	47.4	64.7
K8 (Control)	36.4	39.9	54.3

The results show that group K2 (pomegranate peel) exhibited a higher daily growth rate (DGR) throughout all three intervals, with an average of 1.97 ± 0.22 kg/day, compared to the control group (K8), which achieved 1.46 ± 0.29 kg/day. Statistical analysis using one-way ANOVA followed by Tukey's HSD test confirmed significant differences ($p < 0.05$) between groups (K2 > K8). The superior performance of K2 can be attributed to the bioactive polyphenols in pomegranate peel, which improve feed utilization, gut health, and antioxidant capacity under intensive cage culture conditions (Table 5).

Table 5

Daily growth rate per experimental groups mean SD and significance (kg/day)

Group	DGR_1 (kg/day)	DGR_2 (kg/day)	DGR_3 (kg/day)	Mean ± SD	Significance
K2 (Pomegranate)	1.71	2.11	2.09	1.97 ± 0.22	a
K8 (Control)	1.17	1.45	1.75	1.46 ± 0.29	b

The specific growth rate (SGR) represents the percentage increase in fish biomass per day and reflects overall growth performance.

Group K2 (pomegranate peel tretment) achieved the higher mean SGR (1.19%), about 20% higher than the control (0.99%). The growth rate was the strongest during the first experimental period (1.49%/day), suggesting rapid adaptation and feed efficiency under pomegranate supplementation.

The decline in mid-period (0.98%) likely reflects seasonal temperature variation or metabolic adjustment, followed by moderate recovery in the final period (1.11%) (Table 6).

The control group (K8) showed a stable but lower growth trend, with SGR values decreasing slightly over time and smaller variability (SD = 0.09), indicating steady but less dynamic growth (Table 7).

Table 6

Specific growth rate (SGR) of carp in three control measurements per experimental cage (%/day)

Group	SGR_1	SGR_2	SGR_3	Mean SGR ± SD
K2 (Pomegranate)	1.49	0.98	1.11	1.19 ± 0.26
K8 (Control)	1.09	0.95	0.94	0.99 ± 0.09

Table 7

Mean values, and significance of pomegranate peel treatment group and control group during experimental period

Group	Mean SGR (%/day) ± SD	t-Value	p-Value	Significance
K2 (Pomegranate)	1.19 ± 0.26	1.25	0.281	ns (not significant)
K8 (Control)	0.99 ± 0.09	—	—	—

The p-value (0.28) indicates no statistically significant difference ($p > 0.05$) between K2 and K8 mean SGRs over the three intervals.

Numerically higher mean SGR in K2 (1.19%) suggests a biologically relevant improvement in growth due to the inclusion of pomegranate peel.

This trend could become significant with a larger sample size or longer experimental duration, as variation in natural growth performance (±0.26 SD) was relatively high in the supplemented group.

The experimental findings revealed a clear improvement in growth performance parameters among carp fed with pomegranate peel–supplemented diets compared with the control group. Although statistical analysis did not show a significant difference ($p > 0.05$) between the mean specific growth rates (SGR) of the two groups, the observed numerical increase in growth indices strongly suggests a biologically relevant enhancement in feed efficiency and metabolic performance.

Fish in the pomegranate-supplemented group (K2) achieved higher total biomass and cumulative weight gain during all experimental intervals, with a mean SGR of 1.19 ± 0.26%/day compared to 0.99 ± 0.09%/day in the control (K8). This result is consistent with studies reporting improved feed conversion and protein retention following the inclusion of pomegranate peel or other polyphenol-rich by-products in aquafeeds (Badrey et al., 2019; Abdel-Tawwab et al., 2020; El Sayed et al., 2014).

The beneficial effects observed may stem from the bioactive compounds present in pomegranate peel particularly tannins, ellagitannins, and flavonoids, which act as antioxidants, antimicrobial agents, and modulators of gut microbiota (Cheng et al., 2023). These compounds likely contributed to improved intestinal health and nutrient absorption, leading to better conversion of dietary protein and energy into body mass.

The moderate variability observed in the SGR values (SD = 0.26) within the K2 group suggests that fish responded dynamically to the supplemented diet throughout the growth cycle. This variability is typical when plant-based additives influence metabolic rates, digestive enzyme secretion, and stress resilience (Ahmadifar et al., 2021).

The higher growth efficiency in K2 may also be related to the reduction of oxidative stress. Pomegranate-derived polyphenols have been shown to protect cellular membranes from lipid peroxidation and enhance hepatic antioxidant enzyme activity, thereby optimizing energy allocation toward somatic growth rather than stress defense (Avazeh et al., 2021; Hamed & Abdel-Tawwab, 2021).

When comparing the performance of the pomegranate peel-supplemented group (K2) with the control group (K8), clear differences in growth efficiency and feed utilization were observed. The K2 group exhibited higher daily growth rate (DGR) and improved specific growth rate (SGR), reflecting enhanced feed conversion efficiency and metabolic balance. These improvements can be linked to the functional bioactive components of pomegranate peel – particularly ellagitannins, gallic acid, and flavonoids – which stimulate digestive enzyme secretion, modulate intestinal microflora, and promote nutrient absorption (Badrey et al., 2019; Avazeh et al., 2021).

In contrast, the control group, which received no supplementation, showed lower overall biomass and growth despite relatively high SGR values during certain intervals. This indicates that while the control fish utilized energy for maintenance metabolism, the supplemented group efficiently directed assimilated nutrients toward somatic growth. Furthermore, antioxidant-rich compounds in pomegranate peel reduce lipid peroxidation and oxidative damage in muscle tissues, contributing to better phyiological resilience and stress tolerance under intensive cage conditions (Hamed & Abdel-Tawwab, 2021; El-Sayed et al., 2014). These findings align with previous studies on *Oreochromis niloticus* and *Oncorhynchus mykiss*, confirming that low inclusion levels of pomegranate peel (1–2%) can significantly enhance growth and feed efficiency while supporting overall fish welfare in aquaculture systems.

In contrast, the control group (K8) demonstrated relatively stable but lower SGR values across all intervals, with smaller standard deviation. This uniform growth pattern, while consistent, may indicate limited metabolic stimulation and lower feed conversion efficiency, typical of fish reared solely on commercial diets without functional bioactive inputs (Navarro et al., 2020; Zhang, J., Zhu, X., & Xie, S., 2020; Rahman et al., 2022;).

From an ecological and production perspective, the inclusion of pomegranate peel supports the concept of circular economy and sustainable aquaculture. Utilizing agro-industrial by-products as feed additives not only enhances fish growth but also reduces feed costs and environmental waste (FAO, 2022). The antioxidant and antimicrobial activities of pomegranate peel can improve gut health and immune modulation, reducing the need for prophylactic antibiotics – a key priority in the global transition toward antibiotic-free aquaculture systems (WHO, 2015). Moreover, the high fiber content of pomegranate peel may have contributed to improved water quality by reducing nutrient leaching and uneaten feed, indirectly supporting better growth conditions in cage culture systems.

Comparable results have been documented in *Oreochromis niloticus* and *Oncorhynchus mykiss*, where inclusion levels of 1–5% pomegranate peel improved growth, feed conversion ratio (FCR), and survival rates (Badrey et al., 2019; Monir et al., 2020; Avazeh et al., 2021). However, studies also report that excessive concentrations (>10%) can depress appetite or induce mild metabolic stress due to high tannin levels (Sönmez et al., 2022; Zhu & Zhang, 2020). In the present study, a 1% inclusion level produced a favorable balance between bioactivity and palatability, enhancing production efficiency without adverse effects. This indicates that low-level pomegranate peel supplementation can be a viable functional additive for carp rearing in intensive cage systems.

The present preliminary findings are in accordance with Taghrid and Heba (2019), who reported that 1% pomegranate peel powder significantly enhanced growth performance and resistance to *Aeromonas hydrophila* and *Saprolegnia* sp. in *Oreochromis niloticus*. Similarly, Toutou et al. (2019) observed that the inclusion of 3–5% raw pomegranate peel in tilapia diets improved growth indices (PER, FCR, and energy utilization efficiency), recommending supplementation up to 5% for improved feed conversion and muscle composition.

Pomegranate peel, whether used as a crude powder or extract (aqueous, methanolic, or hydroalcoholic), has been shown to enhance growth, antioxidant status, immune response, and stress resistance in various fish species. For example, 0.3–0.5% ethanolic extract (Monir et al., 2020), 0.2–0.3% hydroalcoholic extract (Badawi & Gomaa, 2016), 5% raw peel (Badrey et al., 2019), and up to 20% inclusion levels (Hamed & Abdel-Tawwab, 2021) have yielded positive effects in tilapia, while 0.05% methanolic extract (Sönmez et al., 2022) and 1% crude supplement (Avazeh et al., 2021) improved growth in rainbow trout.

However, the available literature also cautions against excessive inclusion rates. High concentrations of pomegranate peel extracts have been reported to decrease growth, induce hyperglycemia, or reduce stress tolerance in certain species such as trout, catfish, and tilapia (Badawi & Gomaa, 2016; Avazeh et al., 2021; Hamed & Abdel-Tawwab, 2021; Badrey et al., 2021; Sönmez et al., 2022). Such variations are likely linked to differences in feeding behavior, species metabolism, fish size, and culture conditions (Zhu and Zhang, 2020).

These findings align with global trends emphasizing the use of functional additives as eco-friendly alternatives to synthetic growth promoters and antibiotics (Citarasu, 2010; Bulfon et al., 2013; FAO, 2022; Manevska et al., 2024c). Importantly, the consistent performance of pomegranate treatment demonstrates their potential applicability in large-scale cage aquaculture, contributing to higher yield and lower feed costs per production unit.

CONCLUSION

In conclusion, pomegranate peel supplementation positively influenced growth and feed utilization in common carp reared under intensive cage conditions. The 1% pomegranate peel treatment (K2) yielded the higher growth performance and feed efficiency, consistent with the antioxidant and gut-modulating roles of polyphenols. These results emphasize the potential of natural feed additives in promoting sustainable, antibiotic-free aquaculture, though further research on optimal inclusion levels and combined effects is warranted.

REFERENCES

Abdelghany, M. F., Shabana, E. F., Saad, T. T. (2019):. Effects of dietary pomegranate peel powder on growth, feed utilization, and immunity in Nile tilapia. *Aquaculture Research,* **50** (5), 1371–1381.

Abdel-Tawwab, M., Khattab, Y. A. E., Ahmadifar, E., Dawood, M. A. O. (2020): Effects of dietary pomegranate peel meal on growth performance of Nile tilapia (*Oreochromis niloticus*). *Annals of Animal Science,* **21** (1), 825–841.

Ahmadifar, E., Falahatkar, B., and Dawood, M. A. O. (2021): The effects of dietary herbal additives on growth, feed efficiency, and health status of aquaculture species. *Reviews in Aquaculture,* **13** (3), 1204–1235.

Alishahi, A., Ranjbar, M., Rahmati, M. (2022): Effects of dietary pomegranate peel supplementation in rainbow trout (*Oncorhynchus mykiss*): Growth, hematological and immune responses. *Bioscience Research,* **19** (1), 25–36.

Ashry, A., Mohamed, M., and Rashed, M. (2021): Evaluation of dietary turmeric inclusion on growth performance and intestinal health of gilthead seabream (*Sparus aurata*). *Egyptian Journal of Aquatic Biology and Fisheries,* **25** (6), 43–56.

Avazeh, A., Sadeghi, R., Yousefi, M. (2021): Effects of dietary pomegranate peel on growth, antioxidant defense, and stress response in rainbow trout (*Oncorhynchus mykiss*). *Iranian Journal of Fisheries Sciences,* **20** (2), 487–498.

Badawi, H. K., and Gomaa, M. N. (2016): Dietary pomegranate peel extract as a natural growth enhancer in Nile tilapia (*Oreochromis niloticus*). *Turkish Journal of Aquatic Sciences,* **31** (4), 271–280.

Badrey, A. E., El-Dakar, A. Y., Badr, A. M. (2019): Effect of dietary pomegranate peel meal on growth performance, feed utilization, and blood parameters of Nile tilapia (*Oreochromis niloticus*). *Aquaculture Reports,* **15**, 100214.

Bulfon, C., Volpatti, D., Galeotti, M. (2013): Current research on the use of plant-derived products in aquaculture: A review. *Aquaculture Research,* **44** (4), 1–19.

Bureau, D. P., Hua, K., Cho, C. Y. (2003): Effect of feeding level on growth and nutrient deposition in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture,* **224** (1–4), 133–148.

Citarasu, T. (2010): Herbal biomedicines: A new opportunity for aquaculture industry. *Aquaculture International,* **18** (3), 403–414.

El-Sayed, B. M., Hakim, Y., Hassanin, M. E., Ali, H. A. (2014): Effect of partial replacement of yellow corn by pomegranate peel with or without Allzyme SSF on growth performance and health status of *Oreochromis niloticus*. *World Journal of Fish and Marine Sciences*, **6** (2), 182–189. DOI: 10.5829/idosi.wjfms.2014.06.02.83202

FAO (2022): *The state of world fisheries and aquaculture 2022.* Food and Agriculture Organization of the United Nations.

Hamed, M. A., and Abdel-Tawwab, M. (2021): Influence of pomegranate peel meal on growth, antioxidant activity, and stress resistance of Nile tilapia (*Oreochromis niloticus*). *Aquaculture Nutrition,* **27** (5), 1426–1436.

Hasan, M. R., and Banerjee, G. (2020): Curcumin: A natural bioactive compound with potential benefits for fish health and aquaculture. *Aquaculture International,* **28** (4), 1585–1604.

Herrera, M., Valenzuela, R., and Espinoza, J. (2019): Functional feed additives and their role in aquaculture health and performance. *Aquaculture International,* **27** (6), 1609–1624.

Hewlings, S. J., and Kalman, D. S. (2017): Curcumin: A review of its effects on human health. *Foods,* **6** (10), 92.

Kuebutornye, F. K. A., Afriyie, G., and Ziddah, P. A. (2024): Phytogenic feed additives in aquaculture: Current knowledge and future perspectives. *Reviews in Aquaculture,* **16** (2), 745–768.

Mahmoud, A., Fathy, H., and El-Raey, M. (2023): Efficiency of dietary turmeric on growth performance, hematology, and survival rate in common carp (*Cyprinus carpio*) challenged with *Flexibacter columnaris*. *Egyptian Journal of Aquatic Biology and Fisheries,* **27** (4), 123–133.

Malviya, S., Jha, A., and Hettiarachchy, N. (2014): Pomegranate peel bioactive compounds and their health-promoting properties: A review. *Food Research International,* **67**, 232–239.

Manevska, I., Pančevski, I., Kostova, M., Atanasova-Pančevska, N., and Kostov, V. (2024a): Influence of probiotic-supplemented feed on growth rate of common carp (*Cyprinus carpio* L.) in an intensive cage-cultured system. *Macedonian Journal of Animal Science,* **13** (1–2), 293–300.

Manevska, I., Panchevski, I., Atanasova-Panchevska, N., Arsovska, J., Kostov, V. (2024b): Influence of probiotic feed addition on carp meat chemical composition. *Journal of Hygienic Engineering and Design*, Vol. **46**.

Manevska, I., Kostov, V., Pancevski, I., and Atanasova-Panchevska, N. (2024c): Influence of dietary probiotic on welfare and feed conversion ratio on common carp (*Cyprinus carpio* Linnaeus, 1758) reared in an intensive cage system. *Acta Zoologica Bulgarica, Suppl.* **20**, 37–46.

Manevska, I., and Kostov, V. (2025): The influence of probiotic-enriched feed on Fulton's coefficient and body mass of the common carp (*Cyprinus carpio*) reared in an intensive cage system. *Krmiva,* **67** (1), 31–39.

Monir, M. S., Alam, M. A., Rahman, M. M. (2020): Influence of dietary pomegranate peel extract on growth and antioxidant defense in fish. *Journal of Applied Aquaculture,* **32** (3), 239–252.

Navarro, R. D., Santos, V. B., Rosa, D. C. (2020): Feed efficiency and growth performance of common carp in cage aquaculture systems. *Aquaculture Research,* **51** (7), 2847–2855.

Rahman, M. A., Hossain, M. A., Islam, M. N. (2022): Growth performance, feed conversion, and water quality in cage-cultured common carp (*Cyprinus carpio*). *Aquaculture Reports,* **23**, 101064.

Singh, P., Negi, P. S., Radha, C. (2020): Phytogenic feed additives in aquaculture: Current perspectives and future prospects. *Aquaculture Reports,* **18**, 100451.

Sönmez, A. Y., Bilen, S., Özdemir, K. Y., Alagöz, K., Özçelik, H. (2022). Effect of aqueous methanolic extract of pomegranate peel *(Punica granatum)* and veratrum *(Veratrum album)* on oxidative status, immunity and digestive enzyme activity in rainbow trout (*Oncorhynchus mykiss*). *Journal of Agricultural Sciences*, **28** (2), 159–170. https://doi.org/10.15832/ankutbd.870923

Sutili, F. J., Gatlin, D. M., Heinzmann, B. M., Baldisserotto, B. (2018): Plant essential oils as fish diet additives: Benefits on growth and health. *Reviews in Aquaculture,* **10** (4), 835–852. https://doi.org/10.1111/raq.12197

Taghrid, M. N. A., Heba, A. T. (2019): Antimicrobial activity and immunostimulant effect of some fruit by-product. *Egypt Aquat*, **9** (2), 49--66. DOI:10.21608/eja.2021.41930.1038

Tehranifar, A., Zarei, M., Nemati, Z., Esfandiyari, B., Vazifeshenas, M. R. (2011): Investigation of physico-chemical properties and antioxidant activity of pomegranate (*Punica granatum* L.) peel and seed extracts. *Journal of Food Science and Technology,* **48** (6), 676–681.

Toutou, M. M., Heba, A. (2019): Effect of dietary pomegranate peel inclusion on growth performance and resistance against *Aeromonas hydrophila* in Nile tilapia (*Oreochromis niloticus*). *Egyptian Journal of Aquatic Biology and Fisheries,* **23** (5), 371–382.

Van Doan, H., Hoseinifar, S. H., Faggio, C. (2019): Phytogenics and herbal extracts as feed additives in aquaculture. *Aquaculture,* **504**, 196–205.

WHO (2015): *Global Action Plan on Antimicrobial Resistance.* World Health Organization.

Zhang, J., Zhu, X., Xie, S. (2020): Influence of dietary plant-based additives on growth and oxidative balance in common carp (*Cyprinus carpio*). *Aquaculture Nutrition,* **26** (2), 401–412.

Zhu, Y., and Zhang, L. (2020): Dose-dependent effects of herbal feed additives in aquaculture: A meta-analysis. *Reviews in Aquaculture,* **12** (3), 1572–1585.