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Product Quality and Safety

Effect of dietary supplementation of cinnamon (*Cinnamomum verum* Presl) extract to rainbow trout (*Oncorhynchus mykiss* W.) feed on the chemical and fatty acid profile of meat

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Abstract. *The aim of this study was to evaluate the effect of dietary supplementation with cinnamon (Cinnamomum verum Presl) on meat chemical composition and fatty acid profile in rainbow trouts (Oncorhynchus mykiss W.), cultivated in a recirculation system. One hundred and twenty rainbow trouts were allotted into two variants - control (C) and experimental (C.v), each in two replication with thirty fish. The average intial body weight of fish was 41.55±7.76 g (control group) and 41.48±7.95 g (C.v group) and final live weights on the 60th day: 117.25±19.15 g (C) and 121.42±19.39 g (C.v). The trial was carried out in a recirculation system that maintained water chemical parameters optimal for rainbow trout farming. The 1% powdered cinnamon extract was given to fish from the C.v. group by lubrication of extruded feed granules with 5 ml/100 g feed sunflower oil, whereas the feed of controls was lubricated only with the same amount of sunflower oil. After the end of the feeding period, six groups from each group were euthanised, heads and viscera were removed, then they were filleted and deboned. The meat was minced, homogenised and chemical and fatty acid analyses were performed. The meat water, dry matter, lipid, protein and ash contents were not changed after feed supplementation with 1% cinnamon extract. However the tested phytoextract had a beneficial effect on the meat fatty acid profile. SFA content of meat was statistically significantly reduced along with considerable increase in the content of UFA, MUFA, PUFA and n-3 fatty acid groups. The levels of n-6 fatty acids were not influenced by the dietary supplementation with cinnamon extract. The beneficial effect of this additive on fatty acid content of meat was proved by the improved PUFA/SFA and n-6/n-3 ratios in the meat of group C.v. Both ratios were within the beneficial ranges from the point of view of human nutrition: above 0.4 and less than 5, respectively.*

Keywords: *Cinnamomum verum*, cinnamon extract, *Oncorhynchus mykiss*, chemical composition, fatty acid profile

Introduction

The improvement of aquaculture efficiency depends on many factors, yet the most important one in the used feed. The supplements to fish feeds are known to improve their quality, e.g. absorption, taste, consistency, water solubility, fish meat quality and many others (Bai et al., 2015).

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People have been familiar with the antimicrobial and antioxidant effects of various plants and plant extracts for a long time (Gabor et al., 2010), so they are believed to be suitable alternatives to antibiotics in aquaculture. Phytoadditives pose no threat either to fish and human health or to the environment, as they are natural substances (Gabor et al., 2011). Nowadays, the influence of plant extract on different fish species and on the quality of their meat is not fully investigated. A large part of available studies have investigated their effects on productive performance and blood parameters of fish, and economic results linked to feed conversion (Georgieva and Zhelyazkov, 2018; Stoyanova et al., 2018a,b; Zhelyazkov et al., 2018; Sirakov et al., 2019; Velichkova et al., 2019; Georgieva et al., 2020; Zhelyazkov and Stoev, 2020; Stoev and Zhelyazkov, 2021). Far less studies have been published on the meat chemical composition of fish supplemented with phytoadditives (Georgieva et al., 2018, 2019; Koshinski 2019, 2020; Stoev and Zhelyazkov, 2020).

Cinnamon is among the oldest spices used in global culinary (Rao and Gan, 2014). Although many species from the genus *Cinnamomum* are offered on the market as cinnamon, the inner dried bark of *Cinnamomum verum* Presl syn. *Cinnamomum zeylanicum* Blume is considered true cinnamon (Avula, 2015). *Cinnamomum verum* is a tropical shrubby evergreen tree of the Lauraceae family, native to Sri Lanka and South India, but also distributed in Southeast Asia, China, Burma, Indonesia, Madagascar, the Caribbean, Australia and Africa (Abeysekera et al., 2013; Goyal et al., 2018). Cinnamon contains a lot of vitamins, minerals, and phenolic compounds. It was reported to possess anti-inflammatory, antimicrobial, antibacterial, antitumour, cardiovascular, cholesterol lowering, immunomodulatory, larvicidal and antioxidant properties (Charles, 2012). A complete phytochemical and pharmacological overview of *Cinnamomum verum* as universal food spice was made by Singh et al. (2021). The proximate analysis of cinnamon according to this study was as follows: carbohydrates 52.0%; crude protein 3.5%, crude fat 4%, crude fibre 33.0%, moisture 5.1% and ash 2.4% (Gul and Safdar, 2009). The cinnamon fatty acid composition is characterized by 47.68% stearic acid, 26.08% linoleic acid, 15.58% palmitic acid, 7.73& oleic acid, 2.43% undecanoic acid and 0.5% lauric acid (Jamil et al., 2016).

Before inclusion of a specific supplement in commercial fish feeds, its effect on the respective fish species should be studied in detail (Gabor et al., 2010). So far, the investigations on cinnamon as fish feed additive focused on its effects on growth performance, feed conversion, body composition, resistance to *Aeromonas hydrophila* in Nile Tilapia (Mohammad et al., 2011), growth performance and economic effect from feeding in carps (Stoyanova et al., 2018a), growth performance, blood parameters and economic efficiency in rainbow trouts (Zhelyazkov and Stoev, 2020). Data on meat proximate analysis in cinnamon-supplemented fish are few, whereas information about meat fatty acid profiles is not available. Regardless of the fact that PUFA/SFA and n-6/n-3 ratios in fish meat are within the beneficial range - >0.4 and <5 (Simopoulos, 2004; Taşbozan and Gökçe, 2017), means for their improvement in farmed fish are still sought, and this could be done through the feed.

The aim of this study was to evaluate the effect of dietary supplementation with cinnamon (*Cinnamomum verum* Presl) on meat chemical composition and fatty acid profile in rainbow trouts (*Oncorhynchus mykiss* W.), cultivated in a recirculation system.

Material and methods

Ethical approval

The study was performed in line with international, national, and/or institutional guidelines for the care and use of animals (Directive 2010/63/EU; Regulation № 20/2012).

Experimental design

One hundred and twenty rainbow trouts were allotted into two variants - control (C) and experimental (C.v), each in two replication with thirty fish. The average initial body weight of fish was 41.55±7.76 g (control group) and 41.48±7.95 g (C.v group). The trial was carried out in a recirculation system that maintained water chemical parameters

optimal for rainbow trout farming: mean water temperature 14.00ºC, dissolved oxygen content over 9.00 mg.l^{-1}, pH 7.64-7.72. The concentrations of ammonia, nitrates, nitrites and orthophosphates were below 1.0 mg.l^{-1}, 2.0 mg.l^{-1}, 0.01 mg.l^{-1} and 0.40 mg.l^{-1}, respectively. The 1% powdered cinnamon extract (P.I.C.Co LTD) was given to experimental fish from the C.v. group by lubrication of extruded feed granules (Aqua garant UNI, manufactured by Garant-Tiernahrung Gesellschaft m.b.H. - Austria) with 5 ml/100 g feed sunflower oil, whereas the feed of controls was lubricated only with the same amount of sunflower oil. The daily ration was 3% of fish live weight, distributed into 3 portions, given manually. The experimental period lasted 60 days. The feed received by the 2 experimental groups contained crude protein - 45%, crude lipids - 16%, crude fiber - 2.40%, crude ash - 8%, Ca - 1.60%, P - 1.20%, ME - 18.50 MJ/kg. One kg feed contained: vitamin A - 10000 IE, vitamin D3 - 1500 IE, vitamin E - 200 mg, vitamin C - 150 mg, Fe - 62 mg, Mn - 26 mg, Cu - 5 mg, Zn - 103 mg, I - 2.6 mg, Se - 0.3 mg.

The final live weight of fish on the 60th day was 117.25±19.15 g (C) and 121.42±19.39 g (C.v), respectively.

Preparation of samples for chemical analysis

After the end of the feeding period, six subgroups from each group were euthanised, heads and viscera were removed, and then they were filleted and deboned. The meat was minced, homogenised and analysed.

Chemical composition

After preparation of fish meat samples (AOAC, 2006; method 983.18), their water content was determined by air drying (AOAC, 1997; method 950.46). Crude protein (%) was determined by Kjeldahl's method, (Kjeltec 8400, FOSS, Sweden). Meat lipid content (%) was assayed according to the method of Soxhlet (Soxtec 2050, FOSS, Sweden). The ash content (%) was obtained after incineration at 550°C for 8 h (MLW, Germany).

Fatty acid composition

The determination of fatty acid composition (%) of the total lipids of the rainbow trout was carried out by the application of a gas chromatographic method, using a gas chromatograph "Perkin Elmer" Clarus 500 with a flame ionization detector, a 60 m capillary column "Trace Gold T6-WAXMS GC Column"; column temperature – 130°C (1 min), with change 6.5°C/min to 170°C, with change 3.0°C/min to 215°C (12 min) 40.0/min to 230°C (1 min), detector temperature 280°C; injector temperature – 270°C, gas holder – hydrogen (H), split - 1:50.

Statistical analysis

Statistical analysis was performed with independent-sample Student's t-test at $p<0.05$.

Results

Chemical composition

The chemical composition of rainbow trout meat was not influenced by the addition of 1% cinnamon extract to the feed as the between-group differences were not statistically significant ($P>0.05$; Table 1). Meat water content of fish from group C.v was 0.13% lower than in controls, the average value of which was 77.07±0.17%. The dry matter content of the supplemented fish meat was by 0.43% higher than that of group C (22.93±0.17%). Meat protein percentage of control rainbow trouts was 18.61±0.20%, e.g. 0.97% higher than that of fish that received 1% cinnamon extract with the feed. The fat content of the supplemented trouts was 10.30% higher compared to the control fat content of 3.01±0.28%. Meat ash of cinnamon-supplemented fish (1.28±0.06%) was reduced by 2.29% compared to the ash content of controls.

Table 1. Chemical composition of the fillets of rainbow trout (*Oncorhynchus mykiss* W.), cultivated in a recirculation system

Parameters	n	C $\bar{x}$ ±SD	C.v $\bar{x}$ ±SD	Significance
Water, %	6	77.07±0.17	76.97±0.30	NS
Protein, %	6	18.61±0.20	18.43±0.28	NS
Lipids, %	6	3.01±0.28	3.32±0.25	NS
Dry matter, %	6	22.93±0.17	23.03±0.30	NS
Ash, %	6	1.31±0.03	1.28±0.06	NS

NS – Non-significant.

Fatty acid composition

The addition of 1% cinnamon extract to the feed of rainbow trouts resulted in statistically significantly higher (P<0.001) myristic acid content in fish meat – by 20.31% compared to the average control percentage of 2.61±0.24% (Table 2). Palmitic acid percentage in the meat of non-supplemented controls (20.30±0.94%) exceeded substantially this fatty acid in fish fed 1% cinnamon extract (C.v), the content of which was 14.93% lower (P<0.001) (Table 2). There was no statistically significant difference between the groups regarding stearic acid content in meat (P>0.05; Table 2). A considerably lower percentage (P<0.001) – by 8.02%, was established for SFA acids in supplemented trouts in comparison to the control value of 27.69±0.94% (Table 2).

The oleic and palmitoleic acids in the meat of experimental fish were not influenced by the addition of 1% cinnamon extract to the feed. The differences between both groups were inconsistent (P>0.05), and the same was true for the total MUFA meat content (Table 2).

The addition of cinnamon extract to the feed did not alter the content of linoleic, α-linolenic, eicosadienoic and docosapentaenoic fatty acids (P>0.05; Table 2). Considerably lower (P<0.05) eicosatrienoic acid level (by 44.12%) was found in the meat of group C.v compared to the control content of 0.68±0.32% (Table 2). The eicosapentaenoic acid content in group C.v was 2.36 times higher (P<0.001) vs the average control percentage of 0.91±0.36% (Table 2). Also, meat docosahexaenoic acid content was substantially (P<0.001) higher (3.05 times) in cinnamon-supplemented group C.v compared to controls, the average level of which was 1.26±0.71% (Table 2). The addition of cinnamon extract to the feed led to statistically significantly (P<0.001) higher content of UFA, PUFA and n-3 fatty acids in experimental fish – by 3.07%, 12.79% and 77.75% respectively, whereas in control trouts, the average concentrations of these fatty acid groups were 72.31±0.94%, 21.42±0.51% and 4.63±0.92%. No statistically significant differences were detected with respect to n-6 fatty acids (P>0.05) (Table 2).

After addition of 1% cinnamon extract to rainbow trout feed, the PUFA/SFA ratio increased by 23.38% (P<0.001) in group C.v and the average level in control fish was 0.77±0.01% (Table 2). The n-6/n-3 ratio also changed considerably (P<0.01), but this time it was by 48.29% lower than the same ratio in the meat of non-supplemented trouts - 3.81±1.10% (Table 2).

Table 2. Fatty acid composition of the fillets of rainbow trout (*Oncorhynchus mykiss* W.), cultivated in a recirculation system

Parameters	n	C $\bar{x}$ ±SD	C.v $\bar{x}$ ±SD	Significance
C14:0 Myristic	6	2.61±0.24	3.14±0.04	***
C16:0 Palmitic	6	20.30±0.94	17.27±0.52	***
C16:1 Palmitoleic	6	3.14±0.30	3.63±0.95	NS
C18:0 Stearic	6	4.79±0.24	5.06±0.86	NS
C18:1 Oleic	6	47.76±1.74	46.75±1.16	NS
C18:2 Linoleic	6	15.59±1.07	14.69±1.05	NS
C18:3n-3 α-linolenic	6	2.12±0.11	2.00±1.10	NS
C20:2 Eicosadienoic	6	0.53±0.04	0.86±0.41	NS
C20:3 Eicosatrienoic	6	0.68±0.32	0.38±0.02	*
C20:5 Eicosapentaenoic	6	0.91±0.36	2.15±0.13	***
C22:5 Docosapentaenoic	6	0.34±0.04	0.26±0.13	NS
C22:6 Docosahexaenoic	6	1.26±0.71	3.84±0.43	***
SFA[1]	6	27.69±0.94	25.47±0.30	***
UFA[2]	6	72.31±0.94	74.53±0.30	***
MUFA[3]	6	50.90±1.44	50.38±0.21	NS
PUFA[4]	6	21.42±0.51	24.16±0.51	***
n-6[5]	6	16.79±1.42	15.93±1.44	NS
n-3[6]	6	4.63±0.92	8.23±0.94	***
PUFA/SFA	6	0.77±0.01	0.95±0.03	***
n-6/n-3	6	3.81±1.10	1.97±0.40	**

Significant difference: *** P≤0.001; ** P≤0.01; * P≤0.05; NS – Non-significant.

[1]SFA-Saturated fatty acids; [2]UFA–Unsaturated fatty acids; [3]MUFA–Monounsaturated fatty acids; [4]PUFA–Polyunsaturated fatty acids; [5]n-6– УС18:2;C20:2;C20:3;C20:4; [6]n-3–УС18:3n-3;C20:5;C22:6.

Discussion

The meat proximate analysis results showed that the chemical composition was not changed from the addition of 1% cinnamon extract to the feed of trouts P>0.05). This was in line with the results of Mohammad et al. (2011) who added *Cinnamomum zeylanicum* to the feed of Nile Tilapia; comparable results were obtained by Georgieva et al. (2018, 2019) with paprika, curcumin, garlic and thyme extracts added to the rainbow trout and carp feeds. On the contrary, other researchers reported increased total meat lipids in common carps (Wojno et al., 2021) and in *Labeo rohita* (Matiullah et al., 2016) supplemented with black pepper. Higher meat water content and lower fat and dry matter content were found by Koshinski (2019, 2020) with *Achillea millefolium* and *Taraxacum officinale* dietary extracts in rainbow trouts, as well as by Georgieva et al. (2018) by adding oregano to carp feed. Koshinski (2020) affirmed higher protein and lower ash content in rainbow trout meat supplemented with extract from *Taraxacum officinale*, whereas Matiullah et al. (2016) found higher meat protein and ash percentages in *Labeo rohita* that received 0.5% black pepper with the feed.

The addition of 1% cinnamon extract resulted in statistically significantly increased (P<0.001) meat myristic acid content compared to untreated fish, whereas palmitic acid in group (C.v) was substantially lower (P<0.001) than in controls. Stearic acid in the meat of rainbow trouts was not influenced by cinnamon addition. Stearic

acid is neutral from the point of view of human nutritional science, whereas both myristic and palmitic acids are important as they increase blood total cholesterol concentrations. SFA in the meat of cinnamon-fed fish was considerably ($P<0.001$) lower than that in the control group. Unlike our results, a previous study (Georgieva et al., 2018) reported lower levels of myristic acid in the meat of trouts fed curcumin, paprika, thyme, oregano and garlic with the feed, whereas the results regarding palmitic acid and SFA were in line with our findings.

Oleic, palmitoleic and total MUFA levels in the meat of the experimental fish were not influenced by the addition of 1% cinnamon extract ($P>0.05$) opposing to other data that evidenced higher levels of these fatty acids in trouts supplemented with curcumin, paprika, thyme, oregano and garlic (Georgieva et al., 2018).

The contents of linoleic, α-linolenic, eicosadienoic and docosapentaenoic fatty acids in the meat of rainbow trouts was not changed ($P>0.05$) by the addition of 1% cinnamon extract to the feed. The results for linoleic, eicosadienoic and docosapentaenoic acids were comparable to those reported by Georgieva et al. (2018) for rainbow trouts fed feeds containing curcumin, paprika, thyme, oregano and garlic, yet the authors found rather lower levels of α-linolenic acid opposite to our data. A statistically significantly ($P<0.05$) reduced amount of eicosatrienoic acid was found in the meat of fish from group C.v compared to controls, which disagreed with the results of Georgieva et al. (2018) in trouts fed curcumin, paprika, thyme, oregano and garlic with feed. The contents of eicosapentaenoic and docosahexaenoic fatty acids in the meat of trouts from group C.v was substantially higher ($P<0.001$) than that in control fish, whereas Georgieva et al. (2018) did not report any significant effect from the addition of curcumin, paprika, thyme, oregano and garlic with regard to these fatty acids. Meat UFA, PUFA and n-3 in rainbow trout meat supplemented with cinnamon extract was considerably ($P<0.001$) higher compared to those in controls, in line with the data of Georgieva et al. (2018), who also observed a tendency for higher concentrations of these fatty acid groups in rainbow trouts after dietary supplementation with curcumin, paprika, thyme, oregano and garlic. The n-6 fatty acids in the meat of the experimental group C.v were not influenced by cinnamon extract supplementation of feed, similar to what was reported by Georgieva et al. (2018).

The addition of 1% cinnamon extract to rainbow trout feed led to statistically significant differences in PUFA/SFA ($P<0.001$) and n-6/n-3 ($P<0.01$) rations between the groups. PUFA/SFA was higher in supplemented fish, whereas the n-6/n-3 ratio was higher in controls. Contrary to our results, dietary supplementation of rainbow trouts with curcumin, paprika, thyme, oregano and garlic showed no effect on these two ratios (Georgieva et al., 2018). The positive effect on meat fatty acid profile in rainbow trouts that received cinnamon extract was proven by the improved PUFA/SFA and n-6/n-3 ratios: 0.95±0.03 and 1.97±0.40, respectively. The beneficial range for humans was reported to be >0.4 for PUFA/SFA and <5 for n-6/n-3 (Simopoulos, 2004).

Conclusion

The water, dry matter, lipid, protein and ash contents in the rainbow trout meat were not changed after feed supplementation with 1% cinnamon extract; however, the phytoextract had a beneficial effect on the meat fatty acid profile. SFA content of meat was statistically significantly reduced along with considerable increase in the content of UFA, PUFA and n-3 fatty acid groups. The levels of n-6 fatty acids were not influenced by the dietary supplementation with cinnamon extract. The beneficial effect of the additive on the fatty acid content of the meat was proved by the improved PUFA/SFA and n-6/n-3 ratios in the meat of group C.v as both ratios were within the beneficial ranges required by human nutritional science: above 0.4 and less than 5, respectively.

References

Abeysekera WPKM, Premakumara GAS and Ratnasooriya WD, 2013. In vitro antioxidant properties of leaf and bark extracts of Ceylon

cinnamon (*Cinnamomum zeylanicum* Blume). Tropical Agricultural Research, 24, 128-138.

AOAC, 1997. Official Methods of Analysis of Association of Official Analytical Chemists, (16th edition).

AOAC, 2006. Official Methods of Analysis of Association of Official Analytical Chemists, (18th edition).

Avula B, Smillie TJ, Wang YH, Zweigenbaum J and Khan IA, 2015. Authentication of true cinnamon (*Cinnamon verum*) utilising direct analysis in real time (DART)-QToF-MS. Food Additives and Contaminants: Part A, 32, 1-8.

Bai SC, Katya K and Yun H, 2015. Additives in aquafeed: an overview. In: D.A. DAVIS, ed. *Feed and feeding practices in aquaculture.* Amsterdam: Woodhead Publishing, chap. 7, pp. 171-202. Woodhead Publishing Series in Food Science, Technology and Nutrition. http://dx.doi.org/10.1016/B978-0- 08-100506-4.00007-6.

Charles DJ, 2012. Cinnamon. In: Antioxidant Properties of Spices, Herbs and Other Sources. Springer, New York, NY, pp. 427-534. Online ISBN 978-1-4614-4310-0. https://doi.org/10.1007/978-1-4614-4310-0_19.

Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes. (Official Journal of the European Union L 276/33/20.10.2010).

Gabor E, Єara A and Barbu A, 2010. The effects of some Phyto-additives on growth, health and meat quality on different species of fish. Animal Sciences and Biotechnologies, 43, 61-65.

Gabor E, Єara A, Molnar F and Benюea M, 2011. The influence of some phytoadditives on growth performances and meat quality in rainbow trout (Oncorhynchus mykiss). Animal Science and Biotechnologies, 44, 12-18.

Georgieva K and Zhelyazkov G, 2018. Effect of dietary phytoextracts supplementation on growth performance and blood parameters of rainbow trout (*Oncorhynchus mykiss* W.), cultivated in a recirculation system. Trakia Journal of Sciences, 4, 292-299. doi:10.15547/tjs.2018.04.005

Georgieva K, Zhelyazkov G, Staykov Y and Georgiev D, 2018. Effect of dietary phytoextracts supplementation on the chemical composition and fatty acid profile of rainbow trout (*Oncorhynchus mykiss* W.), cultivated in recirculation system. Agricultural Science and Technology, 10, 215-221. DOI: 10.15547/ast.2018.03.041.

Georgieva K, Zhelyazkov G, Staykov Y and Georgiev D, 2019. Effect of dietary phytoextracts supplementation on chemical composition of common carp (*Cyprinus carpio* L.), cultivated in recirculating system. Bulgarian Journal of Agricultural Science, 25 (Suppl. 3), 178-181.

Georgieva K, Zhelyazkov G and Georgiev D, 2020. Effect of dietary phytoextracts supplementation on biochemical blood parameters of common carp (*Cyprinus carpio* L.) cultivated in a recirculation system. Bulgarian Journal of Agricultural Science, 26 (Suppl. 1), 175-179.

Goyal M, Kaur H, Bhandari M, Rizvanov AA, Khaiboullina SF and Baranwal M, 2018. Antioxidant and immune effects of water soluble polysaccharides isolated from *Cinnamomum verum* bark. Bio Nano Science, 8, 935-940.

Gul S and Safdar M, 2009. Proximate Composition and Mineral Analysis of Cinnamon. Pakistan Journal of Nutrition, 8, 1456-1460. DOI: 10.3923/pjn.2009.1456.1460 https://scialert.net/abstract/?doi=pjn.2009.1456.1460

Jamil M, Salahuddin S, Akter H and Shahjahan M, 2016. Fatty Acid Analysis of *Cinnamomum zeylanicum* (Dalchini) Bark Fatty Oil. UITS Journal, 1, 70-74.

Koshinski R, 2019. Growth efficiency, biochemical blood parameters and meat quality of rainbow trout (*Oncorhynchus mykiss* W.) fed with supplement of white yarrow extract (*Achillea millefolium* L.). AACL Bioflux, 12, 2298-2305.

Koshinski R, 2020. Effect of Taraxacum officinale Weber ex Wiggers extract on growth performance, biochemical blood parameters and meat quality of rainbow trout (*Oncorhynchus mykiss* W.), cultivated in a recirculating system. AACL Bioflux, 13, 109-117.

Matiullah FR, Bhatti EM, Khan N and Parveen S, 2016. Use of black pepper seed as growth enhancer in *Labeo rohita*. International Journal of

Biosciences, 8, 1-9. http://dx.doi.org/10.12692/ijb/8.3.1-9

Mohammad HA, El Mesallamy AMD, Samir F and Zahran F, 2011. Effect of Cinnamon (*Cinnamomum zeylanicum*) on growth performance, feed utilization, whole-body composition, and resistance to *Aeromonas hydrophila* in Nile Tilapia. Journal of Applied Aquaculture, 23, 289-298. DOI: 10.1080/10454438.2011.626350

Rao PV and Gan SH, 2014. Cinnamon: A multifaceted medicinal plant. Evidence-Based Complementary and Alternative Medicine, 1-12.

Regulation № 20/ 1.11.2012 on the minimum requirements for protection and welfare of experimental animals and site requirements for use, cultivation and/or their delivery. Ministry of Agriculture and Food (OG, issue 87/ 09.11.2012) (Bg).

Simopoulos AP, 2004. Omega-6/Omega-3 essential fatty acid ratio and chronic diseases. Food Reviews International, 20, 77-90. https://doi.org/10.1081/FRI-120028831

Singh N, Rao AS, Nandal A, Kumar S, Yadav SS, Ganaie SA and Narasimhan B, 2021, Phytochemical and pharmacological review of *Cinnamomum verum* J. Presl-a versatile spice used in food and nutrition. Food Chemistry, 338, 127773. https://doi.org/10.1016/j.foodchem.2020.127773

Sirakov I, Velichkova K, Stoyanova S, Zhelyazkov G and Staykov Y, 2019. The effect of diet supplemented with dandelion's (*Taraxacum officinale*) extract on the productive and blood parameters of common carp (*Cyprinus carpio* L.), cultivated in the recirculation system. Macedonian Veterinary Review, 42, 131-139.

Stoev T and Zhelyazkov G, 2020. Productive traits, blood biochemical parameters and meat quality of rainbow trout (*Oncorhynchus mykiss* W.) fed with supplement of nutmeg extract (*Myristica fragrans*). Agricultural Science and Technology, 12, 324-330.

Stoev T and Zhelyazkov G, 2021. Effect of black pepper (*Piper nigrum*) extract on productive traits, economic efficiency and blood biochemical parameters of rainbow trout (*Oncorhynchus mykiss* W.). Agricultural Science and Technology, 13, 266-271.

Stoyanova S, Zhelyazkov G, Velichkova K, Sirakov I and Staykov Y, 2018a. Influence of dietary cinnamomum verum extract on the growth and economic efficacy of common carp (*Cyprinus carpio* L.), reared in a recirculation system. Trakia Journal of Sciences, 4, 307-312. doi:10.15547/tjs.2018.04.007

Stoynova S, Zhelyazkov G, Velichova K, Sirakov I, Staykov Y, 2018b. Effect of savory extract supplementation on some productive traits and economic efficiency of common carp (*Cyprinus carpio* L.). Aquatic Research, 1, 110-114. DOI: 10.3153/AR18012.

Taşbozan O ans Gökçe MA, 2017. Fatty Acids in Fish [Internet]. Fatty Acids. InTech. Available from: http://dx.doi.org/10.5772/68048

Velichkova K, Sirakov I, Stoyanova S, Zhelyazkov G, Staykov Y and Slavov T, 2019. Effect of *Acorus calamus* L. extract on growth performance and blood parameters of common carp (*Cyprinus carpio* L.) cultivated in a recirculation system. Journal of Central European Agriculture, 20, 585-591.

Wojno M, Mandas A, Kwasek K and Dabrowski K, 2021. The Effect of Dietary Supplements of Black Pepper *Piper nigrum* and Turmeric *Curcuma longa* Extracts on Dietary Amino Acid Utilization and Growth Performance in Common Carp. North American Journal of Aquaculture, 83, 155-164. https://doi.org/10.1002/naaq.10179.

Zhelyazkov G, Stoyanova S, Sirakov I, Velichkova K and Staykov Y, 2018. Effect of nutmeg extract supplementation on some productive traits and economic efficiency of common carp (*Cyprinus carpio* L.) cultivated in recirculation system. Agricultural Science and Technology, 10, 54-56. DOI: 10.15547/ast.2018.01.013.

Zhelyazkov G and Stoev T, 2020. Effect of cinnamon (*Cinnamomum verum*) extract on productive traits, economic efficiency and blood biochemical parameters of rainbow trout (*Oncorhynchus mykiss* W.). Bulgarian Journal of Agricultural Science, 26 (Suppl. 1), 175-179.