Iranian Journal of Fisheries Sciences
http: doi.org/ 10.22092/ijfs.2026.135187 2026, 25(2) 317-331

Research Article

Qualitative study of medicinal plants and tilapia (*Oreochromis* sp.) cultivated in an aquaponic system

Mashaii N.[1*], Hosseinzadeh Sahafi H.[2], Mosaddegh M.H.[3]

1National Research Center of Saline-waters Aquatics, Iranian Fisheries Science Research Institute (IFSRI), Agricultural, Research, Education and Extension Organization (AREEO), Bafgh, Iran
2Iranian Fisheries Science Research Institute (IFSRI) Agricultural, Research, Education and Extension Organization (AREEO), Tehran, Iran
3Department of Pharmacology, School of Pharmacy, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
* Correspondence: nassrinmashaii@yahoo.com

Keywords

Aquaponic,
Tilapia,
Fatty acid,
Medicinal plants,
Essential oil

Article info

Received: April 2025
Accepted: July 2025
Published: March 2026

Abstract

The production of aquatic animals and plants in an aquaponic system helps conserve water and soil while aligning with environmental sustainability and food security initiatives, as it eliminates the need for agricultural fertilizers and pesticides. This study investigates the quality of red hybrid tilapia (*Oreochromis* sp.) and various medicinal plants, including peppermint (*Mentha piperita*), common mint (*Mentha sativa*), oregano (*Mentha pulegium*), green and purple basil (*Ocimum basilicum*), miniature basil (*Ocimum basilicum minimum*), and fennel (*Foeniculum vulgare*), cultivated in an aquaponic system. In this system, which operated at water salinity levels of 1.1 ± 0.1 ppt, fish production reached 53.3 kg/m³ over a seven-month breeding period. The plant production ranged from 0.64 to 2.30 kg/m² monthly. The analyzed plants had iron levels ranging from 12.3 to 34.1 mg/100g, calcium levels between 1.3 and 24.6 mg/100g, and potassium levels from 3.3 to 30 mg/100g. Proline and chlorophyll concentrations were measured at 0.44-3.70 mg/g and 2.49-5.10 mg/g, respectively. Nitrite concentrations were found to be between 0.9 and 2.8 mg/kg, while nitrate levels ranged from 56.6 to 805.3 mg/kg of fresh plant weight, both significantly lower than permissible thresholds. The total essential oil percentage in the examined medicinal plants ranged from 0.11% to 0.82%, indicating the presence of beneficial compounds. Overall, aquaponic production can play a significant role in contributing to the development of healthy food products in both the agriculture and aquaculture sectors.

Introduction

Aquaponics is a sustainable food production technology that includes the integration of the hydroponic system with recycling aquaculture. In this system, the metabolites produced from farmed fish are removed from the environment by bacteria present in food particles and those associated with plant roots, through nitration and absorption by plants, which reduces the use of fertilizers (Hussain and Brown, 2024; Mudashiru, 2025). Aquaponic systems offer a promising solution to address contemporary challenges in food production, especially in the face of increasing food scarcity and demand. This relatively new system has been considered with the potential to revolutionize agriculture, especially for climate-vulnerable regions, in order to achieve food security (Mishra *et al*., 2024).

This technology has been experienced in many regions of the USA under the United States Department of Agriculture (USDA) license, as part of the Good Agricultural Practices Program (GAP[1]). It is also implemented in Mexico, Canada, Asia and Australia and is developing rapidly in Europe. This system can be used from the backyard level to commercial scale (Somerville *et al.,* 2014). The most important advantages of aquaponic systems are that agricultural chemicals and nitrogen fertilizers are not used, water is recycled, there is no effluent, and the products produced are healthy (Pantanella and Colla, 2013).

To choose fish and plant species for aquaponic production, climatic conditions, light, and available energy reserves should be considered. Generally, plants that are grown hydroponically can also be produced in an aquaponic system. Plant production should be done according to the ability and goal of the producer and the market for the products (Karlsdottir, 2012).

Aquaponics is a relatively new innovation in Iran, and research has been conducted on the production of tilapia and plants within this system (Rafiei and Saad, 2006; Rajabipour *et al*., 2017; Soltani, 2021; Javanmardi et al., 2022; Mashaii, 2023). In the studies of raising tilapia in the aquaponic system at the National Research Center for Saltwater Aquatics, rearing tilapia fish with a variety of vegetables and herbs was investigated (Rajabipour *et al*., 2017), and the components of the production of edible plants and fodder in this system were defined (Mashaii, 2023). Considering the health of the products produced in this system, the production of medicinal plants is of particular importance. Because of the nutritional value and medicinal properties of the sweat of various types of mints, their consumption has a wide range. Fennel essential oil, especially anethol, is used in the pharmaceutical, food and cosmetic industries (Aćimović *et al*., 2015, Poonkodi, 2016). In the present study, the quality of fennel and some Lamiaceae plants and tilapia fish produced in an aquaponic system have been considered.

[1] (https://www.ams.usda.gov/services/auditing/gap-ghp/aquaponics)

Materials and methods

An aquaponic system, in 15 m^3 of fish breeding greenhouse space and 90 m^2 of plant cultivation area on a floating bed, with a water salinity of 1.1-2.6 ppt, was launched at the National Research Center of Saltwater Aquatics from June to December 2018, based on the University of the Virgin Islands (UVI) aquaponics package (Rakocy *et al*., 2004). Fries of red hybrid tilapia *Oreochromis* sp. were stocked with a density of 120/m^3 and fed with carp fattening extrude feed containing 30% protein, three times a day until satiety. Peppermint (*Mentha piperita*), common mint (*Mentha sativa*), oregano (*Menthum pulegium*), green and purple basil (*Ocium basilium*), miniature basil (*Ocium basilium minimum*), and fennel (*Foeniculum vulgare*) were cultivated.

The fish were harvested after a 7-month cultivation period, and the plants were harvested alternately after ripening. The general composition of fish muscle tissue and plants was investigated based on the standard method of Association of official analytical chemists (AOAC, 2015). The carbon chain of fatty acids in fish muscle tissue was examined by GC/MS using the Acq method methyl ester according to the instructions of the Iran National Standards Organization (INSO 13126). The total chlorophyll content in the leaves and stems of plant products was measured using the methods of Arnon (1949) and Lightenthaler (1987), while proline levels were determined following Mashayekhi and Atashi (2016). Iron, calcium, and potassium concentrations were measured using the atomic absorption method described by Ghazan-Shahi (2006) with a Phoenix-986 AA device.

The amount of nitrite and nitrate in plants was determined by the diazo method (Emami, 1996). Plant compounds were measured in the Iran Research Institute of Forests and Rangelands laboratories. Essential oil analysis was performed by Azma Nano System laboratory, licensed by the Iran Food and Drug Administration, using GC/MS with a capillary column according to the guidelines of the Institute of Standard and Industrial Research of Iran (ISIRI 6117).

Results

The production of red tilapia in the 7-month breeding period was 53.3 kg/m^3. The monthly production of peppermint, common, oregano, green basil, purple basil and miniature basil were 2.3±0.9, 2.1±1.5, 1.9±1.4, 1.1±0.5, 0.1±0.64, 0.9±0.6 kg/m^2, respectively.

The percentage of protein, fat, and ash in red tilapia fish fillet was 27.43, 7.5 and 4.18, respectively. Fatty acid profiles with C14 to C20 chains of cultured tilapia fish muscle tissue (and values taken from Nutritional Fact, N.F.) are shown in Table 1. The amount of moisture, protein, proline and chlorophyll in the examined medicinal plants is listed in Table 2. The concentration of nitrate and nitrite in plant products is shown in Table 3. The amounts of iron, calcium, and potassium are shown in Table 4.

The essential oil in peppermint was 0.73% one month after germination and 1.36% three months after the last harvest, in common mint, 0.11%, oregano, 0.36%, common green basil, 0.82%, miniature basil, 0.35% and in fennel, 0.43%, about one month after the last harvest.

Table 1: Content of fatty acids in farmed tilapia fillets of the present study and Nutritional Fact (N.F.) values.

Fatty acid		Present study		N.F.
		%	(g/100g)	(g/100g)
Meristic acid	C14:0	2.89	0.22	0.05
Palmitoleic acid	C16:1	5.32	0.40	0.10
Palmitic acid	C16:0	28.80	2.16	0.42
Linoleic acid	C18:2	10.66	0.80	0.16
Oleic acid	C18:1	44.78	3.36	0.38
Stearic acid	C18:0	6.79	0.51	0.11
Arachidic acid	C20:0	0.78	0.06	<0.01

Table 2: Content of chlorophyll and proline (mg/g), percentage of moisture and protein of plants in the present study.

	Moisture (%)	Crude protein (%)	Total chlorophyll (mg/g)	Proline (mg/g)
Peppermint	91.8	7.11	3.71	0.44
Common mint	88.8	6.30	2.57	3.22
Oregano	86.9	5.05	2.49	1.76
Green basil	91.0	6.11	2.57	2.04
Purple basil	91.8	10.25	-	-
Fennel	89.0	8.47	5.10	3.70

Table 3: Amount of nitrate and nitrite (mg/kg) in dry weight /wet weight in the plants of the present study.

nitrate and nitrite (mg/kg)		Peppermint	Common mint	Oregano	Green basil	Purple basil	Fennel
Nitrate	Dry weight	1106	7190	1004	874	690	810
	Wet weight	90.7	805.3	131.5	78.7	56.6	89.1
Nitrite	Dry weight	34.0	22.0	8.0	10.0	24.0	8.0
	Wet weight	2.8	2.5	1.0	0.9	2.0	0.9

Table 4: Amount of iron, calcium and potassium (mg/100g of fresh weight) and percentage of potassium based on dry weight in the plants of the present study

	Fe	Ca	K	
	Wet weight (mg/100g)	Wet weight (mg/100g)	Wet weight (mg/100g)	Dry weight (%)
Peppermint	20.4	1.3	10.8	0.13
Common mint	12.3	11.1	20.9	0.19
Oregano	25.7	24.6	12.1	0.09
Green basil	16.7	3.4	3.3	0.04
Fennel	34.1	2.5	30.0	0.27

The percentage of essential oil compounds in the plants was as follows:

- Peppermint (one month after germination): menthol (38.9%), menthone (30.1%), iso-menthone (9.4%), menthofuran (3.5%), methyl chavicol (3.0%);
- Peppermint (more than 3 months after the last harvest): menthol (57.23%), iso-menthone (19.90%), menthyl acetate (5.97%) percent; menthone (5.55%), limonene (2.24%);
- Common mint: carvone (46.5%), pulegone (25.6%), limonene (3.6%),

germacrene D (2.4%), iso-menthol (2.4%);

- Oregano: pulegone (67.2%), menthone (7.4%), iso-menthone (7.1%), (E)-caryophyllene (2.6%), 1,8-cineole (2.4%);
- Green basil: methyl chavicol (34.8%), epi-α-cadinol (6.4%), linalool (5.8%), germacrene D (5.4%), trans-a-bergamotene (4.6%);
- Miniature basil: methyl chavicol (66.9%), (E)-caryophyllene (6.9%), -bisaboleneλ (E)-(5.1%), germacrene D (3.0%), methyl eugenol (2.9%);
- Fennel: trans-anethole (72.2%), limonene (12.2%), methyl chavicol (3.9%), p-cymene (2.2%), fenchone (2.0%).

Discussion

Examining the general composition of fish fillets showed 27.43% crude protein. The amount of protein in tilapia fish fillets cultured in earthen ponds has been reported from 19% (Morady *et al*., 2012) to over 30% (Opiyo *et al*., 2014). Analysis of the profile of fatty acids in farmed tilapia fillets indicates that oleic unsaturated fatty acid was the most abundant. Palmitic acid was the most abundant saturated fatty acid found in fish fillets. The abundance of saturated fatty acids such as palmitic acid (C16), myristic acid (C14), stearic acid (C18) and arachidic acid (C20) was about 39.25%. Unsaturated fatty acids included a total of about 60.75% of the abundance of fatty acids. The abundance of monounsaturated fatty acids, including oleic acid (C18:1) and palmitoleic acid (C16:1), was 50.10%, and linoleic acid, which is a polyenoic unsaturated fatty acid, was 10.66%. The amount of unsaturated fatty acids differed from the estimated values presented in the Nutritional Facts (Table 1). The main differences in the amount of fatty acid composition in cultured fish are the result of nutritional factors. Breeders can alter the fat composition of fish as early as one month prior to harvest (Kinsella *et al*., 1978; Aras *et al*., 2003). Fish fillets usually have 25-35% saturated, 15-40% monounsaturated fatty acids (MUFA) and 38-51% polyenoic Fatty acids (Razavi-Shirazi, 2001), which in the present study are also in the same range.

Results of examining the general composition of plants (Table 2) showed that the amount of protein was higher than the values presented by Nutritional Facts. Protein was found to be 7.1% of fresh weight in peppermint. Peppermint protein in ground cultivation has been recorded at 2.19% (Mainasara *et al*., 2018), 5-6% (Sadat and Ladan-Moghadam, 2018), 4.5-6% (Danaee and Abdossi, 2021), and in the USDA food data, it has been reported at 3.75%. The protein content of green basil was 4.8% (Akah *et al*., 2017), and it is declared to be 3.15% in N.F., while it was found to be 6.1% in the present survey. The protein content in fennel was 8.47% in the present study, but in N.F., it has been declared to be 1.24%.

The chlorophyll of peppermint was obtained at 3.71 mg/g of fresh weight, and proline was 0.44 mg/g of fresh weight. The amount of chlorophyll of peppermint in soil culture under water salinity conditions was obtained as 10-15 mg/g of fresh weight, and proline was about 5.5-10.5 mg/g of fresh weight. As water salinity increases, the amount of chlorophyll decreases (Danaee and Abdossi, 2021). In another study, under salinity stress, the amount of chlorophyll was reported to be 3.6-4.5 mg/g of fresh weight and proline 0.30-1.12 mg/g of fresh weight (Fathi *et al*., 2020). In the present study, the amount of total chlorophyll in common mint was 2.57 mg/g of fresh weight. In a study on common mint under conditions of low sodium chloride concentration, the amount of chlorophyll changed in the range of 8-50 mg/g of fresh weight and decreased with increasing salinity. An increase in salinity causes an increase in oxygen reaction and the concentration of ions in the plant, and subsequently a decrease in chlorophyll (Sultana *et al*., 1999). In this study, the concentration of chlorophyll and proline was 2.57 and 2.04 mg/g of fresh weight in common green basil. In another study, the concentration of proline in common green basil was obtained 0.14-0.90 mg/g of fresh weight under water stress conditions (Zarei *et al*., 2019). In a study comparing some vegetable qualities in soil and hydroponic cultivation, the chlorophyll content of green basil and lettuce has been reported as 4-12 and 7-13 mg/g of fresh weight, respectively (Poorshahabadi *et al*., 2019). In another study about green basil under pollution stress in soil cultivation, the amount of chlorophyll was obtained 0.39-1.4 and proline 0.84-2.8 mg/g of fresh weight (Poursaeid *et al*., 2021). The most important environmental factors that can lead to stress in plants are light, drought, water salinity, ionic factors, and pollution. Chlorophyll concentration increases in response to low-level stress and decreases with high-level stress (Agathokleous *et al*., 2020). In many plant species, proline accumulation occurs in response to various types of environmental stress. When proline is applied exogenously at low concentrations, it increases stress tolerance in plants (Dar *et al*., 2016). The amount of chlorophyll in the products of this study is not far from the results of other studies under land cultivation. In this study, peppermint had the lowest amount of proline, and at the same time, it was richer in chlorophyll. The amount of proline in fennel is high, and it can be concluded that it was under severe environmental stress. It has been found that the fennel accumulates prolines to combat drought stress (Geravand, 2016).

The highest amount of nitrate was observed in mint as 7190 mg/kg of dry weight (equivalent to 805 mg/kg of fresh weight), and nitrite in peppermint as 34 mg/kg of dry weight (equivalent to 2.8 mg/kg of fresh weight) (Table 3). The amount of nitrate in ground cultivation of mint has been reported 546 mg/kg of fresh weight and 5068 mg/kg of dry weight (Shahbazzadegan *et al*., 2019), 311-1154 mg/kg of fresh weight (Kiani and Gheytasim, 2015), 112-138 mg/kg of fresh weight (Tabande and Zarei, 2018), 48-90 mg/kg of fresh weight. The standard range of nitrate in leafy vegetables is 1000 mg/kg of fresh weight. Even though it is considered up to 3000 mg/kg of fresh weight for mint (Ali *et al*., 2021), which indicates there is a large gap between the amount of nitrate in the samples of this study and the threshold of unpermitted nitrate concentration.

The amount of nitrate in ground cultivation of green basil has been reported 184 mg/kg of fresh weight and 3765 mg/kg of dry weight (Shahbazzadegan *et al*., 2019), 1363-2442 mg/kg of fresh weight (Kiani and Gheytasim 2015), 1015 mg/kg of fresh weight (Tabande and Zarei, 2018); in purple basil 345 mg/kg of fresh weight and 2162 mg/kg of dry weight (Shahbazzadegan *et al*., 2019), 1185-3701 mg/kg of fresh weight (Kiani and Gheytasim 2015), and in fennel 650-3767 mg/kg of fresh weight (Koudela and Petříková, 2008).

In this study, the highest amount of nitrite was found in peppermint and the lowest amount in oregano and fennel (Table 3). The concentration of nitrite in ground cultivation of green basil has been reported 0.2-1.3 mg/kg of fresh weight, in common mint 0.5-5.2 mg/kg of fresh weight, in purple basil 0.3-1.7 mg/kg of fresh weight (Kiani and Gheytasim, 2015), in oregano 1.1-3.1 mg/kg of fresh weight (Pirsaheb *et al*., 2012). It has been reported to be 0.82-1.64 mg/kg of dry weight in common mint (Alemzadeh-Ansari *et al*., 2019).

The permissible limit of daily intake of nitrate and nitrite is 0-3.7 and 0-0.06 mg/kg body weight of each person, respectively (EFSA, 2008). Thus, for a 75 kg person, the daily intake of nitrates and nitrites will be about 278 and 4.5 mg, respectively. Therefore, based on the optimal amount of vegetable consumption for each person as 266-350 g/day, and the per capita amount that is less than this amount (Ebadi, 2017), according to the findings of the present study even if only the vegetable that has the most nitrites and nitrates is consumed, it is still less than a third of the permissible limit and far from the unauthorized threshold.

Iron content has been reported 5.05 mg/100g of fresh weight (USDA) in peppermint, 3.17 mg/100g of fresh weight (N.F.) and 13.7 mg/100g of fresh weight in green basil, 13.4 mg/100g of fresh weight in common mint (Eissa and AL-Ahmary, 2005) and 0.73 mg/100g of fresh weight (N.V.) in fennel. The amount of iron in oregano has been reported to be 36.8 mg/100g of dry weight (USDA), while in the present study, it was 25.7 mg/100g of fresh weight, equal to 196 mg/100g of dry weight (Table 4). The iron concentration in the surveyed plants in the present study is higher than the mentioned values. Calcium content is given in peppermint 243 mg/100g of fresh weight (USDA), in green basil 177 mg/100g of fresh weight (N.F.), in common mint 179 mg/100g of fresh weight (Eissa and AL-Ahmary, 2005), in fennel 49 mg/100g of fresh weight (N.V.) and 5.6-36.3 (Koudela and Petříková, 2008), and oregano 211.7 mg/100g of fresh weight (Eissa and AL-Ahmary, 2005) and 1.6 mg/100g of dry weight (USDA). Potassium content has been reported 569 mg/100g of fresh weight in peppermint (USDA), in green basil 295 mg/100g of fresh weight (N.F.) and 574.7 mg/100g of fresh weight, in common mint 470 mg/100g of fresh weight (Eissa and AL-Ahmary, 2005), in fennel 414 mg/100g of fresh weight (N.V.) and 424-585 mg/100g of fresh weight (Koudela and Petříková, 2008), and in oregano 1.26% dry weight (USDA). In the present study, the amount of iron was high and favorable for consumption compared to other sources and the amounts recommended by

Nutritional Facts. The amount of calcium and potassium was low and far from the optimal amount, and the values obtained in other studies (Table 4). To compensate for the lack of some minerals in aquaponic plant products, some ions such as iron can be added to the water and leaf spraying may be done. The exact amount of foliar spraying is defined for some ions and not specified for some others, and varies depending on the characteristics and conditions of each aquaponic package (Rakocy *et al*., 2004; Treadwell *et al*., 2010).

In this study, the essential oil in peppermint one month after germination was 0.73%, and in peppermint three months after the last harvest, it was almost doubled to 1.36%. In other studies, the essential oil value of soil-cultivated peppermint has been reported as 1% (Benabdallah *et al*., 2018) and 3.7% (Mimica-Dukić *et al*., 2003). Menthone and menthol are some of the most important and practical components of essential oils in mints. In peppermint essential oil composition, the amount of menthol was 38.92-57.23% and menthone was 5.55-30.08%, thus in the range or more than some researchers' findings for soil-cultivated peppermint samples. In a study in Serbia, the amount of menthol and menthone in peppermint plant essential oil in soil culture has been reported as 39.6% and 8.9%, respectively (Mimica-Dukić *et al*., 2003). The amount of menthol in peppermint grown in soil in different regions of Iran has shown 34.4-56.4% (Yazdani *et al*., 2002). In a survey, with the use of biological fertilizers for peppermint, the amount of menthol was 28-40% and in the control sample without fertilization, it was 27%. The amount of menthone was 15-20% and in the control sample, it was about 15% (Mehrafarin *et al*., 2011). Regarding the performance of peppermint essential oil, it is suggested to use water with an electrical conductivity of less than 2 mm/cm for cultivation, because it seems that the performance of the essential oil in higher values of the electrical conductivity of the water will reduce (Ghorbani *et al*., 2018). In this study, the essential oil in common basil was 0.82%, which seems favorable. In some studies, the essential oil of common basil in land crops has been reported at 0.7% (de Oliveira *et al*., 2013), under brackish water stress conditions, 0.36% and less than 0.8% (Khalid, 2006; Bione *et al*., 2014). Common green basil, *O. basilicum,* is divided into four groups based on the composition of essential oil components and the richness of the following four compounds: methyl chavicol, linalool, methyl eugenol and methyl cinnamate (Klimankova *et al*., 2008; Bione *et al*., 2014). As the results showed, the basil examined in this study was in the first category and rich in methyl chavicol. Similar results have been reported in the study of green basil essential oil in Iran and India (Poonkodi, 2016; Sharafati-Chaleshtori *et al*., 2018). The results of a study about the performance of common green basil essential oil in the hydroponic system in brackish water treatments have shown that, with an increase in water salinity, the main component of the essential oil, which included methyl cinnamate, increased significantly (Bione *et al*., 2014). The essential oil of oregano in the present study obtained 0.36%, which is lower than the results of its land cultivation study of 1.8% (Benabdallah *et al*., 2018) and 5.4% (Bouyahya *et al*., 2017). In the present study, pulegone, the most common composition of oregano essential oil, was 62.2%. The amount of this compound in the studies of other researchers in the field of cultivation of oregano has been reported as 2.3% (Mahboubi and Haghi, 2008), 23.2% (Teixeira *et al*., 2012), 40.98% (Bouyahya *et al*., 2017), 74.8% (Bekka-Hadji *et al*., 2022), and 85.5% (El Arch *et al*., 2003). Pulegone is a potent antioxidant and anti-inflammatory compound with many pharmacological applications, with toxic and carcinogenic properties when consumed orally, and therefore, its oral use should be accompanied by considerations (Jabba and Jordt, 2019). The essential oil in the stem and leaves of fennel in the present study was 0.43%, which is within the expected and desirable range. In ground cultivation of fennel, the essential oil in flowering branches and aerial parts has been reported to be 2.3% (Sefidkon, 2001) and 0.20-0.29% (Miguel *et al*., 2010), respectively. The amount of trans-anethole, the most important effective compound of fennel essential oil in the stem and leaves, was more than 72.2%, which is favorable. The amount of this compound in different parts of fennel has been reported in other studies as 31-83.4% (Sefidkon, 2001; Miguel *et al*., 2010).

Overall, tilapia fish and plants produced in the aquaponic system had desirable quality, and medicinal plants were desirable in terms of percentage and composition of essential oil.

Conclusion

In the medicinal plants studied, the percentage and composition of essential oils are desirable, the amount of protein and iron is high, and the amount of nitrite and nitrate is much lower than the permissible consumption threshold. Foliar spraying can be used to compensate for the deficiency of some minerals in the plants. Considering the health of the products of the aquaponic system, it is a suitable option for the production of medicinal plants. The residues of agricultural chemicals and mineral fertilizers have adverse effects and consequences on health. Production in the aquaponic system is carried out without the use of chemical fertilizers and pesticides, and the development of production in this system and the promotion of the use of healthy fish and plant products are desirable in line with nutritional health and improving food hygiene. To produce better quality farmed fish, the use of high-quality feed and attention to diet, especially in the last month of cultivation, is recommended.

Acknowledgements

We are grateful to the Management and Planning Organization of Iran for the financial support of this research.

Conflicts of Interest

The authors declare no conflict of interest.

References

Aćimović, M., Tešević, V., Marina, T. Jovana, D. and Snezana, O., 2015. Compositional characteristics of the essential oil of *Pimpinella anisum* and *Foeniculum vulgare* grown in Serbia. *Botanica Serbica*, 39(**1**), 9-14.

Agathokleous, E., Feng, Z. and Peñuelas, J., 2020. Chlorophyll hormesis: Are chlorophylls major components of stress biology in higher plants?. *Science of the Total Environment*, 726, 138637. DOI: 10.1016/j.scitotenv.2020.138637

Akah, N.P., Eze, E. and Omah, E.C., 2017. Proximate composition, total phenol content and sensory properties of sweet basil (*Ocimum basilicum* L.) leaves dried using different methods. *Agro-Science*, 16(**3**), 23-28. DOI:10.4314/as.v16i3.4

Alemzadeh-Ansari, N., Sharifmanesh, D. and Mousavi-Fard, S., 2019. Evaluation of the Accumulation of Nitrate and Nitrite in Vegetables Grown in Different Regions of Ahvaz. *Plant Productions*, 42(**3**), 333-344. DOI: 10.22055/ppd.2019.26457.1626 (In Persian)

Ali, R.A., Muhammad, K.A. and Qadir, O., 2021. A survey of nitrate and nitrite contents in vegetables to assess the potential health risks in Kurdistan, Iraq. IOP Conference Series: Earth and Environmental Science, IOP Publishing. 910(**1**), 012065. DOI:10.1088/1755-1315/910/1/012065 1

Amon, D.I., 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, 24(**1**), 1-15. DOI:10.1104/pp.24.1.1

AOAC., 2015. Official methods of analysis. Association of Official Analytical Chemists. Arlington. 814 P.

Aras, N.M., Haliloğlu, H.İ., Ayik, Ö. and Yetim, H., 2003. Comparison of fatty acid profiles of different tissues of mature trout (*Salmo trutta labrax*, Pallas, 1811) caught from Kazandere Creek in the Çoruh Region, Erzurum, Turkey. *Turkish Journal of Veterinary and Animal Sciences,* 27(**2**), 311-316.

Bekka-Hadji, F., Bombarda, I.F., Djoudi, S.B. and Touati, A., 2022. Chemical composition and synergistic potential of *Mentha pulegium* L. and Artemisia herba alba Asso. Essential oils and antibiotics against multi-drug resistant bacteria. *Molecules*, 27(**3**), 1095. DOI:10.3390/molecules27031095

Benabdalla, A.M., Boumendjel, O., Aissi, C., Rahmoune, M.B. and Messaoud, C., 2018. Chemical composition, antioxidant activity and acetylcholinesterase inhibitory of wild Mentha species from northeastern Algeria. *South African Journal of Botany*, 116, 131-139. DOI:10.1016/j.sajb.2018.03.002

Bione, M., Paz, V., da Silva, F., Sartoratto, A. and Soares, T., 2014. Production of hydroponic basil essential oil with conventional nutrient solution in brackish waters and organic nutrient solution. Proceedings of the II Inovagri International Meeting, Fortaleza, Brazil, 2014. DOI:10.12702/ii.inovagri.2014-a060

Bouyahya, A., Et-Touys, A., Bakri, Y., Talbaui, A., Fellah, H., Abrini, J. and Dakka, N., 2017. Chemical composition of Mentha pulegium and Rosmarinus officinalis essential oils and their antileishmanial, antibacterial and antioxidant activities. *Microbial Pathogenesis*, 111, 41-49. DOI:10.1016/j.micpath.2017.08.015

Danaee, E. and Abdossi, V., 2021. Effects of silicon and nano-silicon on some morpho-physiological and phytochemical traits of peppermint (*Mentha piperita* L.) under salinity stress. *Iranian Journal of Medicinal and Aromatic Plants Research*, 37(**1**), 98-

112. DOI:10.22092/ijmapr.2021.343340.2810 (In Persian)

Dar, M.I., Naikoo, M.I., Rehman, F., Naushin, F. and Khan, F.A., 2016. Proline accumulation in plants: roles in stress tolerance and plant development. In: Iqbal, N., Nazar, R. and Khan, N.A. (eds) Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies. Springer, New Delhi. pp 155-166. DOI:10.1007/978-81-322-2616-1_9

de Oliveira, R., Moreira, I. and Oliveira, F., 2013. Linalool and methyl chavicol present basil (*Ocimum* sp.) cultivated in Brazil. *Revista Brasileira de Plantas Medicinais*, 15, 309-311. DOI:10.1590/S1516-05722013000200020

Ebadi, F., 2017. Food basket and indicators of food security and outlook in the horizon of 2014., Research Services Management, Agricultural Planning, Economic and Rural Development Research Institute Pub., Iran. 216 P. (In Persian)

EFSA (European Food Safety Authority), 2008. Nitrate in vegetables: scientific opinion of the panel on contaminants in the food chain. *The EFSA Journal*, 689, 1-79. DOI:10.2903/j.efsa.2008.689

Eissa, M.W. and AL-Ahmary, K.M., 2005. Determination of Some Elements in Local Food Products in the Kingdom of Saudi Arabia. *Science,* 17(**1**), 117-132.

El Arch, M., Satrani, B., Farah, A., Bennani, L., Boriky, D., Fechtal, M., Blaghen, M. and Talbi, M., 2003. Composition chimique et activités antimicrobienne et insecticide de l'huile essentielle de Mentha rotundifolia du Maroc. *Acta Botanica Gallica*, 150(**3**), 267-274. DOI:10.1080/12538078.2003.10515996

Emami, A., 1996. Methods of chemical analysis of plants (V1), Ministry of Jihad Agriculture, Soil and Water Research Institute. Pub. No. 982, Tehran, Iran, 128P. (In Persian)

Fathi, A., Oveysi, M., Nasri, M., Tohidi, H. and Kasraei, P., 2020. Physiological responses of peppermint (*Mentha piperita* L.) to plant growth regulators and salinity stress. *Iranian Journal of Plant Physiology,* 11(**1**), 3499-3508. DOI:10.22034/ijpp.2020.677291

Geravand, F., 2016. Investigation of different levels of potassium nitrate on some physiological characteristics of the fennel plant under drought stress conditions. Master's thesis, Science Research Institute, Lorestan University, Khorramabad, Iran. 103P. (In Persian)

Ghorbani, M., Movahedi, Z., Kheiri, A. and Rostami, M., 2018. Effect of salinity stress on some morpho-physiological traits and quantity and quality of essential oils in Peppermint (*Mentha piperita* L.). *Environmental Stresses in Crop Sciences*, 11(**2**), 413-420. DOI:/10.22077/escs.2018.953.1188 (In Persian)

Hussain, A.S. and Brown, P.B., 2024. A literature review of tilapia/lettuce aquaponics production status, varieties, and research gaps. *Aquaculture Research*, 2642434. DOI:10.1155/2024/2642434

Institute of Standard and Industrial Research of Iran (ISIRI). 2002. Essential oils - General method for analysis and identification of components by capillary column gas chromatography. Institute of Standard and Industrial Research of Iran, Iran. 20 P. (In Persian)

Iran National Standards Organization (INSO)., 2021. Standard of vegetable and animal oils and fats, gas chromatography of methyl esters of fatty acids, part 2: preparation of methyl esters of fatty acids. Iran National Standards Organization, Iran. 21 P. (In Persian)

Jabba, S.V. and Jordt, S.E., 2019. Risk analysis for the carcinogen pulegone in mint-and menthol-flavored e-cigarettes and smokeless tobacco products. *JAMA Internal Medicine (Journal of the American Medical Association),* 179(**12**), 1721-1723. DOI:10.1001/jamainternmed.2019.3649

Javanmardi, S., Rezaei Tavabe, K., Rafiee, G., Moradi, S., and Sivaji, D., 2022. Assessment of vitamin C different levels in an aquaponic system on Nile tilapia (*Oreochromis niloticus*) and saffron (*Crocus sativus*): growth performances, hematology, serum biochemistry, and digestive enzyme activity. *Aquaculture International,* 30, 2145–2163. DOI 10.1007/s10499-022-00894-8

Karlsdottir, S., 2012. Aquaponics – Grønn vekst, Funded by Nordisk Atlantsamarbejde (NORA) 2011-2012, Final report from the project, Project number: 510-072, September 2012.

Khalid, K.A., 2006. Influence of water stress on growth, essential oil, and chemical composition of herbs [*Ocimum* sp.]. *International Agrophysics*, 20(**4**), 289-296.

Kiani, S. and Gheytasim, M., 2015. Evaluation of nitrate and nitrite accumulation in vegetables exposed in ShahreKord's markets. *Journal of Food Hygiene*, 5(**20**), 67-80. (In Persian)

Kinsella, J., Shimp, J. and Mai, J., 1978. The proximate and lipid composition of several species of freshwater fishes. *New York's Food and Life Sciences Bulletin*, 69, 1-20.

Klimankova, E., Holadová, K., Hajšlová, J., Čajka, T., Poustka, J. and Koudela, M., 2008. Aroma profiles of five basil (*Ocimum basilicum* L.) cultivars grown under conventional and organic conditions. *Food Chemistry*, 107(**1**), 464-472. DOI:10.1016/j.foodchem.2007.07.062

Koudela, M. and Petříková, K., 2008. Nutritional compositions and yield of sweet fennel cultivars-*Foeniculum vulgare* Mill. ssp. *vulgare* var. *azoricum* (Mill.) Thell. *Horticultural Science*, 35(**1**), 1-6. DOI: 10.17221/644-HORTSCI

Mahboubi, M. and Haghi, G., 2008. Antimicrobial activity and chemical composition of *Mentha pulegium* L. essential oil. *Journal of Ethnopharmacology*, 119(**2**), 325-327. DOI:10.1016/j.jep.2008.07.023

Mainasara, M.M., Abu Bakar, M.F., Waziri, A.H. and Musa, A.R., 2018. Comparison of phytochemical, proximate and mineral composition of fresh and dried peppermint (*Mentha piperita*) leaves. *Journal of Science and Technology*, 10(**2**), 85-91. DOI:10.30880/jst.2018.10.02.014

Mashaii, N. 2023. An investigation on production components of tilapia culture in Aquaponic System. Final report of the project, National Research Center of Saline Water Aquatics, Iranian Fisheries Science Research Institute, Iran. 87 P. (In Persian)

Mashayekhi, K. and Atashi, S., 2016. The analysis methods in plant physiology (surveys before and after harvest).

Agricultural Research and Education Pub., Tehran, Iran. 318 P. (In Persian)

Mehrafarin, A., Naghdi-Badi, H., Poorhadi, M., Hadavi, E., Qavami, N. and Kadkhoda, Z., 2011. Phytochemical and agronomical response of peppermint (*Mentha piperita* L.) to bio-fertilizers and urea fertilizer application. *Journal of Medicinal Plants*, 10(**4**), 107-118.

Miguel, M.G., Cruz, C., Faleiro, L., Simões, M.T., Figueiredo, A.C., Barroso, J.G. and Pedro, L.G., 2010. *Foeniculum vulgare* essential oils: chemical composition, antioxidant and antimicrobial activities. *Natural Product Communications,* 5(**2**), 319-328. DOI:10.1177/1934578X1000500231

Mimica-Dukić, N., Božin, B., Soković, M., Mihajlović, B. and Matavulj, M., 2003. Antimicrobial and antioxidant activities of three *Mentha* species essential oils. *Planta Medica*, 69(**5**), 413-419. DOI:10.1055/s-2003-39704.

Mishra, U., Ghodichore, N., Jethwa, K., Ray, M. and Singh, A., 2024. Fish and Plant Growth in Aquaponic and its Water Quality Parameters. *Research Journal of Agricultural and Environmental Sciences,* 15, 661-664.

Morady, Y., Mashaii, N., Karami, B. and Zaregashti, Gh., 2012. Investigation on proximate composition, fatty acid profile and sensory evaluation of Nile (*Oreochromis niloticus*) and Hybrid Red Tilapia fillet farmed in brackish groundwater of Bafgh, Yazd. *Iranian Scientific Fisheries Journal*, 21(**2**), 125-132. DOI:10.22092/ISFJ.2017.110061 (In Persian)

Mudashiru, R.B., Yusuf-Olawuyi, M., Tijani, A., Umar, L., Okeke, F., Adeyemi, O., Amototo, I., and Salaudeen, F., 2025. Design and Construction of an Aquaponics System: A Sustainable Approach to Enhancing Local Food Security in Offa, Nigeria. *ABUAD Journal of Engineering Research and Development*, 8(**1**), 50-60. DOI:10.53982/ajerd.2025.0801.06-j

Opiyo, M.A., Githukia, C.M., Munguti, J.M. and Charo-Karisa, H., 2014. Growth performance, carcass composition and profitability of Nile tilapia (*Oreochromis niloticus* L.) fed commercial and on-farm made fish feed in earthen ponds. *International Journal of Fisheries and Aquatic Studies*, 1(**5**), 12-17.

Pantanella, E. and Colla, G., 2013. Advances in freshwater aquaponic research. International Aquaponic Conference, Aquaponic and Global Food Security, University of Wisconsin.

Pirsaheb, M., Rahimian, S. and Pasdar, Y., 2012. Nitrite and Nitrate content of fruits and vegetables in Kermanshah, 2010. *Journal of Kermanshah University of Medical Sciences*, 16(**1**), 76-83. (In Persian)

Poonkodi, K., 2016. Chemical composition of essential oil of *Ocimum basilicum* L.(Basil) and its biological activities-an overview. *Journal of Critical Review,* 3(**3**), 56-62.

Poorshahabadi, L., Mirdehghan, H. and Roosta, H.R., 2019. Comparison of minerals and bioactive compounds of six vegetable species in the microgreen stage in hydroponic and soil production systems. *Journal of Horticultural Science*, 33(**1**), 113-126. DOI:10.22067/jhorts4.v33i1.70902 (In Persian)

Poursaeid, M., Iranbakhsh, A., Ebadi, M. and Fotokian, M.H., 2021. Common basil (*Ocimum basilicum* L.) responses to lead (Pb $(NO_3)_2$) stress:

Germination, morpho-physiological, and phytochemical. *Iranian Journal of Plant Physiology*, 11(2), 3561-3570. DOI:10.30495/IJPP.2021.1902917.1235

Rafiei, Gh. and Saad, Ch., 2006. The effect of natural zeolite (Clinoptiolite) on aquaponic production of red tilapia (*Oreochromis* sp.) and lettuce (*Lactuca sativa* Var. longifolia), and improvement of water quality. *Journal of Agricultural Science and Technology*, 8 (4), 313-322.

Rajabipour, F., Mashaii, N., Sarsangi, H., Mohammadi, M. and Matinfar, A., 2017. An investigation on tilapia culture in aquaponic system in Iran. *Modern Agricultural Science and Technology*, 3(**5-6**), 12-17. DOI:10.15341/mast(2375-9402)/03.03.2017/003

Rakocy, J.E., Bailey, D.S., Shultz, R.C. and Thoman, E.S., 2004. Update on Tilapia and vegetable production in the UVI aquaponic system. In Blivar: R.B., Mair, G.C. and Fitzsimmons, K. (eds) Proceedings from the Sixth International Symposium on Tilapia in Aquaculture, Manila, Philippines. pp 676–690.

Razavi-Shirazi, H., 2001. Marine Products Technology, Naqshmehr Pub., Tehran, Iran. 292 P. (In Persian)

Sadat, N. and Ladan-Moghadam, A.R., 2018. Effect of Salicylic Acid Foliar Application on Control of NaCl Salt Salinity on Some Morphological, Physiological Traits and Growth of Peppermint Mint (*Mentha piperita*). *Journal of Plant and Biotechnology.* 13(**3**), 31-43. (In Persian)

Sefidkon, F., 2001. Essential oil content and chemical composition of *Foeniculum vulgare* Mill. at different stages of plant growth. *Iranian Journal of Medicinal and Aromatic Plants Research*, 10(**1**), 85-104. (In Persian)

Shahbazzadegan, S., Hashemimajd, K. and Shahbazi, B., 2019. Determination of nitrate concentration of consumed vegetables and fruits in Ardabil. *Journal of Ardabil University of Medical Sciences*, 10(**1**), 38-47. (In Persian)

Sharafati-Chaleshtori, R., Rokni, N., Rafieian-Kopaei, M., Drees, F. and Salehi, E., 2018. Antioxidant and antibacterial activity of basil (*Ocimum basilicum* L.) essential oil in beef burger. *Journal of Agricultural Science and Technology*, 17, 817-826.

Soltani, M., 2021. Effect of water hyacinth (*Eichhornia crassipes*) density on water quality, growth performance and survival of koi carp (*Cyprinus carpio carpio*) in an aquaponic system. *Iranian Journal of Fisheries Sciences*, 20(**5**), 1442-1453. DOI:10.22092/ijfs.2021.349365.0

Somerville, C., Cohen, M., Pantanella, E., Stankus, A. and Lovatelli, A. 2014. Small-scale aquaponic food production, integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Paper 589. Rome. 262P.

Sultana, N., Ikeda, T. and Itoh, R., 1999. Effect of NaCl salinity on photosynthesis and dry matter accumulation in developing rice grains. *Environmental and Experimental Botany*, 42(**3**), 211-220. DOI:10.1016/S0098-8472(99)00035-0

Tabande, L. and Zarei, M., 2018. Overview of nitrate concentration in some vegetables produced in Zanjan province. *Iranian Journal of Soil Research*, 32(**3**), 373-381. DOI:10.22092/IJSR.2018.117826 (In Persian)

Teixeira, B., Marques, A., Ramos, C., Batista, I., Serrano, C., Matos, O., Neng, N.R., Nogueira, J.M., Saraiva, J.A. and Nunes, M.L., 2012. European pennyroyal (*Mentha pulegium*) from Portugal: Chemical composition of essential oil and antioxidant and antimicrobial properties of extracts and essential oil. *Industrial Crops and Products,* 36(**1**), 81-87. DOI:10.1016/j.indcrop.2011.08.011

Treadwell, D., Taber, S., Tyson, R. and Simonne, E., 2010. Foliar-applied micronutrients in aquaponics: A guide to use and sourcing. Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. pp 1-8.

Yazdani, D., Jamshidi, A. and Mojab, F., 2002. Comparison of menthol content of cultivated peppermint in different regions of Iran. *Journal of Medicinal Plants*, 1(**3**), 73-77. (In Persian)

Zarei, F., Shahriari, M.H., Nikkhah, R., Bayat, P. and Dindarlou, A., 2019. Growth and Physiological Responses of Sweet Basil to Foliar Application of Chelate and Nano Chelate of Potassium under Deficit Irrigation Stress. *Journal of Crops Improvement,* 20(**4**), 849-868. DOI:10.22059/jci.2018.261491.2061 (In Persian)