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A Qualitative Analysis of the Aquaponic System Products

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Abstract

The aquaponic system includes hydroponic system and recycling aquaculture in which the wastes and metabolites produced by farmed fish are removed from the environment through nitration and absorbed by plants. In this system, water productivity without dependence on soil and agricultural lands happen simultaneously with healthy fish/plant products throughout the year in conditions in accordance with environmental considerations. In the present study, the quality of tilapia and plant products produced in the aquaponic system including mint, peppermint, pennyroyal, green basil, purple basil, fodder beet, Swiss chard, various cultivars of lettuce, watercress, celery, and tomato have been investigated. Results of sensory evaluation of the cooked fillet showed high score for sensory parameters. In all plant products, the amount of nitrite and nitrate were considerably lower than permissible limit of consumption. Peppermint, fodder beet, Swiss chard, watercress and celery had the lowest proline content, while peppermint, fodder beet, Swiss chard were also richer in chlorophyll. Higher levels of proline were obtained in lettuce and basil, indicating more severe environmental stress conditions for them. The amount of protein and iron in plant products were high, however calcium and potassium were a few lower than the desired amount.

Keywords: Aquaponics, Tilapia, Plant Products, Quality

Introduction

The aquaponic system involves the integration of the hydroponic system with recycling aquaculture in which the wastes and metabolites obtained from farmed fish are removed from the environment through nitration and their uptake by plants. Plants improve water quality by removing compounds from fish waste, as a biological filter. Bacteria play an important role in nutrient transport (El-Sayed, 2006) [15]. Application and development of production in aquaponic system, which is based on water conservation and productivity, independence from agricultural soil, reducing the use of fertilizers and pesticides, co-production of fish and healthy plant products, is a good response to the agricultural needs.

Research on tilapia production in aquaponic system has a history of several decades in the world and has led to favorable results (Palada *et al*., 1999; Rakocy and Allison, 1981; Rakocy *et al*., 2004 & 2010 & 2011; Pantanella and Colla, 2013) [33, 43, 47, 44, 45], in our country it belongs to recent decades. The use of zeolite substrate in the aquaponic system of combined production of tilapia and lettuce has increased lettuce growth (Rafiei and Saad, 2006) [40]. Integrated cultivation of carp with plants (Roosta, 2009; Roosta and Ghorbani, 2011) [49, 50] and the effect of lettuce on the water quality of Oscar fish tank in the aquaponic system (Manouchehri *et al*., 2010) are also studied. Investigation of aquaponic system of tilapia culture in the National Saltwater Aquatic Research Center on the outskirts of Bafgh in the center of Iran led to the production of fish at a rate of 17-17.2 kg per cubic meter and plant products of basil, mint, cucumber, tomato and lettuce, and bell pepper (Rajabipour, 2015; Rajabipour *et al*., 2017) [41, 42]. In other studies, the effect of diets containing vitamin C in the aquaponic system with salmon and vitamin B3 on tilapia and lettuce growth indices in the aquaponic system has been investigated (Salamroudi *et al*., 2020, a & b). In the present study, quality of tilapia fillets and plants produced in aquaponic system are investigated.

Materials and Methods

In the present study, products grown in an aquaponic system inspired by the University of Virgin Island (UVI) aquaponic package (Rakocy *et al*., 2004 and 2010 [47, 44]; Baily *et al*., 2017) in greenhouse condition, 15m^3 fish farming space and 90m^2 floating bed plant culture, water salinity of 1.1-2.6ppt, were evaluated from June to December2017 and February 2011 to September 2021. Fish were fed with food containing 30% protein. Muscle tissue composition of cultured red hybrid tilapia Oreochromis sp. in terms of dry matter was performed based on standard method (AOAC, 1990) [6]. Carbon chain of fatty acid in muscle tissue of fish was investigated using GC/MS by Acq method methyl ester according to the instructions of the National Standard Organization of Iran (INSO 13126).

Some compounds of medicinal and forage plants and vegetable products including mint (Mentha sativa), peppermint (Mentha piperita), pennyroyal (Menthum pulegium), green and purple basil (Ocium basilium), fodder beet (Beta vulgaris), Swiss chard (Beta vulgaris cicla), three cultivars (C1, C2, C3) of Lettuce sativa, water cress (Nasturtium officinale), celery (Apium graveolens, and tomato (Solanum lycopersicum) were investigated. The amounts of chlorophyll by Arnon (1949) [8] and Lighenthaler (1987), proline according to the method of Mashayekhi and Atashi (2016) [30], iron, calcium and potassium using the method of Ghazan Shahi (1997) [18] using Phoenix- 986 AA, nitrite and nitrate by diazo method in plant products were measured based on dry weight.

Sensory evaluation test of cooked tilapia fillets in aquaponic system was performed by two groups of evaluators. Color, odor, texture and taste were evaluated at 5 levels of 1 to 5, very good, good, acceptable, poor and very poor, respectively (Lin and Morrissey, 1994; Watts *et al.*, 1989) [27, 62].

Results

According to the results of sensory evaluation of tilapia fillets farmed in the aquaponic system (Fig 1), cooked fillets in terms of color, texture, odor and taste, were evaluated closed to very good score. In terms of sensory factors, it was in the range of 4.9-4.5 (of 5).

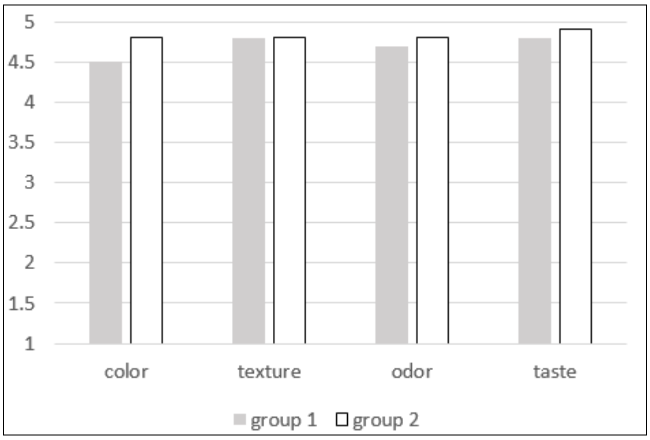

Fig 1: Results of sensory evaluation of tilapia fillet farmed in aquaponic system by two groups of evaluators

The results of the study of the total composition of farmed tilapia fillets showed protein, fat and ash percentages were 27.43, 7.5 and 4.18, respectively. The profile of fatty acids with C14 to C20 chains of muscle tissue of farmed tilapia fish (also values taken from the Nutritional Facts, © 2021 www.traditionaloven.com) is shown in Table 1.

The amount of general compounds, total chlorophyll and proline density in the plant products are listed in Table 2.

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

		Current	**study**	**N. F.**
Fatty acid	Carbon chain	Percent	(g/100g)	(g/100g)
Meristic acid	C14:0	2.89	0.22	0.05
Palmitoleic acid	C16:1	5.32	0.40	0.1
Palmitic acid	C16:0	28.8	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: Chlorophyll and proline contents (mg/g), percentages of moisture, protein and fiber (by wet weight) of plant products from aquaponic system and Nutritional Facts values

	Moisture		**Protein**		**Fiber**		**Chlorophyll**	**Proline**
	Current study	**N. F.**	**Current study**	**N. F.**	**Current study**	**N. F.**		
Pepper mint	91.8		7.11				3.71	0.44
Mint	88.8		6.3		13.2		2.57	3.22
Pennyroyal	86.9		5.05		13.1		2.49	1.76
Green basil	91	92.1	6.11	3.15	17.18	1.6	2.57	2.04
Purple basil	91.8		10.25		25.71			
Fodder beet	91	91.0	6.51	2.2			4.15	0.60
Swiss chard	92.5	92.7	6.45	1.8	15.67	1.6	4.10	0.86
Lettuce C1	94.5	95.0	5.27	1.36	18.47	1.3	2.94	1.24
Lettuce C2	94.5		1.15		13.44		4.67	3.10
Lettuce C3	94.5		1.3		12.73		5.59	2.84
Water cress	95	95.1	9.7	2.3	27.1	0.5	0.42	0.79
Celery	95	95.4	7.6	0.69	14.32	1.6	1.53	0.74
Tomato	94.5	94.5	5.12	0.88	34.15	1.2		

Nitrate and nitrite concentrations, iron, calcium and potassium of plant products (and values taken from the Nutritional Facts, standard and findings of some other researchers) are given in Tables 3, 4 and 5, respectively. The amount of nitrate and nitrite in plant products was much lower than their allowable concentration threshold for consumption. Iron content in plant products was high but calcium and potassium were low.

Table 3: Nitrate content in wet weight (WW)/dry weight (DW) of plant products in aquaponic system, standard amount and results of other studies

Reference	**(mg/kg)**	**Pepper mint**	**Mint**	**Pennyroyal**	**Green basil**	**Purple basil**	**Fodder beet**	**Swiss chard**	**Lettuce (C1, C2, C3)**	**Water cress**	**Celery**	**Tomato**
Current study	DW	1106	7190	1004	874	690	780	750	648, 4432, 1016	912	478	492
	WW	90.7	805.3	131.5	78.7	56.6	70.2	56.3	35.6, 243.8, 55.9	45.6	23.9	27.1
National Standard of Iran, 2013	WW	1000	1000	1000	1000	1000	1000	1000	1500	1000	400	120
Shahbazzadegan *et al*., 2019	DW		546		184	345			618			59
	WW		5068		3765	2162			15761			118
Pirsaheb *et al*., 2012	WW								589-608		601-786	7.7-17.4
Kiani and Gheitasi, 2015	WW		311-1154		1363-2442	1185-3701	1306					
Fatemi-Ghomsheh and Nezami, 2020	WW						713-2801		64-117		109-1558	13.3-39.5
Tabandeh and Zarei, 2018 [59]	WW		4.4-805		4.5-1015		3.5-1275				3.8-516	1.05-80
Pourmoghim *et al*., 2010	DW								910-1445			3.6-376
Ziarati and Bidgoli, 2012	WW								820-4788		3004-4562	
Alamzadeh Ansari *et al*., 2019	DW		1.6-4.2				1.4-4.1					
Hassani-Moghadam *et al*., 2019	DW		5452		9282							
Pérez-Urrestarazu *et al*., 2019	WW							2388	613			
Ali *et al*., 2021	WW							245-487			28-404	
Alcarraz *et al*., 2018	WW								1079			

Table 4: Nitrite content in wet weight (WW)/dry weight (DW) of plant products in plant products of aquaponic system and results of other studies

Reference	**(mg/kg)**	**Pepper mint**	**Mint**	**Pennyroyal**	**Green basil**	**Purple basil**	**Fodder beet**	**Swiss chard**	**Lettuce (C1, C2, C3)**	**Water cress**	**Celery**	**Tomato**
Current study	DW	34	22	8	10	24	4	18	6, 96, 26	6	6	28
	WW	2.8	2.5	1.0	0.9	2.0	0.4	1.4	0.3, 5.3, 1.4	0.3	0.3	1.5
Pirsaheb *et al*., 2012	WW			1.1-3.1			0.4-0.6	0.3	0.2-0.3		0.1-1.3	2.6-3.4
Kiani and Gheitasi, 2015	WW		0.5-5.2		0.2-1.3	0.3-1.7	0.1-0.6					
Alemzadeh-Ansari *et al*., 2019	DW		0.82-1.64				0.59-1.31					
Ali *et al*., 2021	WW							0.22-1.2			0.03-2.8	

Table 5: Iron, calcium and potassium content in wet weight (WW)/dry weight (DW) of plant products in the present study and other studies

			Pepper mint	**Mint**	**Pennyroyal**	**Green basil**	**Fodder beet**	**Swiss chard**	**Lettuce**	**Celery**
	Current study	WW (mg/100g)	20.4	12.3	25.7	16.7	19.6	10.1	12.7	12.0
Iron	N. F.	WW (mg/100g)				3.17	2.57	1.8	0.86	0.2
	Eissa and Al-Ahmary, 2005	WW (mg/100g)		13.4		13.7			0.9	
	Current study	WW (mg/100g)	1.3	11.1	24.6	3.4	1.8	13.7	1.2	0.9
Calcium	N. F.	WW (mg/100g)				177	117	51	36	40
	Eissa and Al-Ahmary, 2005	WW (mg/100g)		179	211.7				19	
	Current study	WW (mg/100g)	10.8	20.9	12.1	3.3	16.2	10.0	8.5	4.2
		DW (%)	0.13	0.19	0.09	0.04	0.18	0.13	0.15	0.08
Potasium	N. F.	WW (mg/100g)				295	762	379	194	260
	Pourshah-Abadi *et al*., 2019	DW (%)				2.71-3.2			3.84-4.6	
	Eissa and Al-Ahmary, 2005	WW (mg/100g)		470		574.7			178	

Discussion

Cooked tilapia fillets cultured in the aquaponic system had high sensory quality with score of 4.5-4.9 from 5. They were evaluated as very good, in terms of color, texture, odor and taste.

Tilapia fillets contained 27.43% of crude protein, which is more than the amount obtained for farmed tilapia in the earthen pond (Moradi *et al*., 2012). Examination of fatty acid profiles in farmed tilapia fillets indicated that oleic unsaturated fatty acids were most abundant. Palmitic acid was the most abundant saturated fatty acid found in fish fillets. There are usually 25-35% saturated, 15-40% monounsaturated and 51-38% polyunsaturated fatty acids in fish (Razavi-Shirazi, 2001; Nelson and Cox, 2005; Honeyfield, 1994) [48, 32, 22]. Fatty acids are in the same range in the current study. The frequency of saturated fatty acids including palmitic acid (C16), meristic acid (C14), stearic acid (C18) and arachidonic acid (C20) were about 39.25%. Unsaturated fatty acids (UFA) were about 60.75% of the total fatty acids. The prevalence of monounsaturated fatty acids (MUFA) including oleic acid (C18:1) and palmitoleic acid (C16:1) was 50.1%, and the PUFA, linoleic acid, was 10.66%. The amount of UFA was different from the estimated values per 100 g of fillet and compared to the values taken from Nutritional Facts (Table 1). Different factors affect the fatty acid composition of different fish and most of the differences are due to nutritional factors. Fish farming conditions, nutrition and physiology have a significant effect on the growth, tissue composition and fatty acids of muscle tissue. Fish food quality is one of the most important factors affecting the fillet composition of farmed fish, especially in late culture period. Breeders can change the fat composition of fish from one month before harvest. (Aras *et al*., 2003; Kinsella *et al*., 1978) [7, 25].

The protein content of plant products in the present study was higher than the Nutritional Facts amounts. Protein was 7.1% (FW) of peppermint. In the studies of other researchers, percentage of protein has been reported 2.19 (Mainasara *et al*., 2018) [28], 6-5 (Sadat and Ladan-Moghadam, 2018) [52], 6-4.5 (Danaei and Abdousi, 2021) of peppermint in terrestrial cultivation. In the current study, the percentages of moisture, protein and fiber of green basil were 91, 6.1 and 17.2, and that of lettuce were 94.5, 5.3-1.2, 18.5-12.7% wet weight, respectively. In other studies, these percentages are reported 85.8, 4.8 and 0.68 for green basil in land cultivation (Akah *et al*., 2017) [2], 13.5, 13.3 and 13.8 for lettuce in land cultivation using different fertilizers (Sanni and Ewolu, 2015), respectively.

The chlorophyll and proline amount of peppermint were obtained 3.71 and 0.44 mg/gfw. In one study, the chlorophyll and proline content of peppermint in soil culture under water salinity has been reported 10-15 and 10.5-5.5 mg/gfw, respectively. With increasing salinity of water, the amount of chlorophyll decreases (Danaei and Abdousi, 2021; Sadat and Ladan-Moghadam, 2018 [52]). In another study under salinity stress, the amount of chlorophyll and proline of peppermint were 4.5-3.6 and 1.12-0.3mg/gfw (Fathi *et al*., 2020) [17]. The total chlorophyll content in common mint was 2.57 mg/gfw. In a study of common mint at low sodium chloride concentrations, the amount of chlorophyll varied in the range of 8-50 mg/gfw and decreased with increasing salinity. Increasing salinity increases reactive oxygen species and ion density in the plant and consequently decreases chlorophyll. Similar results have been obtained for other plants such as lettuce (Safari Mohammadieh *et al*., 2015; Silavi and Eftekhari, 2016 [58]). In the case of lettuce, the amount of chlorophyll 1.2-0.7 mg/gfw has been reported in land cultivation (Mobeen *et al*., 2021) [31]. In the current study, the chlorophyll and proline contents of green basil were 2.57 and 2.04 mg/gfw. In another study, the concentration of proline under water stress in green basil changed in the range of 0.14-0.9 mg/gfw (Zarei *et al*., 2019) [63]. In a study comparing some vegetables in soil and hydroponics cultivation, chlorophyll content in green basil and lettuce were obtained in the range of 4-12 and 7-13 mg/gfw (Pourshahabadi *et al*., 2019). In another study on soil cultivation of green basil under stress conditions, the amount of chlorophyll was 1.45-0.39 and proline 2.8-0.84 mg/gfw (Poursaeid *et al*., 2021) and in drought stress, proline 0.35-0.24 mg/gfw (Hasani *et al*., 2003). Proline content of lettuce in the stress condition of contamination was 0.12-0.001 mg/gfw (Haghighi *et al*., 2010) [19]. Proline of different lettuce cultivars in the present study was 3.1-1.24 mg/gfw.

Chlorophyll is an indicator of plant photosynthetic power. Inappropriate environmental factors can lead to stress in the plant, of which light, drought, water salinity, ionic factors and pollution are the most important. High oxidative stress prevents the synthesis and accumulation of chlorophylls that absorb and use light. Chlorophyll concentration increases in response to low-level stress and decreases in response to high-level stress (Agathokleous *et al*., 2020) [1]. In a wide range of plant species, proline accumulation occurs in response to various types of environmental stresses. There is many evidence about positive correlation between proline accumulation and plant stress tolerance. Although proline acts as an osmolite, plays an important role during stress as a metal chelator and an antioxidant defense molecule. In addition, when exogenously applied at low concentrations, proline increases stress tolerance in plants. The role of proline in germination, flowering and other seed growth programs has also been demonstrated (Dar *et al*., 2016). Proline can be increased against environmental stresses as a protective substance to regulate osmosis. Accumulation of proline under stress can increase the antioxidant capacity of the plant and stabilize enzymes and proteins and neutralize hydroxyl free radicals. Failure to increase proline against stress indicates plant intolerance (Safari *et al*., 2015; Vendruscolo *et al*., 2007) [61]. The amount of chlorophyll in the products of the present study is not far from the results of other studies in terms of land cultivation. In the products of this study, peppermint, beet leaves, Swiss chard, watercress and celery had the lowest amount of proline, and at the same time, peppermint, beet leaf, Swiss chard were richer in chlorophyll. Lettuce and basil have higher levels of proline, and it can be inferred that these plants have been exposed to more severe environmental stress. Plant products of the present study in terms of chlorophyll content in comparison with the results of land crops of other researchers and values taken from 2021 www.traditionaloven.com (Table 2), indicate the appropriate conditions for photosynthesis and quality of plants.

In this study, the highest amount of nitrate was obtained in mint 7190 mg/kgdw (equivalent to 805 mg/kgfw) and nitrite in a lettuce cultivar 96 mg/kgdw (equivalent to 5.3 mg/kgfw). The standard range of nitrate in mint is 3000 mg/kg fresh weight (Hambridge, 2003) and in lettuce 4500 mg / kg fresh weight (EFSA, 2008) [13] which indicates a large distance between the amount of nitrate in the samples of this study and threshold of unauthorized nitrate concentration.

The permissible daily intake of nitrate and nitrite is 0.7-0 and 0.06-0 mg / kg body weight, respectively (EFSA, 2008) [13]. Thus, for a 75 kg human being, the permissible daily intake of nitrate and nitrite will be about 278 and 4.5 mg, respectively. Therefore, according to the desired amount of vegetable consumption for each person 350-266 g/day (with an average about 300 g/day, (Ebadi, 2018) [12], and the findings of the present study, consuming the vegetables that had the highest amount of nitrite and nitrate in this study is still less than one third of the allowable limit and there is a long distance to the unauthorized limit.

In several studies conducted in the country on the amount of nitrite and nitrate in various plant products of the soil cultivation system, the amount of nitrate has been reported in many cases above and beyond the allowable limit (Tables 3 & 4).

In lettuce grown in greenhouse conditions, plant access to sufficient light can be effective in increasing the health and nutritional value of the crop. In sufficient light, plant biomass increases, however nitrate concentration decreases. In conditions of low light, plant antioxidant compounds decrease (Stagnari *et al*., 2015).

The levels of iron, calcium and potassium in plant products were compared with some other studies and the recommended amounts of Nutritional Facts (Table 5). In the studied plant products, the amount of iron was high compared to other sources and the amounts recommended by Nutritional Facts and suitable for consumption. The amount of calcium and potassium in most vegetables was low and far from the desired amount and values obtained in other land cultivation and hydroponics studies (Pourshahabadi *et al*., 2019; Mainasara *et al*., 2018 [28]; Eissa and Al-Ahmary, 2005 [14]). To compensate for the lack of some minerals in aquaponic plant products, some ions such as iron are added to water or by foliar spraying. The exact amount of foliar application is defined for some ions and varies depending on the characteristics and conditions of each aquaponic package (Rakocy *et al*., 2004 & 2013; Treadwell *et al*., 2010; Roosta, 2014) [47, 46, 60, 51].

Conclusion

Residues of pesticides and chemical fertilizers in inorganic agriculture have adverse effects on public health. Therefore, the development of production in the aquaponic system and the promotion of the use of healthy fish plant products of this system in order to promote nutritional health and promote food hygiene is recommended. Tilapia fillets were evaluated as highly desirable in terms of protein content and sensory factors of color, texture, odor and taste. In plant products, the amount of nitrite and nitrate was far below the permissible consumption threshold and the amount of protein and iron in plant products was high. Production in the aquaponic system takes place without the use of fertilizers and chemical pesticides, and as the results of this study showed, the fish and plant products are of good quality.

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References

1. Agathokleous E, Feng Zh, Peñuelas J. Chlorophyll hormesis: Are chlorophylls major components of stress biology in higher plants? Science of the Total Environment. 2020; 726:p138637. Doi: 10.1016/j.scitotenv.2020.138637
2. Akah NP, Eze, K, Omah, EC. Proximate composition, total phenol content and sensory properties of sweet basil (Ocimum basilicum L.) leaves dried using different methods Agro-Science. Journal of Tropical Agriculture, Food, Environment and Extension. 2017; 16(3):23-28.
3. Alcarraz E, Flores M, Tapia ML, Bustamante A, Wacyk J, Escalona, V. Quality of lettuce (Lactuca sativa L.) grown in aquaponic and hydroponic systems. ISHS Acta Horticulturae 1194: VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits - Ethical and Technological Issues, 2018. 10.17660/ActaHortic.2018.1194.6
4. Alemzadeh-Ansari N, Sharifmanesh D, Mosavifard S. Evaluation of the Accumulation of Nitrate and Nitrite in Vegetables Grown in Different Regions of Ahvaz Plant Productions. Journal of Plant Productions. 2019; 42(3):335-344. Doi: 10.22055/ppd.2019.26457.1626. In Persian.
5. Ali RA, Muhammad KA, Qadir OK. A survey of Nitrate and Nitrite Contents in Vegetables to Assess the Potential Health Risks in Kurdistan, Iraq. Fourth International Conference for Agricultural and Sustainability Sciences IOP Conf. Series: Earth and Environmental Science, 2021; 910 012065 IOP Publishing. Doi:10.1088/1755-1315/910/1/012065 1
6. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists. In: W Horwitz (ed.). Arlington, USA, 1990.
7. Aras NM, Halilo˘glu HI, Ayik O, Yetim H. Comparison of fatty acid profiles of different tissues of mature trout (Salmo trutta labrax, Pallas, 1811) caught from Kazandere creek in the C¸ oruh region, Erzurum, Turkey. Turk. J. Vet. Anim. Sci. 2003; 27:311-331.
8. Arnon DI. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiology. 1949; 24:1-15.
9. Bailey DS, Ferrarezi RS. Valuation of vegetable crops produced in the UVI Commercial Aquaponic System. Aquaculture Reports. 2017; 7:77-82. Doi: https://doi.org/10.1016/ j.aqrep.2017.06.002
10. Danaee E, Abdossi V. 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. 2021; 37(1):98-112. In Persian.
11. Dar MI, Naikoo MI, Rehman F, Naushin F, Khan FA. Proline Accumulation in Plants: Roles in Stress Tolerance and Plant Development. In: Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies, 2016, 155-166. ISBN: 978-81-322-2615-4 Plant Development SpringerLink
12. Ebadi F. Food basket and food security indicators and 2021 landscape. Planning Research Institute Pub. Agricultural Economics and Rural Development, Management of Research Services, 2018, p216. In Persian.
13. EFSA, (Europian Food Safety Authority). Nitrate in vegetables. Scientific Opinion of the Panel on Contaminants in the Food chain. The EFSA Journal. 2008; 689:1-79.
14. Eissa MWA, Al-ahmary KHMA. Determination of Some Elements in Local Food Products in Kingdom of Saudi Arabia. Journal of King Abdulaziz University-Science, KAU. 2005; 17:117-132.
15. El-Sayed AM. Tilapia culture. Edited by CABI Publishing, Cambridge, USA, 2006.
16. Fatemi-Ghomsheh A, Nezami S. Study of nitrate status in some vegetables collected from Kermanshah vegetables markets. Iran. J. Health and Environ. 2020; 13(1):77-86. In Persian.
17. Fathi A, Oveysi M, Nasri M, Tohidi H, Kasraei P. Physiological responses of peppermint (Mentha piperita L.) to plant growth regulators and salinity stress. Iranian Journal of Plant Physiology, 2020; 11(1):3499-3508.
18. Ghazanshahi J. Soil and plant analysis. Homa pub, Tehran, Iran, 1997, p131. In Persian
19. Haghighi M, Kafi M, Taghavi TS, Kashi AK, Savabeghi, GhR. Effect of Humic Acid on N, P and Stress Indicators of Lettuce Polluted by Cadmium. Water and soil science of Journal. 2010; 20(1):87-98. In

Persian.
20. Hasani A, Omid-Beygi R, Heidari-Shrifabad H. Study of Some Drought Resistance Indices in Basil (Ocimum Basilicum). Bimonthly Journal of Agricultural Sciences and Natural Resources. 2004; 10(4):65-74. In Persian.
21. Hassani-Moghaddam E, Bazdar A, Shaaban M. Study of nitrate rate in some vegetables cultivated in Poldokhtar and Khorramabad, Lorestan province. Iran. J. Health and Environ. 2019; 12(1):101-112. In Persian.
22. Honeyfield D. Systematic Approach for Evaluating Aquaculture Feed and Identifying Feed Related Problems. Idaho Commission for Libraries Cooperative, university of Idaho, Moscow, 1994.
23. Iranian National Standardization Organization. Maximum levels for mitrates in agricultural products. 1 1st Edition. 2013; INSO 16596. 11P.
24. Kiani Sh, Gheytasim M. Evaluation of nitrate and nitrite accumulation in vegetables exposed on ShahreKord's markets. Journal of Food Hygiene. 2015; 5(4):67-80. In Persian.
25. Kinsella J, Shimp J, Mai J. The proximate and lipid composition of several species of freshwater fishes. New York's food and life sciences bulletin. 1978; 69:1-20.
26. Lightenthler H. A study of enzymes. Methods Enz. 1987; 148:350-382.
27. Lin D, Morrissey M. Iced storage characteristics of Northern squawfish (Ptychocheilus oregonensis), Journal of Aquatic Food Production Technology. 1994; 3(2):25-43.
28. Mainasara M, Abu Bakar M, Waziri H, Musa AR. Comparison of Phytochemical, Proximate and Mineral Composition of Fresh and Dried Peppermint (Mentha piperita) Leaves. Journal of Science and Technology. 2018; 10(2):85-91.
29. Manuchehri H, Hosseinifard S, Sadeghi A. Effect of lettuce plant on water quality of Oscar fish (Asteronotus ocellatus) tank in aquaponic system. Journal of Aquatic Sciences. 2010; 1(3):21-33. In Persian.
30. Mashayekhi K, Atashi S. A Guide to plant physiology tests (pre- and post-harvest studies). Agricultural Research and Education Pub. Ministry of Jahad-e-Keshavarzi, Tehran, Iran, 2016, p318. In Persian.
31. Mobeen W, Saleem M, Parveen A, Mumtaz S, Hassan A, Adnan M, *et al*. Proximate Composition and Nutritive Value of Some Leafy Vegetables from Faisalabad, Pakistan. Sustainability. 2021; 13:p8444. Doi: https://doi.org/10.3390/su13158444
32. Nelson D, Cox M. Lehninger principles of biochemistry. 4th ed. Freeman Pub, 2005, p1119.
33. Palada MC, Cole WM, Crossman SMA. Influence of effluents from intensive aquaculture and sludge on growth and yield of bell peppers. Journal of Sustainable Agriculture. 1999; 14:85-103.
34. Pantanella E, Colla G. Advance in freshwater aquaponic research. International Aquaponic Conference, Aquaponic and Global Food Security, University of Wisconsin, 2013.
35. Pérez-Urrestarazua L, Lobillo-Eguíbab J, Fernández-Cañerob R, Fernández-Cabanás V. Food safety concerns in urban aquaponic production: Nitrate contents in leafy vegetables. Urban Forestry and Urban Greening. 2019; 44:p126431.
36. Pirsaheb M, Rahimian S, Pasdar Y. Nitrite and Nitrate Content of Fruits and Vegetables in Kermanshah. Journal of Kermanshah University of Medical Sciences (BEHBOOD). 2012; 16(1):76-83. In Persian.
37. Poorshahabadi L, Mirdehghan S, Roosta, H. Comparison of Minerals and Bioactive Compounds of Six Vegetable Species in Microgreen Stage in Hydroponic and Soil Production Systems. Journal of Horticultural Science. 2019; 33(1):113-126. In Persian.
38. Pourmoghim M, Khoshtinat K, Sadeghi Makkei A, Komeili Fonod R, Golestan B, Pirali M. Determination of nitrate contents of lettuce, tomatoes and potatoes on sale in Tehran central fruit and vegetable market, by HPLC. Iranian Journal of Nutrition Science and Food Technology. 2010; 5(1):63-70.
39. Poursaeid M, Iranbakhsh A, Ebadi M, Fotokian M. Common basil (Ocimum basilicum L.) responses to lead ($Pb(NO_3)^2$) stress: Germination, morpho-physiological, and phytochemical. Iranian Journal of Plant Physiology. 2021; 11(2):3561-3570. In Persian.
40. Rafiei Gh, Saad Ch. 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. 2006; 8(4):313-322.
41. Rajabipour F. Tilapia culture in aquaponic system. Final report of the project, National Research center of Saline Water Aquatics, Iranian Fisheries Research Organization Pub. Agricultural Research, Education and Extension Organization (AREEO), 2015, p44. In Persian.
42. Rajabipour F, Mashaii N, Sarsangi H, Mohammadi M, Matinfar A. An Investigation on Tilapia Culture in Aquaponic System in Iran. Modern Agricultural Science and Technology. 2017; ISSN 2375-9402, USA. 2017; 3(5-6):12-17.
43. Rakocy J, Allison R. Evaluation of a closed recirculating system for the culture of tilapia and aquatic macrophytes, In: Allen, L. J. and Kinney, E. C. (Editors), hoc. of the Bio-Engineering Symposium for Fish Culture. Publ. No. 1, American Fisheries Society, Bethesda, MD, 1981, 296-307.
44. Rakocy J, Bailey D, Shultz C. and Danaher, J. The Status of Aquaponics - University of the Virgin Islands Agricultural Experiment Station, 2010.
45. Rakocy J, Bailey D, Shultz C, Danaher J. The International Aquaponics and Tilapia Aquaculture Course at the University of the Virgin Islands, Agricultural Experiment Station, University of the Virgin Islands, U.S.A, 2011.
46. Rakocy J, Bailey D, Shultz C, Danaher J. Design and Operation of the UVI Aquaponic System. 11th Conference of the Aquaculture Association of Southern Africa Aquaculture 2013, Stellenbosch, South Africa, 2013.
47. Rakocy J, Bailey D, Shultz R, Thoman E. 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, 2004, 676-690.
48. Razavi-Shirazi H. Marine products technology,

processing science. Naghsh\mehr Pub, Tehran, Iran, 2001, p292. In Persian.
49. Roosta H. An introduction to aquaponic system (Integrated culture of fish and plant in a recycle system) of Valiasr Rafsanjan University. First National Congress of Hydroponics and Greenhouse Products, July 2009, Isfahan, Iran, 2009. https://civilica.com/doc/97273. In Persian.
50. Roosta H, Ghorbani F. Investigation of the growth and development, essential oil and minerals content in two species of mint in hydroponics and aquaponics. Soil and plant interactions (Journal of Science and Technology of Greenhouse Culture). 2011; 7:19-27. In Persian.
51. Roosta H. Effects of Foliar Spray of K on Mint, Radish, Parsley and Coriander Plants in Aquaponic System. Journal of Plant Nutrition. 2014; 37:2236-2254. Doi: 10.1080/01904167.2014.920385. In Persian.
52. Sadat N, Ladan-Moghadam A. Effect of Salicylic Acid Foliar Application on Control of Nacl Salt Salinity on Some Morphological, Physiological Traits and Growth of Peppermint Mint (Mentha piperita). Iranian Journal of Plant and Biotechnology. 2018; 13(3):31-43. In Persian.
53. Safari Mohammadieh Z, Samiei L, Abedi B, Moghaddam M. Effects of ionic toxicity of sodium chloride on some physiological and biochemical characteristics of spearmint (Mentha spicata L.). Journal of Plant production. 2016; 22(4):17-34. In Persian.
54. Salamroodi E, Rafiee G, Rezaei-Tavabe K. Effect of increasing vitamin C to water in a combined rainbow trout (Oncorhynchus mykiss) and lettuce (Lactuca sativa) and a functional study of plant and fish growth indices. Journal of Animal Envirionment. 2020; 12(1):237-244. 10.22034/AEJ.2020.105266. In Persian.
55. Salamroodi E, Rafiee Gh, Rezaei-Tavabe K, Hashemi S. Effect of dietary-vitamin B3 on immunity indices of Nile tilapia and growth (Oreochromis niloticus) of lettuce (Lactuca sativa) in an aquaponics system. Journal of Fisheries. 2020; 73(2):163-174. In Persian.
56. Sanni O, Ewulo B. Effects of Phosphorus and Organic fertilizers on the Yield and Proximate nutrient composition of lettuce (Lectuca sativa) in Southwestern Nigeria. International Journal of Horticulture. 2015; 5(1):1-7. Doi: 10.5376/ijh.2015.05.0001 Kehinde
57. Shahbazzadegan S, Hashemimajd K, Shahbazi B. Determination of Nitrate Concentration of Consumed Vegetables and Fruits in Ardabil. Journal of Ardabil University of Medical Sciences. 2010; 10(1):38-47. In Persian.
58. Silavy B, Eftekhari S. Evaluation of the effects of irrigation water salinity on leaf chlorophyll content and nutrient uptake of native lettuce in Ahvaz using different amounts of humic acid. The Second National Conference on Agriculture and Sustainable Natural Resources. Jiroft, Iran, 2016.
59. Tabande L, Zarei M. Overview of Nitrate Concentration in Some Vegetables Produced in Zanjan Province. Iranian Journal of Soil Research. 2018; 32(3):283-412. In Persian.
60. Treadwell D, Taber S, Tyson R, Simonne E. Foliar-Applied Micronutrients in Aquaponics: A Guide to Use and Sourcing. University of Florida, IFAS Extension. HS1163, 2010, p6.
61. Vendruscolo E, Schuster I, Pileggi M, Scapim C, Molinari H, Marur C, Vieira L. Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. Journal of Plant Physiology. 2007; 164(10):1367-1376. Doi: 10.1016/j.jplph.2007.05.001
62. Watts B, Ylimaki G, Jeffery L, Elias L. Basic Sensory Methods for Food Evaluation. International Development Research Center. Ottawa, 1989, 60-63.
63. Zarei F, Shahriari M, Nikkhah R, Bayat P, Dindarlou A. Growth and Physiological Responses of Sweet Basil to Foliar Application of Chelate and Nano Chelate of Potassium under Deficit Irrigation Stress Crops Improvement. Journal of Agricultural Crops Production. 2019; 20(4):846-868. In Persian.
64. Ziarati P, Bidgoli S. Evaluation of the Nitrate Content in Leafy Vegetables of Southern Parts of Tehran: A Four Seasonal Study. Open Access Scientific Reports. 2012; 1,165, 4P. Doi:10.4172/scientificreports.165