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Quality evaluation of water spinach (*Ipomea aquatica*) leaves cultivated through Aquaponics

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Abstract
Nutrient, nutraceutical analysis and shelf life studies were carried out on Water Spinach (*Ipomea aquatica*) leaves to determine the differences in the leaves cultivated on Aquaponics and conventional one. Tilapia fishes were grown along with the plants. Leaves cultivated in Aquaponics showed higher yield and sensory qualities. Significant difference was found in many of the nutrient and nutraceutical components among both the treatments. Antioxidant property was also seen to be higher with significant difference statistically (T value-2.10).

Keywords: Water spinach leaves, Aquaponics, soil, sensory qualities

1. Introduction

Indian farmers are facing many challenges because large areas of farmland have become fragmented and have also become infertile due to the excessive of fertilizers and pesticides.

Global environmental, social and economic challenges drive the need for new and improved solutions for food production and consumption. Food production within a sustainability corridor requires innovations exceeding traditional paradigms, acknowledging the complexity arising from sustainability. The technological and scientific advancements in the area of agriculture have started a new regime of cultivation for the landless households, especially in urban areas (Junge *et al.*, 2017) [21].

Since soil is not needed and only a limited quantity of water is required, aquaponics system can be setup in areas that have traditionally poor soil quality or contaminated water. Besides, aquaponics systems are usually free of weeds, pests and diseases that would affect soil, which allows to produce high quality crop consistently (FAO, 2018) [13].

Aquaponics allows intensive production in small areas, producing fresh and high quality food and also contributes to urban heat island mitigation. Another salient feature of the system is that, it can use harvested rain water and thus act as a reservoir in case of large rain events. Potentially, aquaponic systems can be intended for small, private installations to large commercial enterprises (Zinzi and Agnoli, 2012) [49].

The main components used for Aquaponics are the fish tank and grow beds with a small pump that purifies water. The success of aquaponics system depends on proper maintenance of the plants, fish and the nutrients that contributes a well-balanced and interdependent relationship (Ebeling and Timmons, 2012) [11].

It is an ideal way of raising food that helps to conserve sustainability, as it needs only 10 per cent of water and no use of chemical fertilizers when compared with the traditional farming system. Integrated farming uses leftovers and subproducts of a specific cultivation for the use of the other. It generally contains raising and breeding of duck, cattle and fish etc. Aquaponics, which is accepted as an organic endeavor extensively focusses on combined systems in which a major part of inputs required for farming is raised within the system.

Though Aquaponics has obtained significant attention in foreign countries, Indian farmers are comparatively new towards this system. But, there has been a slow growth in alertness of this system over the past few years in the country.

The vital part of a balanced diet are the “vegetables’, which are declared as unavoidable, as their intake serves as a source of antioxidants, which avoids the new generation diseases and slows down ageing. Aquaponic farmers can make use of a great variety of vegetable crops in their aquaponics systems, in order to meet the increased consumer needs and preferences.

India, being conferred with a diversity of natural surroundings and changing climates and seasons, has a number of edible green leafy vegetables, most of which are locally grown and underutilized. Green leafy vegetables are valued for their color, flavor and health benefits. Leafy vegetables are rich sources of β-carotene, ascorbic acid, iron, zinc, folate and dietary fiber. Besides, they raise well with the ample nitrogen in their system. They take shorter production period than other vegetables, and are in great demand (Negi and Roy, 2000) [29].

Aquaponics poses a varied and constant polyculture system that lets farmers to cultivate vegetables and grow fish at the same time. By having two sources of profits, farmers can earn money even if the market for either fish or plants goes through a low cycle.

2. Materials and Methods

The experimental site for the study was selected at a farmer's field at Ulloor, Thiruvananthapuram, where there was a well established aquaponics unit. The conventional cultivation was also laid out in the same plot. All plants of both treatments were placed inside the poly house to protect them from pests.

2.1 Selection of vegetables

Ipomoea aquatica is Convolvulaceae plant that is widely consumed in Southeast Asia as a vegetable. The plant contains various bioactive components, e.g. phenols and flavonoids (Mariani *et al*., 2019) [27].

Ipomoea aquatica contains carbohydrates and nutrients, especially such minerals as K, Fe, Mg and Mn. It also contains bioactive compounds such as flavonoids and phenols. Moreover, there are so many activities possessed by water spinach such as antioxidants, anticancer, antidiabetic, anti-inflammatory, anti-ulcer, anxiolytic, and antiepileptic (Shetty *et al*., 2013 [39]; Umar *et al*., 2007[43]; El-Sawi *et al*., 2017 [12]; Huang *et al*., 2005) [19].

Treatments

T_1: Plants cultivated through Aquaponics

T_2: Plants cultivated through conventional practices (Organic POP)

The two treatments were compared for their physical characteristics, sensory qualities, nutrient composition, nutraceutical components and shelf life.

Therefore, the experiment had:

Treatments– 2,

No. of plants – 10

2.2 Analysis of physical characters: Number of harvests and Total dry matter production were analysed. When leaves attained an edible size, the leaves were harvested for duration of two months. The observations were recorded. Mature plants were uprooted from each experimental plot. All samples were dried to a constant weight in the hot air oven at 55º C for 24 hours and their dry weights were then recorded using an electronic digital balance and expressed in grams.

2.3 Sensory evaluation: A semi-trained panel of 10 members from college of Agriculture, Vellayani, KAU evaluated using 9 point hedonic scale appearance (Raw vegetable), Color (Raw vegetable), Flavor (Raw and Cooked vegetable), Texture (Raw and cooked vegetable), Taste (Cooked vegetable) of water spinach leaves. The scores on hedonic scale of 1 to 9 where: 1 = I dislike extremely (very bad) and 9 = I like extremely (excellent). The panellists in individual booths were provided with samples in plates code with numbers and were asked to test each sample (Swaminathan, 1995) [42].

2.4 Evaluation of Nutrient Composition

Nutrients analyzed in this experiment are moisture (g) by A.O.A.C (1990) [3], Fibre (g) (Sadasivam and Manikam, 1992) [36], Total minerals (g) A.O.A.C (1995) [2], Acidity (%) A.O.A.C (1984) [1], Soluble sugars (mg) Dey (1990) [10], Vitamin C (mg) (Sadasivam and Manikam, 1992) [36], Beta carotene (μg) Srivastava and Kumar (1998) [40], Calcium(mg) (Jackson, 1973) [20], Iron (mg) Jackson (1973) [20]. The results are presented in the following tables.

2.5 Evaluation of Nutraceutical composition

Phenol content was estimated by the procedure defined by Sharma (2001) [38]. Phytic acid content was determined by the method which was recommended by Wheeler and Ferrel (1971) [44]. Tannins were determined as per the procedure defined by Ranganna (2001) [34]. Oxalate content of green leafy vegetables was estimated by the procedure which was suggested by Day and Underwood (1986) [9]. The radical scavenging activity of the samples was determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay to assess level of antioxidants (Lim *et al*., 2007) [24].

2.6 Shelf life evaluation

Duration with respect to onset of visible marks of deterioration was noted for green leafy vegetable samples grown through aquaponics and conventional methods for 6 days in 2 types of packagings -newspaper and PP covers. Shelf life in ambient and refrigerated conditions were noted.

2.6.1 Physiological loss of water (PLW)

Under ambient and refrigerated conditions, the weight of the GLV was taken on a daily basis and the percentage of loss of water was recorded for each of the samples. They were packed in 2 types of packagings; PP covers and newspaper to compare the quality. This evaluation was carried on for 6 days and physiological changes like wilting and yellowing were noted

PLW of vegetables was determined by using the following formula: Percentage PLW= (Initial weight – Final weight / Initial weight) x100.

2.7 Statistical Analysis

The mean value of the two treatments were compared through "t-test "and sensory evaluation were analyzed through "Man Whitney test".

Plate 1: Initial setup of Aquaponics unit

Plate 2: Polyhouse where aquaponics unit is placed

Plate 3: Tilapia fishes

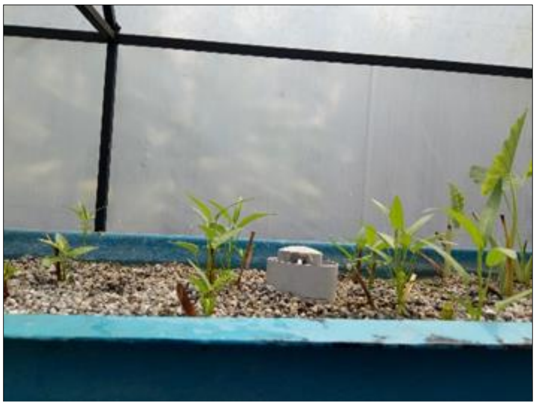

Fig 1: Water spinach leaves growth Aquaponics after 15 days of planting on

Fig 2: Water spinach leaves growth after 15 days of planting in soil

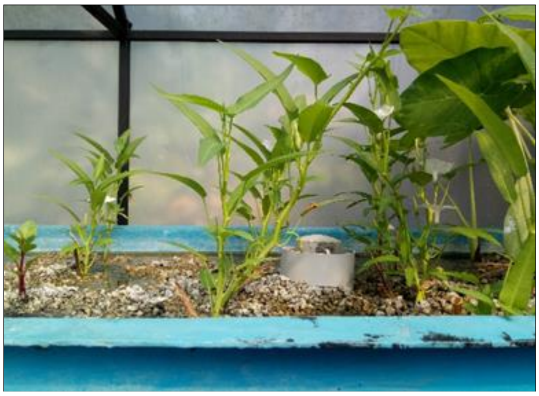

Fig 3: Water spinach leaves growth after 30 days of planting on Aquaponics

Fig 4: Water spinach leaves growth after 30 days of planting on Aquaponics

3. Results and Discussion

Table 1: Details of harvest of Water spinach

Sequence of harvest	Yield (g/plant)	
	T1	T2
1st	20	10
2nd	25	5
3rd	23	12
4th	24	6
5th	21	9
6th	20	10
7th	25	8
8th	15	9
9th	10	7
10th	15	14

(Values depicted are mean of 10 plant units) T1 - Aquaponics treatment; T2 - Conventional treatment

Ten harvests were conducted in two months. From table 1, it is observed that the yield of T1 was higher than T2. The yield was higher (25g) in the second and seventh month of growth of T1 plants. The growth and yield of T2 water spinach was very poor in comparison to T2, indicating that water spinach was not ideal for growth in soil. Their yield ranged from 5-14g per harvest.

Amaranth plants flourished in soils rich in nitrogen and high levels of nitrogen showed delay with onset of flowering and provided higher leaf yield (Achigan-Dako *et al*., 2014) [4].

Aquaponically grown lettuce had lower nitrate concentration (1079 mg kg $^{-1}$ FW) than hydroponically grown lettuce (1229 mg kg $^{-1}$ FW), but the yield was 6.73 per cent higher in the plants of aquaponic unit (Alcarraz *et al*., 2016) [5].

3.1 Total dry matter production

As for water spinach, it was higher for aquaponics samples T1

(36.52 g/plant) than conventional ones T2 (6.98g/plant).
Seginer *et al*. (2004) [37] reported that nitrogen stress led to increased dry matter production that was 3-4 times higher than the normal. Nozzi *et al.* (2018) [30], observed that lettuce and mint had higher dry matter in hydroponic systems ($p<$ 0.05), which is explained by their higher nitrogen availability. In the Water spinach grown in aquaponics had higher dry matter content, probably due to the unavailable nitrogen.

Table 2: Sensory evaluation of Water spinach

Sensory parameters	T1		T2		
	Sum of ranks	U-value	Sum of ranks	U-value	Z value
Appearance (raw vegetable)	145.5	9.5	64.5	90.5	3.023*
Color (raw vegetable)	136.0	19.0	74.0	81.0	2.305*
Flavor (raw vegetable)	109.5	45.5	100.5	54.5	0.302
Flavor (cooked vegetable)	109.0	46.0	101.0	54.0	0.264
Texture (raw vegetable)	126.5	28.5	83.5	71.5	1.587
Texture (cooked vegetable)	127.0	28.0	83.0	72.0	1.625
Taste (cooked vegetable)	120.0	35.0	90.0	65.0	1.096

(Values indicated are sum of rank values of ten members) T1- Aquaponics treatment; T2 - Conventional treatment

From table 2, it is revealed that there was significant difference in the scores for appearance and colour of raw water spinach of both the treatments (Z value = 3.023 and 2.305 respectively). Scores for texture, taste and flavour were higher in the case of T1 treatment, but they did not show significant difference statistically.
Sensory evaluation is of vital significance with increasing consumer awareness towards nutrition and quality. Optimal information on sensory qualities can be acquired distinctly through co-ordination of instrumental and sensory measurements (Meilgaard *et al*., 2006) [28]. All T1 plants were observed to have better sensory qualities in this study.
Gruda (2009) [16] reported that organic samples had good colour when compared with commercial ones, Conventionally cultivated pepper had a more appealing color, than those grown in hydroponics or aquaponics. But Lopez *et al.* (2013) [25], observed that the cropping system did not affect color, it was the harvesting time that was more pronounced.
Ho (2004) [18], has put forth emphatically that, the future of glasshouse production lies in soilless culture systems (SCSs). This is because a control over nutrient and water levels was possible, and thus over yield and quality.

3.2 Nutrient Composition

Table 3: Nutrient composition of Water spinach leaves

Sl. No.	Parameters	T_1	T_2	P value
1	Moisture content (g)	71.60	70.20	0.46
2	Fibre content (g)	0.57	0.57	0.91
3	Total mineral content (g/100g)	13.8	12.8	0.538
4	Acidity (%)	1.00	1.01	0.946
5	Soluble sugars content (mg/100g)	9.30	8.54	3.02E
6	Vitamin C content (mg/100g)	32.43	27.52	9.47702E-05
7	Beta carotene(µg/100mg)	12.46	9.33	3.57E
8	Calcium content (mg/100g)	457.29	422.57	9.16E
9	Iron content (mg/100g)	273.60	246.39	0.004

(Values indicated are mean of 10 replications) Tvalue-2.10 T1- Aquaponics treatment; T2 - Conventional treatment

Statistical analysis revealed there was no significant difference in the moisture content, fibre content, total minerals content, and acidity content among the two treatments. Nutrient analysis revealed significantly higher values for soluble sugars, vitamin C, beta carotene, calcium and Iron for T_1 at 0.5% significance level.
Badau *et al.* (2013) [7] reported that the moisture content of water spinach was 70.2 per cent, which is in line with the observation by Umar *et al*. (2007) [43], being 72.83 per cent. Crude fiber content of water spinach was accounted for to be 1.76 ± 0.35 per cent (Umar *et al*., 2007) [43]. Umar *et al.* (2007) [43] reported that the ash content of water spinach was 10.83±0.80 per cent. Yoon *et al*. (2017) [47] sugar levels increased in lesser time in green house plants than in outdoor plants. This might be due to controlled climate inside the units. Probably the micro climate of aquaponic unit facilitated more photosynthesis that led to significantly higher sugar levels in these plants. Genetics, environmental conditions, cultural practices, maturity indices and handling procedures affect vitamin C content of fruits and vegetables. Sunlight also promotes vitamin C synthesis in plant tissues (Lee and Kader, 2000) [23]. Carotene and its associated compounds were lower in content of hydroponically grown lettuce than conventionally grown ones. Lower carotenogenesis was attributed to lower sunshine, in the polythene covered units that even resulted in lower temperature (Kimura and Rodriguez -Amaya, 2003) [22]. Calcium content of water spinach leaves was 419.70 mg/100g, in the analysis report of Umar *et al.* (2007) [43], which is in line with the T2 water spinach samples of this study.
Umar *et al.* (2007) [43], stated the iron content of Water spinach as 210.30 mg/100g dry matter.

3.3 Nutraceutical composition

Table 4: Nutraceutical composition of Water spinach leaves

Sl. No.	Parameters	T_1	T_2	P value
1	Phenol (mg/100g)	82.07	32.93	5.96E
2	Phytic acid (g/100g)	2.44	3.24	0.00011

3	Tannin (mg/100g)	81.32	76.04	0.00031
4	Oxalates (mg/100g)	44.0	44.0	-
5	Antioxidants (mg/100g)	95.59	89.45	5.03E

(Values indicated are mean of 10 replications) Tvalue-2.10 T1- Aquaponics treatment; T2 - Conventional treatment

In nutraceutical profile analysis, except for oxalate content there was significant differences among the treatments at 0.5% significance level.

Another result obtained by Stewart *et al*. (2001) [41] also suggests that the phenolic content increased as the plant suffered nitrogen deficiency. Nitrogen is obtained only from the fish feed and the proteins it contains along with fish excreta. Moreover, uptake of nitrogen by the plants is affected by carbon dioxide concentration, oxygen levels and denitrifying bacteria, which cannot be precisely predicted (Goddek *et al*., 2018 [15]; Ru *et al*., 2017 [35]; Wongkiew *et al*., 2017 [45]; Yavuzcan Yildiz *et al*., 2017) [46]. Hence the uncertain nitrogen levels could be reason for the higher phenol content. Phytic acid is also an antinutritional component in cereals and legumes as it binds to minerals, proteins and starch, and make them unavailable (Oatway *et al*., 2001) [31]. The amounts of phytic acid in leaves are mostly lower than those of storage organs (Lott *et al*., 2000 [28]; Raboy, 2003 [33]). Tannin content of leaf extract of conventionally cultivated water spinach was reported to be 0.24 + 0.02% (Omale *et al*., 2009) [32]. Zhang *et al.* (2009) [48] reports that nitrogen and calcium nutrition affected oxalate levels. Huang *et al*. (2005) [19] reported 63.90 per cent of antioxidant activity in conventionally cultivated water spinach samples.

3.4 Shelf life

Table 5: Duration with respect to onset of visible marks of deterioration

Water spinach	Shelf life(days) at ambient temperature		
	Control	**PP covers**	**News paper**
T_1	3	3	4
T_2	2	3	3
	Shelf life(days) at Refrigerated temperature(days)		
T_1	4	5	6
T_2	4	5	6

Shelf life period was determined by noting the number of days the vegetables kept fresh without showing any sign of wilting or disease

Table shows there was no significant difference 3for both the treatments. Roof top farming reduces transportation time, thereby producing fresher and longer shelf-life vegetables (Hartogs, 2013) [17]. Both harvest maturity and postharvest handling techniques are frequently geared toward extending the shelf-life of fresh produce after harvest (Baldwin *et al.*, 2007) [8]. Among the three storage conditions refrigerated storage (5±1°C) was found to be the best storage condition for better retention of physico-chemical qualities of different leafy vegetables as compared to zero energy cool chamber and room temperature. The shelf life of fenugreek, spinach and rajgira was extended up to 8 days whereas coriander and pokala recorded 6 days shelf life when stored under refrigerated storage (5±1 °C) (Garande *et al.*, 2019) [14].

Table 6: Physiological loss of water during storage of Water spinach (0-6 days)

Storage in Ambient Conditions (%)		
Packing material	T1	T2
PP covers	26.62	25.57
Newspaper	67.82	70.00
Nil	62.18	64.80
Storage in Refrigerated Conditions (%)		
PP covers	+12.01	+11.76
Newspaper	58.25	60.6
Nil	56.20	57.23

T1 - Aquaponics treatment; T2 - Conventional treatment

Table 6 shows that PLW was higher in paper packing, in the case of both treatments, being slightly higher in T1 in the case of water spinach, but not in the case of other two leaf varieties. However, increase in moisture content was seen when packed in PP covers in refrigerated conditions.

PLW is an indicator of quality of a vegetable or fruit, as it affects the appearance, weight of the marketable produce and also becomes the cause for pathogen attack (Nozzi *et al.*, 2018) [30].

Leafy vegetables are highly perishable and their shelf life depends on duration and conditions of storage. Leafy vegetables are more prone to wilting due to their larger surface are, their physical structure also makes them prone to mechanical injury. Besides, their water loss affects chlorophyll content which in turn leads to fading (Antonio, 2010) [6].

4. Conclusion

From the analysis carried out on Water spinach leaves which were grown on aquaponics and soil, it could be concluded that the yield, total dry matter production was higher for aquaponics leaf samples than conventional ones. The scores for sensory evaluation was higher for T_1 samples than T_2 ones. Higher nutrient and nutraceutical components showed significant differences among the two treatments suggesting that aquaponics samples are better when compared with conventional ones.

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